Report on the Assessment of the Arlington Public Schools’ David M. Brown Planetarium

A report submitted in partial fulfillment of the requirements for George Mason University Grant 221639 sponsored by Arlington Public Schools

By Dr. Harold A. Geller and Dr. Wendy M. Frazier
29 May 2009
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>1.0 Introduction</td>
<td>3</td>
</tr>
<tr>
<td>2.0 Methodology</td>
<td>3</td>
</tr>
<tr>
<td>3.0 Discussion</td>
<td>5</td>
</tr>
<tr>
<td>3.1 Staffing</td>
<td>8</td>
</tr>
<tr>
<td>3.2 General Building/Facilities</td>
<td>9</td>
</tr>
<tr>
<td>3.2.1 Site</td>
<td>9</td>
</tr>
<tr>
<td>3.2.2 Building Exterior</td>
<td>9</td>
</tr>
<tr>
<td>3.2.3 Building Interior</td>
<td>10</td>
</tr>
<tr>
<td>3.2.4 Issues for further evaluation by architects/engineers</td>
<td>10</td>
</tr>
<tr>
<td>3.3 Climate Control and Environment</td>
<td>11</td>
</tr>
<tr>
<td>3.3.1 Temperature and Relative Humidity</td>
<td>11</td>
</tr>
<tr>
<td>3.3.2 Heating, Ventilation, and Air Conditioning</td>
<td>11</td>
</tr>
<tr>
<td>3.3.3 Monitoring of environment</td>
<td>12</td>
</tr>
<tr>
<td>3.3.4 Pollutants and Particulates</td>
<td>12</td>
</tr>
<tr>
<td>3.3.5 Illumination</td>
<td>12</td>
</tr>
<tr>
<td>3.3.6 Filtration used to reduce ultraviolet radiation</td>
<td>13</td>
</tr>
<tr>
<td>3.3.7 Illumination monitors</td>
<td>13</td>
</tr>
<tr>
<td>3.3.8 Photographs of objects within institution</td>
<td>13</td>
</tr>
<tr>
<td>3.3.9 Pest Control</td>
<td>13</td>
</tr>
<tr>
<td>3.3.10 Use of plants and flowers in building</td>
<td>13</td>
</tr>
<tr>
<td>3.3.11 Food storage and preparation</td>
<td>14</td>
</tr>
<tr>
<td>3.4 Planetarium Equipment Policies</td>
<td>14</td>
</tr>
<tr>
<td>3.5 Exhibitions</td>
<td>15</td>
</tr>
<tr>
<td>3.6 Institution Storage Facilities</td>
<td>16</td>
</tr>
<tr>
<td>3.7 Emergency Preparedness</td>
<td>18</td>
</tr>
<tr>
<td>3.8 Education Assessment</td>
<td>19</td>
</tr>
<tr>
<td>3.8.1 Science Content</td>
<td>19</td>
</tr>
<tr>
<td>3.8.2 Grade Appropriateness</td>
<td>23</td>
</tr>
<tr>
<td>3.8.3 Alignment with NSES</td>
<td>27</td>
</tr>
<tr>
<td>3.8.4 Alignment with VSOL</td>
<td>29</td>
</tr>
<tr>
<td>4.0 Recommendations and Conclusion</td>
<td>33</td>
</tr>
<tr>
<td>Appendices</td>
<td></td>
</tr>
<tr>
<td>A. References</td>
<td>A-1</td>
</tr>
<tr>
<td>B. Photographs</td>
<td>B-1</td>
</tr>
<tr>
<td>C. Vendor Information and Quotations</td>
<td>C-1</td>
</tr>
</tbody>
</table>
Abstract

We present an assessment of the David M. Brown Planetarium (also known by its former name, the Arlington Planetarium), run by the Arlington Public School (APS) system, conducted by George Mason University (GMU) personnel. We not only address aspects of operations and maintenance but also the educational aspects of the program including content and pedagogical approach. We highlight the relevancy of the David M. Brown Planetarium, to Virginia state science education standards of learning (SOL) and the National Science Education Standards (NSES). Recommendations are provided which may assist APS to better serve its students and community with its planetarium.

1.0 Introduction

This report describes the data and information obtained by George Mason University (GMU) personnel in performance of GMU Grant 221639 with the Arlington Public School (APS) system. The purpose of this grant is to provide the APS with an assessment of its David M. Brown Planetarium (also known by its former name, the Arlington Planetarium), including its relevancy to the educational goals of the Science Department of Instruction, the Virginia Standards of Learning (SOL), and the National Science Education Standards.

2.0 Methodology

The methodology utilized in this study is summarized here. The approach taken included an initial interview; a review of materials; development of an agenda for the site visit; generation of a questionnaire for the site visit; facility site visits; analysis and synthesis of data for inclusion in draft report; creation of a draft assessment report; revision of the draft assessment report; and, the delivery of two copies of a final report.

As part of the initial contact with Arlington Public Schools (APS) officials, George Mason University (GMU) personnel received an overview of the David M. Brown Planetarium facility; established goals for the assessment; established a timetable for planetarium visits and reporting; identified representatives of APS as points of contact; and, confirmed that the proposed budget satisfied APS assessment goals.

As part of the review of project materials in preparation for facility site visits, GMU personnel performed the following tasks:

- Review planetarium program mission statement
- Review APS long range plans for planetarium program
- Review standards of learning (SOL) related to planetarium goals
Review APS science curriculum especially as related to planetarium goals
- Review curriculum materials utilized during instruction at planetarium
- Review information about equipment in planetarium
- Review information about planetarium building and surrounding spaces
- Review APS emergency preparedness plans
- Review facility environmental data including number of persons to be seated in the planetarium facility
- Review surveys and other reports that APS had conducted in the past related to the planetarium
- Review list of staff positions and people who fill them

After the initial contact with the APS contract officer and a review of material as noted and made available by APS personnel, GMU personnel prepared an agenda and questionnaire for the primary site visit.

The GMU pre-visit questionnaire included a request for the following information from APS personnel:

- Mission statement
- Institutional long-range plan or where it wants to be in future
- Information about the planetarium
- Description of planetarium equipment
- Planetarium equipment management policy
- Planetarium show-related policies, guidelines, and standard operating procedures
- Information about the planetarium building
- Floor plans and photographs
- History of structure
- Facility report
- Written plans for facility expansion/rehabilitation, if any
- Emergency preparedness plan
- Security and fire protection information
- Environmental monitoring and controls
- Environmental monitoring records
- Information on control of climate, light, and pests
- Surveys and reports by other consultants
- Other reports concerning operations and management of planetarium
- List of current and forthcoming grant applications
- Names and positions of staff and key volunteers
- Tentative timetable for site visit.

APS personnel were not able to provide GMU personnel with all of the above requested information, as some of the requested information was not available to APS personnel either because of loss of materials or lack of initial existence.
The primary site visit to the David M. Brown Planetarium facility took place on 11 March 2009. At this time GMU personnel made written, typed, and audio-recorded notes; made a photographic record; and, viewed one live show with students present, and two different recorded planetarium shows with students present.

Furthermore, as follow-ups, GMU project personnel visited the David M. Brown Planetarium on the following dates: 3 April 2009; 6 April 2009; 17 April 2009; 1 May 2009; and 4 May 2009. It should also be noted that during the conduct of this grant, but not financially supported by the grant, GMU personnel visited the Spitz (an E&S Company) headquarters in Chadds Ford, Pennsylvania, on 24 April 2009, and also attended the Middle Atlantic Planetarium Society Conference in Bowie, Maryland, on 14 May 2009, where a brief presentation was made regarding the usefulness and purpose of having planetarium assessments.

Analysis and synthesis of data and information acquired in the process of this assessment effort was compiled by GMU personnel for the purpose of generating a draft and then final report for the Arlington Public Schools. Said data and information constitute the remainder of this report to be provided to Arlington Public Schools in the form of two hardcopies and an electronic version in PDF format.

3.0 Discussion

The David M. Brown Planetarium, formerly known as the Arlington Planetarium, is located at 1426 North Quincy Street in Arlington, Virginia. As noted by planetarium personnel, and Jonathan Harmon, Director, the David M. Brown Planetarium was originally constructed in 1968 and 1969. The planetarium began its service in the fall of 1969. On 1 February 2008, the Arlington Planetarium was officially renamed the David M. Brown Planetarium, in honor of Captain David M. Brown, a Space Shuttle astronaut who lost his life while aboard the Space Shuttle Columbia, 1 February 2003. Captain Brown was an alumnus of the Arlington Public School system, and was so honored with the naming after a childhood friend and fellow alumnus of Arlington Public School system requested the naming in his honor in November of 2007.

The David M. Brown Planetarium consists of a 30-foot diameter planetarium dome. It utilizes a Spitz A-4 planetarium projector, which is the original equipment as installed in 1969 (the Spitz Company has record of the installation taking place in December 1968). The planetarium seats 68 people in individually upholstered auditorium seats manufactured by the American Seating company. It is noted that these are the originally installed seats and that there are a number of seats whose springs are now broken and a number of seats whose upholstery is in need of repair or replacement. The 30-foot Spitz dome is the original planetarium dome, whose foundation is a circular pattern of concrete blocks. The dome itself is perforated aluminum, with old-styled seams, as was common
in 1969. It should be noted that the Spitz Company now has more modern planetarium domes, including the most recent Nano-Seam Projection Dome whose seams are nearly invisible during projection of the planetarium shows.

“A circumferential soffit trough surrounds the base of the dome and serves to contain dome lighting, special effects projectors and as an open conduit for electrical, audio and control cabling.” It should be noted that this trough, also known as the “cove,” utilizes standard short life incandescent light bulbs for the purpose of illumination of the planetarium dome. Light emitting diode (LED) lighting is now the normative for cove lighting. Such LED cove lighting lasts up to 100 times the life of a normal incandescent, is more energy efficient (fewer KWhr required for operation) and are capable of providing a wide range of color effects.

Approximately 15 years ago, the planetarium received an upgrade done largely in-house by the planetarium director at that time. The upgrade included the automation of the planetarium projector and theater lighting utilizing an East Coast Control Systems Hercules automation system. As noted by current director, Jonathan Harmon: “The automation control serves primarily to effect simultaneous, synchronous control of sky projection with multimedia equipment during the performance of multimedia programming.” Additional modifications to the planetarium have included the automated control of: 16 slide projectors; 1 three-electron-gun RGB video projector; 2 laser discs; 2 DVD players; dome and cove lighting in concert with digital stereo sound tracks.

As provided by planetarium staff personnel, the mission statement of the David M. Brown Planetarium is as follows:

“The David M. Brown Planetarium strives to serve both Arlington Public Schools grades, PK-12, and the greater surrounding community. In support of the Arlington Schools science program, the planetarium provides live, interactive lecture/demonstrations and multimedia programs to introduce, reinforce, or expand concepts taught by classroom teachers in accordance with the Virginia science standards of learning. The planetarium also offers teachers the option of custom programs, tailored to particular classroom needs. Additionally, the planetarium offers evening schoolyard, stargazing activities and science night support to individual schools upon request.

“In the dual role as a regional community planetarium, the Arlington Planetarium offers public multimedia programs Fridays, Saturdays, and Sundays and a full, monthly sky lecture the first Monday of each month throughout the academic year. Additionally, the planetarium provides information to the public regarding sky phenomena, and amateur astronomy. Private rentals are available for individual groups. The Arlington Planetarium recorded its first
official wedding ceremony conducted in the sky theater in September of 2004!

“Excess weekday schedule capacity is offered to schools and education programs outside the Arlington Public Schools system. This includes Arlington private schools, Falls Church and Alexandria city schools, as well public and private schools in Fairfax, Loudon, and Prince William counties in Virginia, the District of Columbia, and Montgomery and Prince Georges counties in the Maryland suburbs. Marymount University has scheduled the planetarium to supplement their astronomy classes as well. Schools external to Arlington County pay a fee per visit. As such, the Planetarium returns some income to Arlington County both in fees paid and ticket receipts for public programs.

“Future endeavors include providing on-site school visits to carry specialized planetarium staff expertise and educational tools into the classrooms to augment lessons and enhance or provide timely support to classroom teachers unable to schedule planetarium visits during key intervals in their unit presentations.”

It should be noted that the provided mission statement does not meet the standard criteria for mission statements, such as those highlighted in 1998 by Janel Radtke in Strategic Communications for Nonprofit Organizations (Radtke, 1998). Standard criteria for a mission statement would limit the mission statement to a single paragraph which personnel could readily repeat; avoid jargon; explain the existence of the organization; and, describe what the organization hopes to achieve in the future.

The long-range plans provided to GMU personnel are derived from the provided mission statement, that is: “providing on-site school visits to carry specialized planetarium staff expertise and educational tools into the classrooms to augment lessons and enhance or provide timely support to classroom teachers unable to schedule planetarium visits during key intervals in their unit presentations.”

Further long-range plans are contingent upon the available future equipment. Thus, as noted by the planetarium director:

“The bulk of weekend, public programming employs 35 mm slide based multimedia presentation; the availability of which, in their native form is becoming almost non-existent. The production services and materials to support 35 mm productions are likewise disappearing; a casualty of the digital age. The planetarium owns three additional program kits for slide based shows. Beyond those, rerunning existing programs whose content remains “evergreen”
can continue until the projection equipment fails or can no longer be supported.

“Curriculum programming in support of classroom instruction employs live interactive sessions followed up with multimedia sessions. The interactive sessions are not impacted appreciably by the decline in the slide base medium. However, loss of professionally produced multimedia programming, from professional production facilities equipped to create them would clearly diminish balance and richness to the overall experience students currently enjoy.

“Upgrading to a full dome video, digital based system will assure a current supply of new programming for a content area whose very nature is continually evolving. This insures the availability of a current stream of new programming to serve the public in the planetarium’s capacity as a public planetarium as well as enriching student experience at the planetarium.”

The David M. Brown Planetarium is funded by the Arlington Public School system. Additional funds are supplied by activities paid for by non-Arlington County school related activities including other-county school presentations, public planetarium shows, and special events leasing of the facility.

3.1 Staffing

Staffing at the David M. Brown Planetarium is limited to two full-time (10 month contract) personnel, Jonathan Harmon, who is the Director for the planetarium, and Candice Wilson, the administrative assistant for the planetarium. There is also one person who is assigned 0.5 FTE to the planetarium, Ron Melkis. There is one part-time personnel who conducts weekend shows, along with Candice and Ron, and that is Bill Dedmond.

No position descriptions were provided the GMU team, but all personnel appear to perform all tasks associated with the planetarium as needed. Note that Candice Wilson, administrative assistant, performs duties as a planetarium operator on weekends. Also, as noted on weekends when Bill Dedmond ran an automated show, he opened the planetarium for the public, he collected the money for tickets, set up the show, introduced the show, ran the planetarium show, provided live interaction with the planetarium show, escorted persons to/from seats when needed, and escorted all persons out of planetarium after completion of show.

There are no building maintenance staff personnel dedicated to the planetarium. All building maintenance is handled through the maintenance staff of the main education building adjoining the planetarium, the Arlington Education Center. No
maintenance personnel position descriptions with stated duties were provided the GMU team.

For the planetarium projector, Ash Enterprises provides contracted maintenance personnel experienced in dealing with a Spitz A4 planetarium projector.

Apparently, there is no formal orientation provided in planetarium operations and maintenance. While the current personnel have been associated with the planetarium for many years, they learned on the job, with respect to operations and maintenance of the planetarium facilities. There also appears to be no budget for updating the skills of all planetarium equipment operators.

3.2 General Building/Facilities

The David M. Brown Planetarium is located at 1426 North Quincy Street, Arlington, Virginia. It is a portion of the Arlington Education Center located at that address. In fact, there is no separate signage for the David M. Brown Planetarium, as the signage on the planetarium building itself states that it is the Arlington Education Center (see Photographs B2a and B2b in Appendix B). The planetarium building itself is of cinder block and poured concrete construction. Exterior appearances are excellent for a building its age, now 40 years old.

3.2.1 Site

The David M. Brown Planetarium is surrounded by a ring of bushes (see Photographs B2a and B2b in Appendix B). The bushes in front of the building signage that has the street address and the lettering for the Arlington Education Center have apparently been cut so that the lettering and street number can be visible to passersby’s. The remainder of the bushes has grown to the point that some go above the rim of the planetarium structure itself. There is no evidence that the bushes encircling the planetarium structure have caused any damage to the foundation of the building itself, although this should be investigated, as plant roots can be a problem for all type of building structures.

There are two main entrances to the planetarium building. One of the entrances is marked with a brass plate to the left, stating “planetarium,” and the brass plate on the right states “school & office entrance.” See Photographs B3a and B3b in Appendix B.

The bushes and vegetative debris around base of the building do not appear to be an access point for pests.

3.2.2 Building Exterior

There are no windows on the exterior of the planetarium building. There are only the two entry ways. Both entrances to the planetarium building are provided with
blackened glass, so that no light from the exterior can enter the planetarium, and
no light from the interior can be visible to exterior patrons or guests. See again
Photographs B3a and B3b in Appendix B.

The exterior doors of the planetarium building were both functioning properly
during all of the planetarium visits by GMU personnel.

3.2.3 Building Interior

After entering the “school and office entrance” there is a foyer with an inner door
to the planetarium itself. The door on the right, before the planetarium theater
door, is the entrance to the offices of the planetarium. These offices support the
director, administrative assistant, and the 0.5 FTE personnel, or a total of 2.5
FTE. It should be noted that while this area may be considered adequate for a
typical administrative support office, considerations to the use of these offices for
production of planetarium shows should be made. The door to the left of the
theater entrance door accesses an area that is utilized for storage (see
Photographs B-21a and B21b in Appendix B). Beyond the storage area is a door
that leads to the electrical and HVAC areas.

The office spaces are generally clean, although cramped for any guests visiting
the facility. It was not noted if the office spaces are serviced by the same
building personnel as the main education center, but that is the assumption, as
trash cans are apparently emptied on a regular basis. There was no
housekeeping plan available to GMU personnel.

Planetarium personnel were asked about pest control, which apparently is
monitored on a monthly basis, and there was no evidence of rodents, insects or
mold in the office areas. There was no evidence of improperly stored hazardous
materials, nor any evidence of any hazards that would threaten equipment in the
planetarium.

3.2.4 Issues for further evaluation by architects/engineers

The only exterior access points to the planetarium are the two double door
entrances. A specialist with access to infrared sensing instrumentation may be
utilized to determine the energy leakage that the double doors permit. There
were no signs of condensation on the windowed portion of the entrance doors,
nor other surfaces. There were no water stains noted on any of the visits to the
planetarium. There were no signs of metallic corrosion or deterioration of
structural materials. There were also no noticeable cracks in any structural
materials.

Electrical junction boxes and circuit breaker cabinets all appeared to be sufficient
for their loads. See Photographs B-22a, B22b and B-24a for all electrical circuit
breaker cabinets.
Vibrations were noted during the cycling of the HVAC unit, but it did not appear to be outside of operational norms. APS may wish to have structural engineers with accelerometers monitor the vibrations of the planetarium structure to verify that the vibrations are not outside of operational norms.

3.3 Climate Control and Environment

3.3.1 Temperature and Relative Humidity

There were no identified levels of temperature or relative humidity which may pose a risk to the planetarium structure. There were no provided institutional goals specified for the planetarium building.

It should be noted that on three occasions that GMU personnel were in attendance, specifically the public planetarium show evenings of 3 April 2009, 17 April 2009, and 1 May 2009, that the temperature (no measurement made) was considered uncomfortable. Upon speaking to planetarium personnel in attendance, it was discovered that they do not have control of their own unit. The HVAC unit for the planetarium building is a feeder system off of the main unit of the education center building. Since the main unit is turned off after normal office hours for the main building, it is apparently not operational during some of the hours in which the planetarium is in service. This matter should be addressed by a civil engineer to assure comfortable room temperatures and humidity levels for all guests to the planetarium.

3.3.2 Heating, Ventilation, and Air Conditioning

The heating, ventilation and air conditioning (HVAC) unit for the planetarium building is a feeder sub-system off of the main HVAC unit for the education center building. It is some 40 years old, although it has been serviced routinely during the life of the system, with portions having been repaired or replaced. In general, the HVAC apparently operates well. However, as noted in section 3.3.1 of this report, the HVAC is not controlled by planetarium personnel, and is sometimes not powered up during planetarium operational times.

The HVAC equipment is not in an uncontrolled area and is not at risk of being compromised by unauthorized personnel. Humidity control is apparently integrated into the HVAC system. The controls, as stated are not accessible by planetarium personnel. Calibration of thermostats and humidistats are left for education center building personnel, as is the maintenance of the HVAC system.

The planetarium is open only during the school year and thus would normally not require HVAC system operations during the months of July and August; however, it must be noted that there are computers in the planetarium personnel offices and that any upgrades to digital planetarium projector equipment should keep
APS alerted to the HVAC requirements of such modern equipment, and the possibility of the effects of long duration exposure to extreme summer temperatures and humidity.

3.3.3 Monitoring of environment

There was no evidence of the existence of environmental monitoring, and no records available as to the long term environmental conditions which APS personnel and guests are exposed. APS should consider having electronic monitoring on a regular basis regarding the physical environment, including the temperature and humidity. Devices are available which automatically monitor these physical parameters, and maintain a record of changes in the environment for all major planetarium building spaces.

3.3.4 Pollutants and Particulates

There was no evidence of any regularly scheduled environmental monitoring of the air for pollutants, particulates, or harmful gases. APS should have environmental monitoring of room air for all spaces occupied by personnel, as well as spaces utilized for storage, to assure compliance with state and local regulations, at least once a year. Consideration should be given for the placement of gas alarms, especially carbon monoxide, in occupied spaces.

3.3.5 Illumination

As mentioned previously, cove lights in the planetarium theater are currently incandescent light fixtures. LED lighting for the cove may allow APS to save on long term energy and costs. LED cove lighting will also allow for additional lighting effects for planetarium shows.

Storage areas and office spaces within the planetarium building are provided by fluorescent type lighting fixtures. The public entrance and exit foyer is lighted by incandescent lights as well as fluorescent black lights for foyer exhibitions.

Planetarium personnel appear self reliant for maintenance of all fixtures, with assistance from maintenance personnel for the education center.

Outside natural light is only accessible via the two double-door entryways. The glass of these doors is treated with black out sheaths to mediate the infiltration of direct sunlight.

There were no lighting policies provided to GMU personnel.
3.3.6 Filtration used to reduce ultraviolet radiation

Ultraviolet radiation from sunlight is mediated on the glass of the two double door entryways to the planetarium building. However, the effects of the ultraviolet radiation on materials on display are evident in the cracking of the painted scenes on the walls of the public foyer. Because black lights are utilized, APS should consider repairs of the painted scenes.

3.3.7 Illumination monitors

There was no evidence of any light level monitoring equipment in the planetarium, and there was no reports provided of any light level testing. APS should consider routine monitoring of the illumination in all areas. Considerations should also be made for those persons in attendance at shows that may require higher than normal light levels for ingress and egress to the theater area.

3.3.8 Photographs of objects within institution

Exhibits of any kind are often the subject of visitor photography. During GMU personnel attendance at the planetarium, no mention was made of the use of cameras or other personal image capture devices. While there were no apparent exhibits featuring light sensitive materials which could be damaged by flash photography, planetarium personnel should caution visitors about flash photography during planetarium shows. Also, while exiting the planetarium through the public foyer, with only the black lights in operation, flash photography should be considered rude and annoying to patrons, and should be discouraged. Signage about flash photography, and its prohibition, may be useful.

3.3.9 Pest Control

There was no evidence of pest damage to any planetarium equipment or exhibits. Planetarium personnel informed GMU personnel of monthly visits by pest control experts, whose job it is to inspect and monitor for all type of pests including insects, spiders, rodents, etc.

The current pest control management program appears to be effective, based upon visual inspection during the visits to the planetarium by GMU personnel.

3.3.10 Use of plants and flowers in building

There were no plants or flowers noted within the planetarium building.

There are plants and flowers on the immediate exterior of the planetarium building. The shrubs should be trimmed as to never breach the plane of the planetarium roof. While trimming is evident, especially in the vicinity of the
signage for the address and the education center, some shrubs do appear to have breached the plane of the roof.

3.3.11 Food storage and preparation

There is neither food preparation nor food consumption areas in the David M. Brown Planetarium. Lunch foodstuff and snacks remainders are disposed of in the standard waste baskets provided in the planetarium office. The waste is removed by custodial services for the entire education center.

3.4 Planetarium Equipment Policies

The planetarium director, Jonathan Harmon, provided GMU personnel with this description of the planetarium projector equipment:

“The primary sky projector is a Spitz model A-4, single starball opto-mechanical planetarium instrument with Sun, Moon, inferior and superior visible planet projectors. The projector reproduces apparent daily motion of the day and night sky and the annual motion along the ecliptic of the Sun, Moon and visible planets. Retrograde motion and lunar phasing are also demonstrable with the system. The A-4 also projects ecliptic, local meridian, and celestial coordinate lines, cardinal points, twilight, and overlays for two constellations: Orion and Cassiopeia.

“The projector is capable of demonstrating the day or nighttime sky over any part of the world at any time of day (night) or season, however, the starball is optimized for the northern hemisphere and many southern hemisphere stars are obscured by the instrument’s structural parts when displayed. It is the original equipment from the planetarium’s beginning.”

As noted by Mr. Harmon, the Spitz A-4 is the original equipment as installed by Spitz in late 1968. As one would expect the condition of the projector belies its age. See Photographs B-6b, B-10b, B-11a, B-11b, B-13b, B-14a and B-14b of Appendix B. Note that the flat black paint of the Spitz A-4 has lost its original luster and is largely faded throughout portions of the A-4 ball and mount. There are chips in a number of places on the Spitz A-4 including the projector sphere, the base, and the support armature. While the cosmetic appearance of the Spitz A-4 does not effect its functionality, it does provide guests with a non-professional appearance, which may lead some guests to believe that the unit is too old and in need of repair. It should be noted that if the Spitz A-4 is not replaced, consideration should be given to “spruce up” the planetarium projector and provide it with a cosmetic facelift.
There were no printed procedures available for the handling and use of the planetarium equipment. There appears not to be any formal procedure, or record, for reporting problems with the projector. Such may benefit the understanding of the mean time between repair for various portions of the projector, allowing for better strategic planning and scheduled maintenance and repair.

While numerous historical photographs were shown to GMU personnel, there does not appear to be a formal photographic history of the planetarium projector and its ancillary equipment. Current photographs of all of the equipment in the planetarium building would assist in any damage claims to insurance companies if such unfortunate circumstances befall the planetarium such as major damage from a hurricane.

3.5 Exhibitions

The only exhibits available to the public and school children, outside of the planetarium theater itself, are those that are visible in the entrance/exit foyer between the double doors utilized by the public for entrance and the planetarium theater entry doors.

The inner wall of the planetarium foyer (closest to the planetarium theater) has a large mural covering the wall from floor to ceiling (see Photograph B-18a and B-18b of Appendix B). This mural consists of two scenes, one of Earth from space and another of a rocket ship in space. As the mural apparently contains phosphorescent paints, the entire foyer utilizes “black light” fluorescent bulbs. This provides the visitor with a unique view of the scene. However, apparently the ultraviolet of the black light fixtures, and the touching of the wall by visitors, has led to a mural which is host to many cracks, chips and fractures, throughout the length of the wall. APS may wish to have these murals “touched up,” so that their uniqueness can be enjoyed for many more years to come.

The outer wall of the exhibit area contains a number of murals and three poster-type displays. The mural nearest the women’s restroom is one of the solar system (Photograph B-19b). This mural is not to scale in distance or planet size, merely an artistic rendition of the solar system. Next on the outside wall is a mural of a galaxy (Photograph B-15a). This is a fairly accurate artistic rendition of a generic spiral galaxy, and is followed to the right by more depictions of galaxies (Photograph B-15b). These galaxies all look very stunning in the blacklight. To the right of the galaxies’ rendition are some depictions of generic nebulae (Photograph B-16a). This is followed by the three poster-type displays.

The first poster (Photograph B-16b) is titled “The Meaning of Color” and attempts to explain the utility of different colors in depicting celestial objects. The poster asks if “space images REALLY look like that?” Then, by displaying objects in
enhanced color, representative color and natural color, the poster concludes with three reasons for using different colors in depicting celestial objects.

The second poster (Photograph B-17a) on the outer wall in the exhibit foyer addresses the usefulness of the Hubble Space Telescope, especially with respect to the scientific study of galaxies.

The third poster (Photograph B-17b) addresses the question of how to find two nebulae in the constellation Orion.

All three posters are useful from the viewpoint of teaching something about celestial objects. APS may wish to consider additional teaching posters for more of the wall space in the exit foyer.

Finally, along the outer wall, there is an area that is used to store some of the equipment used during the monthly public star shows (see Photographs B-31b, B-32a, and B-32b in Appendix B). This includes telescopes and ancillary equipment. There does not appear to be adequate barriers between the equipment and the people who walk through the area. Younger visitors were observed to touch and alter how the telescopes and ancillary equipment were set up. The use of hall space as storage space indicates the lack of storage space available to planetarium personnel.

3.6 Institution Storage Facilities

The storage facilities available to planetarium personnel can best be described as any available space in the planetarium building. Mr. Harmon noted that a large portion of the original storage space in the planetarium building was put off limits by the asbestos abatement work done many years ago. Apparently, this work prevented planetarium personnel from utilizing the space above the ceiling behind the planetarium dome, also known as the attic. Although personnel are prohibited from going into the attic, GMU personnel raised a ceiling access tile and took pictures of the former storage area, which can be seen in Appendix B, photographs B-26a through B-31a. It should be noted that while this “attic space” was utilized by original planetarium personnel as storage space, this area also had a function for the planetarium dome. This area, behind the planetarium dome, above the ceiling, is usually used for housing special effects equipment for certain planetarium shows. Obviously, none of these special effects equipment can be utilized for any planetarium shows, since the asbestos abatement was implemented.

The primary storage area for the planetarium is in a room directly opposite from the planetarium personnel office. Photographs B-21a and B-21b show the interior of this primary storage room. As can be seen in the photographs, file cabinets are the primary storage cabinetry. File cabinets examined by GMU personnel did not display signs of rust, and had operable drawers. Additional
storage areas in this storage room consisted of open shelving. Although the primary storage room appears to be adequate for the materials it holds, there was a shelf (visible in Photograph B-21a) which appears to hold various solutions, including cleaning solutions, and the open shelving for these types of materials is not standard in terms of safety considerations. Such materials should be housed in enclosed storage cabinets.

There are other areas of the planetarium building utilized for purposes of storage; in fact, just about every other available open space appears to get some usage for storage, which points to a storage capacity situation. For example, as can be seen in Appendix B, photographs B-31b through B-32b, telescopes used for public observing sessions after live monthly sky shows, are stored against the outer wall of the exit vestibule. These telescopes and miscellaneous equipment are easily accessed by the public guests, and may be in danger of mishandling by guests. This again points to the issue of a lack of sufficient storage spaces for planetarium equipment and accessories.

Planetarium personnel did not mention to GMU personnel any available off-site storage which could be utilized by planetarium personnel.

It is noted that there is a security/alarm system in the David M. Brown Planetarium, and the door to the primary storage facility is within the alarmed region of the planetarium.

Beyond the primary storage room facility is another door which leads to the location of the circuit breaker box, water, steam, drain and fuel pipes. This room can be seen by examining photographs B-22a through B-25a in Appendix B of this report. As can be seen in photograph B-23a, even this utilities room is utilized for some storage. Again, this points to a need for additional storage for planetarium equipment and accessories.

The door to the primary storage room across from the planetarium personnel office, limits access to the primary storage room to planetarium personnel only. However, because there are areas utilized for storage within the planetarium theater and exit vestibule, these materials so stored, have no limited access. These may be a potential danger to guests of the planetarium, especially those with ill intent.

Planetarium personnel did not provide any policies for storage areas. APS should consider maintaining standard policies for storage areas and the monitoring of storage areas. APS may also deem useful the establishment of standard procedures for the movement of major equipment into or out of storage.
3.7 Emergency Preparedness

With respect to emergency preparedness, Superintendent Robert G. Smith has mandated, that school all staff must do the following each year:

- "Review and update their emergency plan;
- Hold staff orientations and review emergency procedures;
- Hold "Shelter-In-Place" drills;
- Identify HVAC system shut-off valves and schedule training in their operation;
- Store emergency water and food supplies;
- Maintain updated weather and emergency alert radios;
- Update plans for students while on field trips or at away practices, and;
- Arrange with public safety officials to review each school’s emergency plan as necessary."

Planetarium personnel are school staff and it is assumed that they must follow the emergency preparedness policies as established under the Superintendent for Arlington Public Schools.

There was no emergency preparedness plan provided to GMU personnel by planetarium personnel.

There are guidelines for responses to chemical, biological, or radiological incidents published online by Arlington Public Schools and the web address for these guidelines is http://www.apsva.us/154010717145827383/blank/browse.asp?a=383&BMDRN=2000&BCOB=0&c=54135. There are bioterrorism guidelines online at http://www.apsva.us/154010717145827383/blank/browse.asp?a=383&BMDRN=2000&BCOB=0&c=54134. There are frequently asked questions about emergency preparedness online at http://www2.apsva.us/154010717145827383/lib/154010717145827383/q_a_english.pdf.

GMU personnel were not made aware of the location of emergency preparedness plans within the planetarium building, the frequency with which these plans are updated, nor the frequency with which drills are conducted.

Planetarium building alarms were demonstrated to GMU personnel and found to be in working condition.

It is not known if local area emergency management personnel are aware of the special nature of the planetarium building and its unique equipment.

GMU personnel were not made aware of the schedule with which fire department inspections are scheduled.
Fire detection and suppression systems were visible, and are present in photographs B-33a and B-33b in Appendix B. The location of the sprinkler heads is considered to be safe.

3.8 Education Assessment

In this section we focus on the science educational content, grade level appropriateness, and relevancies to both Virginia Standards of Learning and the National Science Education Standards, of the David M. Brown Planetarium shows presented to school students.

3.8.1 Science Content

Curricular materials related to the planetarium for teachers of each grade level from kindergarten through high school were provided for this review. An overview of the curricula provided is summarized in Table 3.8-1. Curricular materials include a mix of information to prepare teachers and students for their visit. No content inaccuracies were found in the materials provided.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Curricula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kindergarten</td>
<td>• Our First Planetarium Visit</td>
</tr>
<tr>
<td></td>
<td>• Shadows</td>
</tr>
<tr>
<td></td>
<td>• In My Backyard</td>
</tr>
<tr>
<td>First</td>
<td>• The Sun and Stars</td>
</tr>
<tr>
<td></td>
<td>• The Great Space Treasure Hunt</td>
</tr>
<tr>
<td>Second</td>
<td>• The Moving Earth</td>
</tr>
<tr>
<td></td>
<td>• Our Place in Space</td>
</tr>
<tr>
<td>Third</td>
<td>• Pathways of the Sun</td>
</tr>
<tr>
<td></td>
<td>• The Mystery of the Missing Seasons</td>
</tr>
<tr>
<td>Fourth</td>
<td>• Motions in Space</td>
</tr>
<tr>
<td></td>
<td>• Planet Patrol</td>
</tr>
<tr>
<td>Fifth</td>
<td>• Electromagnetic Spectrum</td>
</tr>
<tr>
<td></td>
<td>• Just Imagine</td>
</tr>
<tr>
<td>High School Earth Science</td>
<td>• Celestial Sphere</td>
</tr>
<tr>
<td></td>
<td>• Celestial Motion and the Ecliptic</td>
</tr>
<tr>
<td></td>
<td>• Stellar Evolution</td>
</tr>
<tr>
<td></td>
<td>• Cosmology Introduction</td>
</tr>
</tbody>
</table>

3.8.1.1 Kindergarten

For kindergarten the focus of curricular materials is more on educating the teacher so they know what to expect and can prepare students in advance. For example, “Our First Planetarium Visit” explains that its purpose is to help
students acclimate to the “strange environment of the Planetarium.” Additionally, there is brief information about protocol, such as how students should be seated. There is information about the format and content of the program, which includes more information about the purpose of the experience to help students “become accustomed to dome images & sound.” Vocabulary is provided without definitions along with handouts of a dome shape, the planetarium instrument, and a descriptive poem about the planets by Fred Penner.

Curricular materials for “Shadows” provide the verbatim text of key concepts the program addresses aligned with VSOL K.7 that identifies shadows as the effect of blocked natural or artificial light, with extension to more advanced concepts of day/night (VSOLs 1.6, 3.8) and moon phases (VSOLs 3.8, 4.7). There is information about the format and content of the program, which includes the terms “opaque” and “transparent” (VSOL 5.3) along with opportunity for students to view astronomical shadows. No vocabulary or concept descriptions are provided of these. Handouts provide ideas for two activities for students to explore their shadows outside to discover the relationship between shadow length and time of day and two poems on shadows by Margaret Hillert and Robert Louis Stevenson.

Curricular materials for “In My Backyard” state that it is aligned with the Life Processes and Interrelationships of Earth and Space strands taught in kindergarten and first grade by beginning with backyard nature and extending to the universe. Along with positive written reviews by teachers, a synopsis of the program is provided to prepare teachers for what will happen during the program. A list of vocabulary is provided with definitions. Handouts include activity descriptions for students to learn about wind (related to the Sun as heat source – VSOLs 1.6, ES.13), clouds (VSOL 4.6), rain and temperature (VSOLs 1.6, 3.9), and day/night (VSOLs 1.6, 3.8, 4.7 - related to Earth’s rotation). One safety instruction is provided that explains that heat activities should be only performed as teacher demonstration.

3.8.1.2 First Grade

Curricular materials for “The Sun & Stars” provide the verbatim text of key concepts the program addresses aligned with VSOL 1.6 that identifies the sun as a source of heat and day/night caused by rotation of Earth. An overview of the program is provided for teachers so they may know in advance what to expect and to prepare their students. There is an embedded review of first grade programs that then segues to new information about the sun and other stars. In addition to providing the teacher with key concepts, vocabulary is defined for the teacher as well. Ideas introduced in the curriculum include that observations of stars and our sun are dependent upon our perspective (VSOL K.1) on a rotating Earth (VSOL 1.6). There is extension to what the sun is made of in terms of states of matter (VSOL 5.4) and the influence of increased pressure due to gravity (VSOL 6.8) on gas (VSOL CH.5) accompanied by a demonstration. Next
follows information about the life cycle of stars (VSOL ES.14). One follow-up activity is provided that asks students to brainstorm how energy from the sun is used (VSOL 3.11).

Curricular materials for “The Great Space Treasure Hunt” inform the teacher of what to expect during the program in order to prepare students for what they will experience. The targeted VSOL 1.6 is provided verbatim, which stipulates that students should “investigate and understand the basic relationships between the sun and the Earth.” Following this reference to VSOL 1.6, the teacher is provided with content that will be covered during the visit that spans the location of the sun in the solar system (VSOL 4.7) with the planets revolving around it, the composition of planets (VSOL ES.4), the Universe (VSOL ES.14), and environmental awareness and appreciation of Earth’s limited resources (VSOL 1.8). Vocabulary with definitions is provided for the teacher (VSOLs 6.8, ES.4, ES.14). A follow-up activity is provided that has students organize and match the planets of the solar system (VSOLs 6.8, ES.4). A booklet is provided to students that describes the solar system and its components in detail (VSOLs 6.8, ES.4).

3.8.1.3 Second Grade

Curricular materials for “The Moving Earth” inform the teacher of what to expect during the program in order to prepare students for what they will experience. The targeted VSOL 2.6 is provided verbatim, which stipulates that students should learn about “temperature, wind, condensation, precipitation, drought flood, and storms; the uses and importance of measuring and recording weather data.” The curriculum continues with attention to concepts of horizon and compass direction (VSOLs 1.6, 2.2, 4.7, ES.3), cause of day and night (VSOL 6.8), cause of shadow (VSOL 6.8), Sun as driving force of water cycle and weather (VSOL 3.9), constellations (VSOL ES.3), and dependent location of constellations (VSOL ES.3). The crossword puzzle provided as a follow-up addresses VSOLs 1.6, 2.2, 3.9, 4.7, 6.8, and ES.3. The workbook provided addresses VSOLs 1.6, 2.2, 3.9, 4.7, 6.8, and ES.3.

Curricular materials for “Our Place in Space” were not provided for review. It is assumed that this curriculum addresses similar VSOLs to that found in the first grade’s “The Great Space Treasure Hunt,” which targets VSOLs 4.7, 6.8, ES.4, and ES.14.

3.8.1.4 Third Grade

Curricular materials for “Pathways of the Sun” inform the teacher of what to expect during the program in order to prepare students for what they will experience. The targeted portions of VSOLs 3.8 and 3.9 are provided, which stipulates that students should learn about the patterns of natural events including “day and night, seasonal changes, phases of the moon, and tides” as
well as the importance of the sun that “drives the water cycle.” The curriculum continues with attention to concepts of rotation and revolution (VSOLs 3.8, 4.7, 6.8), cause of seasons (VSOLs 3.8, 4.7, 6.8, ES.4), horizon and NSWE direction (VSOLs 1.6, ES.3), order (VSOL 3.8) and cause of moon phases (VSOLs 4.7, 6.8, ES.4), change and movement of position of sun and moon and constellations throughout the year (VSOLs 3.8, 4.7, 6.8, ES.4), and differences between southern sky and northern sky view of constellations (VSOL ES.3). A two-page document is provided to teachers covering these ideas along with a workbook for students.

Curricular materials for “The Mystery of the Missing Seasons” were not provided for review. It is assumed that it covers in greater detail VSOLs 3.8, 6.8, and ES.4 on seasonal changes and VSOL 3.1 on the chronological sequencing of natural events.

3.8.1.5 Fourth Grade

Curricular materials for “Motions in Space” inform the teacher of what to expect during the program in order to prepare students for what they will experience. The targeted VSOL 4.7 is provided verbatim, which stipulates that students should learn about “motions of Earth, moon, and sun (rotation and revolution); the relative size, position, and makeup of the Earth, moon, and sun; unique properties of the Earth as a planet and part of the solar system; and historical contributions in understanding the Earth-moon-sun relationship.” The curriculum continues with attention to concepts of the sun’s structure, Earth’s rotation on an axis while revolving around sun (VSOLs 3.8, 4.7, 6.8), seasons caused by tilt of Earth (VSOLs 4.7, 6.8, ES.4), cause of time of day and time zones (VSOLs 3.8, 6.8), mechanics of moon phases (VSOLs 4.7, 6.8, ES.4), historical developments leading to human understanding of solar system (VSOLs 4.7, 6.8), cause of tides (VSOLs 3.8, 6.8), and seasonal constellations (VSOL ES.3). A four-page document of text and graphics is provided to teachers covering these ideas along with a workbook for students.

Curricular materials for “Planet Patrol” were not provided for review. It is assumed that it covers in greater detail characteristics of planets in the solar system as described in VSOLs 4.7, 6.8, and ES.4.

3.8.1.6 Fifth Grade

Curricular materials for “The Electromagnetic Spectrum” inform the teacher of what to expect during the program in order to prepare students for what they will experience. The targeted VSOLs 5.2 and 5.3 are provided verbatim, which provide expectations for students’ understanding of sound and light. The curriculum continues with attention to content of VSOLs 5.2 and 5.3 and extension to invisible portions of the electromagnetic spectrum introduced in VSOLs PS.9 and PH.10.
3.8.1.7 Sixth through Eighth Grades

No curricular materials for these grade levels were provided for review.

3.8.1.8 High School Grades (Earth science)

Curricular materials for high school Earth science were provided: Celestial Sphere, Celestial Motion and the Ecliptic, Stellar Evolution, and Cosmology Introduction. While extending beyond the concepts and skills described in the state's curriculum support materials (Framework and standards), the planetarium's provided curricular materials are aligned with VSOLs ES.3 (Star charts, direction, and location), ES.4 (Earth and solar system), ES.11 (Tides), and ES.14 (Origin and evolution of universe).

3.8.2 Grade Appropriateness

3.8.2.1 Kindergarten

There is an implicit level of developmental readiness implied in the state level standards. This level of readiness along with the direct observation of students at this age level will be used to assess the appropriateness of planetarium program experiences with this age level. Because the emphasis of “Our First Planetarium Visit” is on comfortably acclimating students to the planetarium, appropriateness of the physical surroundings is briefly reviewed in this section. Students entering the planetarium appeared comfortable with their surroundings, even when the lights were out toward the end of the program, but seating was not appropriate due to the structure of the flip-down stadium seats. Students were observed to sit on their knees to see over the seat in front of them (even when advised not to do so) which caused the seats to fold. The resultant gap at the back of the seat was large enough that a child’s limb could dangerously slip through and potentially result in injury during instruction. It is recommended that the physical developmental needs of this group be considered in future seating decisions.

Better alignment of the programs designated for kindergarten with VSOLs K.1 and K.2 is needed to make the programs more developmentally-appropriate. At this stage of development, kindergarten students need experiences on a more concrete level that help them recognize that observations are key to understanding the world around them, that observations can be multi-sensory, observations can be recorded in various formats, and the importance of perspective and multiple observations. It is more developmentally-appropriate for this age group to receive less planned information and have extended time to brainstorm and ask questions about what they are experiencing with their senses while at the planetarium. The planetarium's technology and expertise of its staff are appropriate for this to occur. Less emphasis should be placed on having students learn space concepts from viewing the night sky. Instead more
emphasis should be placed on having students make direct observations of colors; shadows; and position, motion, and physical properties of objects. Informally, this appears to be happening at the planetarium and should be formally incorporated into the curricula distributed to teachers. A suggested resource to consider when designing future experience for this age level is *A Head Start on Science: Encouraging a Sense of Wonder* by William Ritz (2007).

3.8.2.2 First Grade

Better alignment of the programs designated for first grade with VSOLs 1.1 and 1.6 is needed to make the programs more developmentally-appropriate. VSOL 1.6 is focused on helping students make sense of night/day with respect to the Earth-sun relationship, which is instead highlighted in the second grade program, “The Moving Earth.” VSOL 1.6 is also focused on helping students understand that a heat source can warm objects near it. In this case the sun is the heat source and Earth is the object being warmed. Students at this age level need explicit experiences with this concept and opportunities to collect data. For any redesign of curriculum used with this grade level, attention should be directed toward using both the planetarium and the large relatively protected sidewalk directly outside the planetarium to convey the basic relationship of the sun and Earth as being primarily that the sun is a heat source that warms the Earth’s air, water, and land. Students could use their sense of sight and touch to make observations about the effect of the sun’s heat on a filled balloon, a shallow dish of soil, and shallow dish of water. Extension to using a large print thermometer manufactured for primary learners is conceivable as well (VSOLs 2.6, 4.6). Appropriate for this age-level, experiences inside the planetarium and outdoors should be followed with opportunity for students to brainstorm and ask questions to indicate their readiness level, which may indeed lead to portions of the more advanced content supplied in the present curriculum. Planetarium staff would be an appropriate, well-equipped, and knowledgeable resource for each aspect of this endeavor.

3.8.2.3 Second Grade

Better alignment of the programs designated for second grade with the grade level’s VSOLs is needed to make the programs more developmentally-appropriate. While the current program officially targets VSOL 2.6 (weather), its content does not. Instead, attention is provided to VSOL 2.2 (magnetic compass direction) and concepts introduced in later grade levels with one exception: VSOL 1.6 (position of sun throughout day, NSWE direction). It is suggested that in any redesign of curricula for this grade level should embrace and stress the full set of content from VSOL 2.2 with reinforcement and re-teaching of ideas of sun position and NSWE direction in VSOL 1.6. It could be argued that first grade students are not developmentally-ready to learn about relative sun position and NSWE direction until a later grade, so a revisit of this content in the context of the planetarium would be quite beneficial to the students. Appropriate for this age-
level, experiences inside the planetarium incorporating the magnetic compass and outdoors to view the location of the sun in the sky should be followed with opportunity for students to brainstorm and ask questions to indicate their readiness level, which may indeed lead to portions of the more advanced content supplied in the present curriculum. Planetarium staff would be an appropriate, well-equipped, and knowledgeable resource for each aspect of this endeavor.

3.8.2.4 Third Grade

The program’s curriculum appears developmentally-appropriate for the targeted grade level. More emphasis should be placed on exposing students to the targeted concepts with opportunities to practices VSOL 3.1’s organizing of natural events in a chronologic sequence. Recognizing that the targeted ideas are visited in multiple grade levels (third grade, fourth grade, sixth grade, and high school Earth science), less emphasis should be placed on higher level content until basic understanding has been achieved. Any future redesign of curriculum should examine how to combine experiences inside the planetarium with modeling to support students’ chronologic sequencing of events and advancing their understanding of cause/processes of observed phenomena. Appropriate for this age-level, experiences inside the planetarium should be followed with opportunity for students to brainstorm and ask questions to indicate their readiness level, which may indeed lead to portions of the more advanced content found in VSOLs 4.7, 6.8, ES.3, and ES.4. Planetarium staff would be an appropriate, well-equipped, and knowledgeable resource for each aspect of this endeavor.

3.8.2.5 Fourth Grade

The program’s curriculum appears quite developmentally-appropriate for the targeted grade level. More emphasis should be placed on exposing students to the targeted concepts with opportunities to become adept in understanding the nature of science and accurately using associated vocabulary as described in VSOL 4.1. For example, VSOL 4.1 states that “Those conducting investigations need to understand the difference between what is seen and what inferences, conclusions, or interpretations can be drawn from the observation.” Additionally, explanations are provided for the following concepts: inference, prediction, experiment, hypothesis, manipulated variable, and responding variables. Future redesign of curriculum for this grade level should consider how the curriculum can advance students’ mastery of 3.1 to support students’ understanding of the nature of science and accurate use of associated vocabulary and ideas. Recognizing that the targeted ideas are visited in multiple grade levels (fourth grade, sixth grade, and high school Earth science), less emphasis should be placed on higher level content until basic understanding has been achieved. Any future redesign of curriculum should examine how to combine experiences inside the planetarium with opportunities to support students’ understanding of the nature of science. Appropriate for this age-level, experiences inside the
planetarium should be followed with opportunity for students to brainstorm and ask questions to indicate their readiness level, which may indeed lead to portions of the more advanced content found in VSOLs 6.8, ES.3, and ES.4. Planetarium staff would be an appropriate, well-equipped, and knowledgeable resource for each aspect of this endeavor.

3.8.2.6 Fifth Grade

The curriculum appears developmentally-appropriate for the targeted grade level by providing attention to content of VSOLs 5.2 and 5.3. The idea of electromagnetic spectrum is not encountered until VSOL PS.9 with invisible portions of the electromagnetic spectrum introduced in VSOLs PS.9 and PH.10. Care should be taken in ensuring that students have mastered all content stipulated in VSOLs 5.2 and 5.3, with content associated with VSOLs PS.9 and PH.10 considered of secondary importance. While the idea of electromagnetic spectrum appears to be introduced as an idea of primary importance due to the title of the program, the actual extension to the invisible portions of the electromagnetic spectrum are clearly secondary in the curriculum as it is now written. It is recommended that any redesign examine how planetarium experiences can support students’ experiences with prisms (VSOL 5.3), mirrors (VSOL 5.3), understanding of nature of science (VSOL 5.1), and investigative skills as described in VSOL 5.1 while physically visiting the planetarium. Appropriate for this age-level, experiences inside the planetarium should be followed with opportunity for students to brainstorm and ask questions to indicate their readiness level, which may indeed lead to portions of the more advanced content found in VSOLs PS.8, PS.9, PH.9, and PH.10. Planetarium staff would be an appropriate, well-equipped, and knowledgeable resource for each aspect of this endeavor.

3.8.2.7 Sixth through Eighth Grades

No curricular materials for these grade levels were provided for review.

3.8.2.8 High School Grades (Earth science)

For regular high school Earth science courses, care should be taken in ensuring that students have mastered all content stipulated in VSOLs ES.3, ES.5, ES.11, and ES.14 with content beyond these standards considered of secondary importance. Redesign should consider how planetarium resources and staff can support students’ development of knowledge and skills associated with ES.1 so that planetarium visits are embedded smoothly into the curriculum through provision of curriculum encompassing pre- and post-visit experiences.
3.8.3 Alignment with *National Science Education Standards* (NRC, 1996)

3.8.3.1 Kindergarten

“Shadows” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “changes in earth and sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes” and “science in personal and social perspectives.”

“Our First Planetarium Visit” is aligned with NSES K-4 standard, “objects in the sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes,” “science and technology,” and “science in personal and social perspectives.”

“In My Backyard” is aligned with NSES K-4 standard, “objects in the sky” and “organisms and environments.” Additionally, it is aligned with NSES’ “unifying concepts and processes” and “science in personal and social perspectives.”

3.8.3.2 First Grade

“The Sun & Stars” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “objects in the sky” and “changes in earth and sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes” and “science in personal and social perspectives.”

“The Great Space Treasure Hunt” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “objects in the sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes,” “science and technology,” and “science in personal and social perspectives.”

3.8.3.3 Second Grade

Curriculum of “The Moving Earth” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “changes in earth and sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes” and “science in personal and social perspectives.”

While not provided, it is assumed that curriculum for “Our Place in Space” is similar to that targeted in “The Great Space Treasure Hunt,” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “objects in the sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes,” “science and technology,” and “science in personal and social perspectives.”
3.8.3.4 Third Grade

“Pathways of the Sun” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “objects in the sky” and “changes in earth and sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes” and “science in personal and social perspectives.”

3.8.3.5 Fourth Grade

“Motions in Space” is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “changes in earth and sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes” and “science in personal and social perspectives.”

While not provided, it is assumed that curriculum for “Planet Patrol” is similar to that targeted in “Our Place in Space” and “The Great Space Treasure Hunt,” which is appropriately aligned with *National Science Education Standards* (NSES) for content in grades kindergarten through grade four (K-4), entitled “objects in the sky.” Additionally, it is aligned with NSES’ “unifying concepts and processes,” “science and technology,” and “science in personal and social perspectives.”

3.8.3.6 Fifth Grade

“The Electromagnetic Spectrum” is aligned with is appropriately aligned with *National Science Education Standards* (NSES) for content in grades five through eight (5-8), entitled “transfer of energy.” Additionally, it is aligned with NSES’ “unifying concepts and processes,” “science and technology,” and “science in personal and social perspectives.”

3.8.3.7 Sixth through Eighth Grades

No curricular materials for these grade levels were provided for review with respect to *National Science Education Standards* (NSES).

3.8.3.8 High School Grades (Earth science)

Curricular materials for high school Earth science were provided: Celestial Sphere, Celestial Motion and the Ecliptic, Stellar Evolution, and Cosmology Introduction. While extending beyond the concepts and skills described in *National Science Education Standards*, the planetarium’s provided curricular materials are aligned with “origin and evolution of the earth system” and “origin and evolution of the universe.” Additionally, materials are aligned with NSES’ “unifying concepts and processes,” “science and technology,” and “science in personal and social perspectives.”
3.8.4 Alignment with Science Standards of Learning for Virginia Public Schools (VDOE, 2003)

3.8.4.1 Kindergarten

“Shadows” is appropriately aligned with grade level VSOL K.7 that identifies shadows as the effect of blocked natural or artificial light, with extension to more advanced concepts of day/night (VSOLs 1.6, 3.8) and moon phases (VSOLs 3.8, 4.7). Terminology used in the program, such as “opaque” and “transparent,” is not officially introduced until fifth grade (VSOL 5.3).

“Our First Planetarium Visit” lacks alignment with the Kindergarten VSOLs with exception of providing an opportunity for experience with K.1 and K.2 concepts/skills. For example, students experience how objects are observed from different positions to achieve different perspectives and experience how objects can be described with pictures and words. This program excels at providing preliminary experiences to support students’ mastery of VSOL 6.8 through a child-centered approach. Rather than focusing on content vocabulary not officially introduced into the science standards until grade 6 (VSOL 6.8), it is recommended that concepts and skills in these two standards (VSOLs K.1 and K.2) should be highlighted and made explicit for teachers and students in future drafts of program curricula. Direct observation revealed that this content was being addressed during the program but was not made explicit or stressed. The list of vocabulary was not aligned with the grade level VSOLs, and any vocabulary in curriculum materials, especially that which extends beyond grade level, should be defined for teachers.

“In My Backyard” provides an opportunity for students to explore the importance of perspective during multiple observations (VSOL K.1), which should be made more explicit. The program has great potential for enhancing students’ learning of life processes of plants and animals (VSOL K.6). Vocabulary definitions are not aligned with the VSOLs for this grade level or written in a manner easily accessible to this age level.

3.8.4.2 First Grade

“The Sun & Stars” is aligned with VSOL 1.6 that identifies the sun as a source of heat and day/night caused by rotation of Earth. However, emphasis on ideas found in upper grade level VSOLs 3.11, 5.4, 6.8, ES.14, and CH.5 provide evidence that the targeted content of VSOL 1.6 needs more attention and exploration through integration of VSOL 1.1 experiences while visiting the planetarium.

“The Great Space Treasure Hunt” states that it is aligned with VSOL 1.6, but its content is aligned instead with VSOLs 4.7, 6.8, ES.4, and ES.14. It is tangentially
aligned with VSOL 1.8. It should be noted that there is on-going debate and concern with the timing of when the solar system and its components are initially introduced in the VSOLs with some educators arguing for earlier introduction of the solar system’s planets while others educators support waiting to introduce these abstract ideas until students are developmentally-ready to interpret models of abstract ideas. Any future redesign should consider that sixth grade is the earliest grade level where VSOL specifically stipulates that students should have mastery of the solar system’s planets and their characteristics with study beyond our solar system not introduced until high school Earth science.

3.8.4.3 Second Grade

Curriculum of “The Moving Earth” is aligned with VSOLs 1.6, 2.2, 3.9, 4.7, 6.8, and ES.3. It does not appear to be aligned with VSOL 2.6 based on the documents provided. It is suggested that in any redesign of curricula for this grade level should embrace and stress the full set of content from VSOL 2.2 with reinforcement and re-teaching of ideas of sun position and NSWE direction in VSOL 1.6.

While not provided, it is assumed that curriculum for “Our Place in Space” is similar to that targeted in “The Great Space Treasure Hunt,” which covers VSOLs 4.7, 6.8, ES.4, and ES.14. It should be noted that there is on-going debate and concern with the timing of when the solar system and its components are initially introduced in the VSOLs with some educators arguing for earlier introduction of the solar system’s planets while others educators support waiting to introduce these abstract ideas until students are developmentally-ready to interpret models of abstract ideas. Any future redesign should consider that sixth grade is the earliest grade level where VSOL specifically stipulates that students should have mastery of the solar system’s planets and their characteristics with study beyond our solar system not introduced until high school Earth science.

3.8.4.4 Third Grade

“Pathways of the Sun” is aligned with VSOL 3.8 as described. Documentation is not provided to support its alignment with VSOL 3.9 (Sun drives water cycle), but it is most likely tangentially covered during implementation of the program. The curriculum appears to align with VSOLs 4.7, 6.8, ES.3, and ES.4. However, more advanced content from these standards should be secondary to students’ mastery of content stipulated in VSOL 3.8. For any future redesign, the curriculum should be expanded to cover tides so that 3.8 is more fully addressed, and more attention needs to be provided to VSOL 3.1, which stipulates that students need to actively engage in experiences where they organize natural events in chronologic order to better document and understand them. More attention to VSOL 3.1 during redesign will assist students in their eventual mastery of higher level content provided in VSOLs 4.7, 6.8, ES.3, and ES.4.
Also, clarification on the level of vocabulary associated with moon phases should be provided here. Fourth grade is the initial grade level where the names of various moon phases are provided. In grade levels prior to fourth grade, mention of specific names of moon phases should be considered secondary to basic understanding of moon phases.

3.8.4.5 Fourth Grade

“Motions in Space” is aligned with VSOL 4.7 as described. The curriculum appears to align with VSOLs 3.8, 6.8, ES.3, and ES.4 as well. However, more advanced content from these standards should be secondary to students’ mastery of content stipulated in VSOL 3.8. While the current fourth planetarium curriculum covers tides, there is no mention of tides in the fourth grade’s VSOL. It is conceivable that if a redesign of curriculum for third grade introduced tides, then a redesign of curriculum for fourth grade should support students’ continuing understanding of the cause of tides.

Also, clarification on the level of vocabulary associated with moon phases should be provided here. Fourth grade is the initial grade level where the names of various moon phases are provided. In grade levels prior to fourth grade, mention of specific names of moon phases should be considered secondary to basic understanding of moon phases.

While not provided, it is assumed that curriculum for “Planet Patrol” is similar to that targeted in “Our Place in Space” and “The Great Space Treasure Hunt,” which covers VSOLs 4.7, 6.8, ES.4, and ES.14. It should be noted that there is on-going debate and concern with the timing of when the solar system and its components are initially introduced in the VSOLs with some educators arguing for earlier introduction of the solar system’s planets while others educators support waiting to introduce these abstract ideas until students are developmentally-ready to interpret models of abstract ideas. Any future redesign should consider that sixth grade is the earliest grade level where VSOL specifically stipulates that students should have mastery of the solar system’s planets and their characteristics with study beyond our solar system not introduced until high school Earth science.

3.8.4.6 Fifth Grade

“The Electromagnetic Spectrum” is aligned with VSOLs 5.2 and 5.3 as described. The curriculum appears to align with VSOLs PS.8, PS.9, PH.9, and PH.10 as well. However, more advanced content from these standards should be secondary to students’ mastery of content stipulated in VSOLs 5.2 and 5.3. Care should be taken in ensuring that students have mastered all content stipulated in 5.2 and 5.3 with content in the curriculum associated with VSOLs PS.9 and PH.10 considered of secondary importance. While the idea of electromagnetic spectrum appears to be introduced as an idea of primary importance due to the
title of the program, the actual extension to the invisible portions of the electromagnetic spectrum are clearly secondary in the curriculum as it is now written. It is recommended that any redesign examine how planetarium experiences can be expanded to support students’ experiences with prisms (VSOL 5.3), mirrors (VSOL 5.3), understanding of nature of science (VSOL 5.1), and investigative skills as described in VSOL 5.1 while physically visiting the planetarium.

3.8.4.7 Sixth through Eighth Grades

No curricular materials for these grade levels were provided for review. However, any future redesign should consider use of planetarium resources and staff to target students’ understanding of VSOLs 6.4 (Matter), 6.8 (Solar system and relationships among its bodies), LS.2 and LS.3 (Cells and cellular organization), PS.3 and PS.4 (Atomic structure and periodic table), PS.8 and PS.9 (Sound and light), Consideration should be given to how content in the previous standards along with the investigative skills for each targeted grade level could be encompassed simultaneously while students visit the planetarium.

3.8.4.8 High School Grades (Earth science)

Curricular materials for high school Earth science were provided: Celestial Sphere, Celestial Motion and the Ecliptic, Stellar Evolution, and Cosmology Introduction. While extending beyond the concepts and skills described in the state’s curriculum support materials (Framework and standards), the planetarium’s provided curricular materials are aligned with VSOLs ES.3 (Star charts, direction, and location), ES.4 (Earth and solar system), ES.11 (Tides), and ES.14 (Origin and evolution of universe). For regular high school Earth science courses, care should be taken in ensuring that students have mastered all content stipulated in VSOLs ES.3, ES.5, ES.11, and ES.14 with content beyond these standards considered of secondary importance. Redesign should consider how planetarium resources and staff can support students’ development of knowledge and skills associated with ES.1 so that planetarium visits are embedded smoothly into the curriculum through provision of curriculum encompassing pre- and post-visit experiences.
4.0 Recommendations and Conclusion

Based upon the visits made to the Arlington Public Schools’ David M. Brown Planetarium the GMU team is making the following recommendations. The Arlington Public School system should consider:

- upgrading the planetarium projector to a digital full dome system (e.g. the Spitz SciDome projector) to enable development of better curriculum materials as well as opening the door for additional discipline utilization including biology, chemistry, meteorology and physics;
- removing and replacing current theater seats with new theater seats;
- upgrading HVAC to allow for local regulation of temperature and humidity;
- expanding public awareness of planetarium shows and events by utilizing multiple advertising outlets such as student school packages, radio, libraries, newspaper, and the World Wide Web;
- improving signage for directions to planetarium;
- adding David M. Brown Planetarium signage to planetarium building itself;
- upgrading cove lighting, now standard incandescent lighting, to LED cove lighting, for improved lighting control and long-term energy and cost savings;
- ensuring that the content of the curriculum of each program is aligned with the specific Virginia Standards of Learning (VSOL) listed in the curriculum and addresses the targeted standard to the fullest extent possible;
- enhancing the utilization of Science Standards of Learning Curriculum Framework (VDOE, 2003) to guide content selection for space science topics visited during multiple grade levels with progressively more complex mastery (e.g. students’ understanding that there is a pattern to moon phases leading toward their eventual understanding of the mechanics of moon phases and ability to identify the names of particular phases);
- the developmental readiness of audiences with respect to inclusion of content beyond the grade level’s VSOL (e.g. introduction of planets of the solar system prior to grade six);
- how planetarium resources and staff can be maximized to support students’ development of investigative skills stipulated in the VSOL for each grade level through experiences while at the planetarium both indoors and outdoors (e.g. 1 - students make predictions about the impact of the Sun on air-filled balloon, shallow dish of water, and shallow dish of soil with supervision of planetarium staff and students’ teacher; 2 - students enter planetarium to learn about the Sun as provider of heat to earth; 3 - students record observations outdoors; and 4 - students...
brainstorm and ask planetarium staff questions indoors with planetarium staff responding with use of resources available inside planetarium);

- how planetarium visits can be embedded in the curriculum at each grade level with pre- and post-visit experiences consistent with inquiry-based instruction (e.g.: the 5-E Model of Instruction (BSCS, 1989), which is a popularly-used curriculum model to support inquiry-based science instruction, could be used to structure time while students are physically at the planetarium, and the same model could be used to structure a unit of instruction in which planetarium experiences are embedded; and, two other models to consider for structuring time while at the planetarium and entire units of instruction involving the planetarium would be the problem-based learning model (Delisle, 1997) or project-based approach (Krajcik & Czerniak, 2007)); and,

- how planetarium resources and staff can be maximized to support students’ understanding of the nature of science.

In conclusion, GMU personnel have found that the David M. Brown Planetarium, operated under the aegis of the Arlington Public School system in support of elementary education, is a unique vibrant asset of not only the Arlington Public School system, but the people of the County of Arlington. By addressing certain upgrade requirements of the planetarium itself, and by more closely aligning the planetarium to the Virginia Standards of Learning and modern research-based pedagogy, the David M. Brown Planetarium can continue to be a prideful valuable asset of Arlington County and its elementary education system.

Acknowledgements: The authors would like to take this opportunity to acknowledge the contributions of the following persons in the completion of this assessment report, without whom this report could not have been completed: Bill Dedmond, Jonathan Harmon, Ron Melkis, Ralph Petrino, Connie Skelton, and Candice Wilson.
Appendix A

References
References


Biological Sciences Curriculum Study (1989). New designs for elementary school science and health: A cooperative project of Biological Science Curriculum Study (BSCS) and International Business Machines (IBM). Dubuque, IA: Kendall-Hunt.


Appendix B

Photographs
Appendix C

Vendor Information and Quotations
George Mason University  
4400 University Drive  
Science and Technology 1-MSN 3F3  
Dept. of Physics & Astronomy, 363A  
Fairfax, VA 22030  
Re: Arlington Public Schools Planetarium

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extraction of A4 instrument, elevator, and console (if desired). Includes trade-in. Floor plate provided to cover hole in floor.</td>
<td>$7,000</td>
</tr>
<tr>
<td>2</td>
<td><strong>SciDome™ single projector Digital Planetarium System.</strong> Includes LCoS projector with custom fisheye lens, projector stand and enclosure, control desk, Starry Night™ Dome sky software, hard drive storage/playback for fulldome shows, ATM-4 Windows®-based automation/control, &quot;Oasis in Space&quot; fulldome show, fulldome space library, one spare lamp/housing and two days on-site training.</td>
<td>$155,000</td>
</tr>
<tr>
<td>3</td>
<td>360 degree, three-color (RGB) fully programmable LEDCove lighting for 30-foot diameter dome. Features chase sequences, sunrise/sunset effects, mixing thousands of colors and 100,000 hour life. Assumes installation in existing trough. Controlled via ATM-4 automation (included with SciDome).</td>
<td>$18,600</td>
</tr>
</tbody>
</table>

**Notes:**
1. All prices are shown delivered and installed.
2. Prices valid for 180 days.
3. No Federal, State or Local taxes included unless specifically mentioned herein.

**Payment Terms:**
- 25% down with order placement
- 25% 60 days after receipt of order
- 25% upon completion of manufacture
- 15% upon readiness to ship
- 10% upon completion
Digital Planetarium Specifications

Technical Specifications

1.0 General

The fulldome digital planetarium shall display the entire sky on the dome through a single projector. The fulldome digital planetarium shall compose the scene virtually within the computer software. There should be two primary components to the system that will be described below: The operator’s workstation and the projector.

2.0 Operator’s Workstation

The operator’s workstation shall be comprised of an equipment rack housing all the system’s computing hardware and a console top with the user interface. The height shall either be 30” or 40” high (specified at time of order).

2.1 User Interface

The User interface shall include a 24” flat panel LCD monitor, a mouse and a keyboard.

2.2 Computing Rack

The realtime astronomy software shall run on a platform of two high-end PC computers. The first computer shall run the realtime astronomy user-interface application and the system automation software. This computer shall serve as the “Controlling PC” through which the operator programs shows and manually operates the system. The second “Render PC” shall run the realtime astronomy rendering application exclusively, which, taking commands from the controlling computer, shall generate the high-resolution real time sky that will be displayed on the dome.

2.2.1 Controlling PC

Processor: Intelfi Cor i7-920 Processor (2.66 GHZ Quad Core)
Memory: 4GB RAM
Graphics subsystem: NVIDIA Quadro FX 570
Disk Storage: 250GB minimum
2.2.2 Render PC

Processor: Intelfi Core i7-940 Processor (2.93 GHZ) (Quad Core)
Memory: 8GB RAM
Graphics subsystem: NVIDIA Quadro 4600 or better
Disk Storage: 250/500GB minimum

2.2.3 Audio Output

The fulldome digital planetarium computer rack shall provide a 5.1 channel analog unbalanced line level output to the sound system (the sound system is not included). Alternately, stereo output may be specified at time of order.

3.0 Projection System

The fulldome digital planetarium shall employ an WUXGA+ video projector. This projector shall be fitted with a fisheye lens capable of distributing the image over a 180 degree hemisphere. The projector shall be located as close as possible to the center of the dome in the X and Y axes. The projector shall typically be positioned below the center of the dome in the Z axis although the final positioning shall be determined based on the geometry of the dome and the architecture of the room.

3.1 Image Resolution: A minimum resolution of WUXGA (1920X1200 pixels), with 1200 pixel diameter circle delivered to the dome screen.

3.2 Brightness: At least 3200 ANSI lumens over complete 16X10 pixel array.

3.3 Dome Size: Dome sizes ranging from 16 to 40 feet diameter.

3.4 Color Space: DVI input with 8 bit depth per color to yield 16,770,000 addressable colors.

3.5 Contrast Ratio: Contrast ratio nominally 1000:1.

3.6 Projector Tilt: Adjusts to accurately match actual dome tilt.

3.7 Projector Masking: An adjustable mask shall be provided to accurately conform the projected image to the dome edge.

3.8 Power Consumption: 120/240VAC at 50/60 Hz, consumes 390 watts of power.
3.9 **Spare Lamp:** Spare projector lamp/housing shall be provided.

3.10 **Size:** Stand-alone unit with a footprint of less than 2 feet x 2 feet floor area

3.11 **Stand:** Enclosure/stand shall be provided and secured to the floor.

3.12 **Projection Angle:** The projection system shall include “zoom” capability, to change its projection angle from $150^\circ$ to $165^\circ$, allowing the projector to be placed at an optimal position regardless of dome diameter or height.

4.0 **Documentation**

The fulldome digital planetarium shall include user’s guides for the realtime astronomy software and automation software packages.

5.0 **Infrastructure and Installation Requirements**

Documentation shall be provided defining power, conduit and physical placement requirements for the fulldome digital planetarium system. The customer shall be responsible for providing this infrastructure. The customer shall also be required to provide access and labor to help move the equipment into position and an electrician to make final power terminations at the time of installation.

6.0 **Product Development Program**

All specifications here represent the fulldome digital planetarium on the date of this specification and can change to accommodate product improvements.

**Functional Specifications**

This specification will describe the functional capabilities of the fulldome digital planetarium system including realtime 3D astronomy simulation software.

1. **General**

1.1 **Software Architecture:** The fulldome digital planetarium system shall be a true astronomical simulator where the audience, guided by an operator, moves through space and time in a universe comprised of a 3D database.
Objects within this virtual universe shall have a variety of attributes that determine how they will appear. At a distance an object should be point of light. Up close, it shall typically be a sphere with a texture mapped to that sphere to provide a photo-realistic appearance. 3D textured objects (3ds files) shall also be displayed in realtime.

The fulldome digital planetarium shall come complete with over a half billion objects in its database and electronic updates, available for download every few weeks. In addition, the user shall be able to add elements to the database for custom objects within the simulated universe.

1.2 Texture maps: Objects such as planets, moons and asteroids shall come complete with 3D texture maps in the system. Texture maps are defined as wrap around imagery that maps onto the surface of an object to provide a photo realistic view of an object when the viewer is close enough or zoomed in. Users will be able to replace any of the texture graphics in the system or add new texture graphics themselves. Note that the actual phasing and proper illumination of 3D textured objects shall always be properly displayed based on the observer’s position relative to the viewed object and the light source. Simple 2D photographic elements should also be inserted into the sky, tied either to existing objects or as completely new independent objects.

1.3 Viewing the Universe: The fulldome digital planetarium shall include an intuitive, powerful user interface. The systems should not require extensive and complex scripting to change the audience’s view or modify the sky. The realtime astronomy software shall enable the fulldome digital planetarium users to manipulate the sky and their view of the universe through clicking and dragging. Rotating the sky to view something behind the audience should be as simple as clicking on the sky and dragging it round until the view is facing the other direction. Traveling to a distant object shall be as simple as right-clicking that object in the sky and selecting the “go there” option. Accessing all of the capabilities of the realtime astronomy software must be designed to be this simple. No programming experience shall be required to use the system.

1.4 Automation: In addition to permitting live operations, the fulldome digital planetarium shall include a complete automation package that will allow for fully automated show production and playback. This automation system shall control a wide range of other devices. Additionally, the automation system must serve as its own stereo sound source by inserting standard wave files into the automation time line.
1.5 **Educational Capabilities** – The fulldome digital planetarium shall be configured to display lesson materials, and provide compatibility with educational astronomy software. The system shall include teachers’ guides, computer exercises, lesson plans and assessments for Elementary School, Middle School and High School astronomy curricula.

Planetarium presenters must be able to display, on their dome, exercises and complete lesson units from a compatible classroom software via the system’s primary realtime software. Realtime demonstrations and lessons created on classroom versions of the software must be imported to the fulldome digital planetarium system, and realtime simulations created on the fulldome digital planetarium system shall be shown using classroom work stations.

1.6 **Compatibility** – The fulldome digital planetarium shall enable operators to easily share astronomical scenes, simulations and other data with non-planetarium users via a standard data file. The operator can save parameters defining an astronomical scene’s position, field of view, movement through time/space, etc. into a file, and share these files with any person worldwide, regardless of location, who owns a compatible version of the software. Owners of this compatible version of the software shall be able to create astronomy simulations and animations on their computer, save them to disc and transfer the files via email or standard data storage devices for view on the fulldome digital planetarium. Likewise, the planetarium operator shall be able to create views and simulations and give them to non planetarium software users to view on their computers, so long as they own a compatible version of the software.

2. **Star field**

2.1 **Star Data**: The complete star field for the fulldome digital planetarium shall be made up of multiple databases all of which can be shown concurrently for a total of over 500,000,000 stars. Specific star databases shall include Tycho 2 and Hipparcus 3D databases.

2.2 **Proper Motion**: Proper motion vectors shall be displayed in the star field along with 200,000 years of actual 3D proper motion.

2.3 **Galaxies and Deep Sky Objects**: In addition to stars, the fulldome digital planetarium database shall include the PGC database of over 70,000 galaxies.

2.4 **Star System Details**: Stars that are known to have planetary bodies orbiting them or exist as binary pairs shall be represented with this detail.
If the user zooms in on or travels to one of these stars, the orbiting planets or stars shall be visible.

2.5 **Constellation Figures:** The fulldome digital planetarium shall project constellation stick figures, classical illustrations, labels and IAU boundaries for all 88 recognized constellations. In addition, the fulldome digital planetarium shall display stick figures and labels for common asterisms.

3. **Solar System**

3.1 **Planets:** All planets in the local solar system shall be accurately represented in 3D space by the fulldome digital planetarium system. Detailed texture maps for each planet must allow the user to zoom in on or travel to each planet for a realistic view of the surface.

3.2 **Moons:** All of the major natural planetary satellites shall be displayed by the fulldome digital planetarium in 3D space with detailed texture maps for up close viewing. Irregular moons shall be available as realistic 3D models, not simply photographic textures mapped to a sphere.

3.3 **Satellites:** Man made satellites shall be displayed in 3D space with orbital data and new satellite updates available regularly for download.

3.4 **Asteroids:** The fulldome digital planetarium shall include orbital data to display over 100 asteroids properly in 3D space.

3.5 **Comets:** The fulldome digital planetarium shall contain the orbital data to display over 100 comets properly in 3D Space.

3.6 **Orbital Trails:** The fulldome digital planetarium shall display the orbital paths as lines in the sky for each planet, moon, satellite, asteroid and comet.

4. **Coordinate Grids**

4.1 **Local coordinate guides:** Several guides shall be toggled for the Local coordinate system. The local Equator guide (horizon line) shall display the true line of zero elevation, which appears slightly above the apparent horizon due to the refraction of light by the atmosphere. The local Grid shall display an alt-az grid. The Meridian guide shall display the meridian line which runs overhead from north to south. The Poles guide shall display indicators for the Zenith (the point directly above you) and Nadir (the point directly below you). Altitude Azimuth guides shall be displayed in the sky to illustrate the observer’s local horizon based coordinate system.
4.2 **Equatorial Coordinate guides:** Several guides shall be displayed based on the equatorial coordinate system. The Axes guide shall display the equatorial reference plane, with the Sun at its center. The Equator guide shall display the celestial equator, the projection of the Earth's equator onto the celestial sphere. The Grid guide shall turn on the equatorial grid and, by default, the RA and Dec of each gridline. The Meridian guide shall display the celestial meridian, the projection of the line of 0° right ascension in the sky. The Poles guide shall display the projection of the Earth's poles onto the celestial sphere.

4.3 **Ecliptic Coordinate guides:** Several guides shall be displayed for the Ecliptic co-ordinate system. The Axes guide shall display the ecliptic reference plane, with the Sun at its center. The Ecliptic guide shall display the Ecliptic, a projection of the plane of the earth's orbit onto the celestial sphere. The Grid guide shall display the gridlines of ecliptic longitude and latitude. The Meridian shall display the line of 0° ecliptic longitude. The Poles guide shall toggle the display of the Ecliptic poles.

4.4 **Galactic Coordinate guides:** Several guides shall be toggled for the Galactic co-ordinate system. The Axes guide shall display the galactic reference plane, with the Sun at its center. The Equator guide shall display the Galactic equator, the baseline of the plane of the Milky Way. The Grid guide shall display the galactic plane’s gridlines of longitude and latitude. The Meridian guide shall display the line of 0° galactic longitude. The Poles guide shall toggle the display of the galactic poles.

4.5 **Extra-galactic Coordinate guides:** Because a large fraction of the nearest few thousand galaxies are concentrated in a narrow band, as seen from Earth, an extra-galactic coordinate system shall be included based on this band. The center of this band is defined as the extra-galactic equator. Three coordinates shall be defined in relation to this equator: extra-galactic X, extra-galactic Y, and extra-galactic Z. The extra-galactic X and extra-galactic Y axes shall be in the plane of the extra-galactic equator (and are perpendicular to each other), while the extra-galactic Z axis shall be perpendicular to this plane. Several guides must be displayed for the Extra-Galactic co-ordinate system. The Axes guide shall draw the three extra-galactic co-ordinate axes (x,y,z). The Equator guide shall display the extra-galactic equator. The Grid guide shall draw a complete extra-galactic grid, letting the audience see the poles, equator and other lines of latitude and longitude. The Meridian guide shall be a line perpendicular to the equator. The Pole guide toggles the extra-galactic north and south poles.
5. Text Data

5.1 **Labels:** The fulldome digital planetarium shall allow the operator to display a text label on the dome next to any object in the sky. The object names or catalog numbers shall be stored for each of the over 500 million objects in the fulldome digital planetarium database.

5.2 **Descriptions:** The fulldome digital planetarium shall allow the user to access a description for each of the over 500 million objects in the database. This information shall be easily accessed by either entering the object name or simply pointing to a desired object on the screen and clicking. This information shall be displayed on the operators control screen only and not on the dome.

5.3 **Text Display on the Dome:** The realtime software shall display information onto the dome for any object in the database. A movable cursor shall be displayed on the dome that can be used to point out objects in the sky. When this cursor rests on an object, text shall be displayed showing the object’s name, type, position, magnitude, constellation location, apparent size and magnitude, catalog number, etc.

6. Local Viewing Phenomenon

6.1 **Horizon Panorama:** The fulldome digital planetarium shall display a horizon panorama showing the foreground objects on the horizon. This panorama shall be a standard digital photographic format and users must be able to substitute the provided artwork for photographs or illustrations of their own choice. The fulldome digital planetarium shall automatically display the panorama whenever the user is on the surface of the body to which that panorama has been associated (different panoramas may be associated with each planet). The fulldome digital planetarium shall also adjust the Gamma of the panorama automatically to give the effect of transitioning from day into night. The user shall also have the option of turning off this panorama when desired.

6.2 **Light Pollution:** The fulldome digital planetarium shall allow the user to represent the night sky with an accurate representation of the effects of urban light pollution. The user must be able to select a general overall light pollution effect or define a specific scenario by placing light sources at specific angles around the horizon. The light pollution effect must also be capable of being turned off for a full rich sky.

6.3 **Daylight:** When the observer is viewing the sky from the surface of Earth, they shall have the option of viewing the daylight hours with the
natural atmospheric effects of sunrise, sunset and blue sky. Alternately the daylight feature must be able to turn off to permit demonstrations of celestial motions that occur during the day but are normally not visible from Earth.

7. Multimedia Functions

The fulldome digital planetarium shall include special features enabling planetarium producers to program shows using tools that are analogous to the traditional opto-mechanical environment. Virtual special effects or slide projectors must be defined and manipulated using automation tools native to traditional planetarium production. Pre-produced linear shows shall also be displayed through a virtual film projection utility.

7.1 Virtual Slides/Effects - The virtual slide and special effects utility of the fulldome digital planetarium shall allow the producer to utilize scanned images from the traditional show artwork or download original artwork and manipulate it on the dome. In addition, the producer shall be able to employ digitized video clips to emulate the traditional laser disc effects displayed through slewing video projectors.

7.1.1 Supported file formats: .jpg, .bmp, .tiff, .pct, .tga, .mov, .png, .mpg, .avi, .wmv

7.1.2 Slew controls: image shall be placed and moved in either dome or celestial coordinates.

7.1.3 Special controls: the image size, rotation, color and transparency must be capable of manipulation in real-time.

7.1.4 Mixing media: Multiple images and videos shall be displayed simultaneously on the dome with automatic masking for objects passing in front of another object.

8.1 Fulldome Video Playback Utility - The fulldome digital planetarium fulldome video player shall allow the user to play back fulldome video productions as easily as one would operate a DVD player.

Fulldome video player functions shall be supported by the automation system allowing producers to mix real-time sequences with pre-rendered video clips in the same production.

8.1.1 Format: MPEG.

8.1.2 Frame rate: 30fps
George Mason University  
4400 University Drive  
Science and Technology 1-MSN 3F3  
Dept. of Physics & Astronomy, 363A  
Fairfax, VA 22030  
Re: Arlington Public Schools Planetarium  

May 26, 2009  
Bid No.: N/A  

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extraction of A4 instrument, elevator, and console (if desired). Includes trade-in. Floor plate provided to cover hole in floor.</td>
<td>$7,000</td>
</tr>
<tr>
<td>2</td>
<td>SciDomeHD Digital Projection System</td>
<td>$195,000</td>
</tr>
<tr>
<td></td>
<td>High definition digital fulldome video system delivering nearly 3 million pixels to the dome. Includes dual DLP projectors with custom fisheye lenses, projector stand and enclosure, control desk, StarryNight™ Dome sky software, hard drive storage/playback for fulldome shows, auto-alignment system with 10mp digital camera and fisheye lens, ATM-4 Windows® based automation/control, “Oasis in Space” fulldome show, fulldome space library, two spare lamps/housings and two days on-site training.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>360 degree, three-color (RGB) fully programmable LEDCove lighting for 30-foot diameter dome. Features chase sequences, sunrise/sunset effects, mixing thousands of colors and 100,000 hour life. Assumes installation in existing trough. Controlled via ATM-4 automation (included with SciDome).</td>
<td>$18,600</td>
</tr>
</tbody>
</table>

**Notes:**
1. All prices are shown delivered and installed.
2. Prices valid for 180 days.
3. No Federal, State or Local taxes included unless specifically mentioned herein.

**Payment Terms:**
- 25% down with order placement
- 25% 60 days after receipt of order
- 25% upon completion of manufacture
- 15% upon readiness to ship
- 10% upon completion
Comprehensive Astronomy Curriculum for SciDome Planetariums

powered by

starry night™
Fulldome Astronomy Curriculum Designed for Fulldome Educators

To fully achieve the possibilities of fulldome education, you need a curriculum created specifically for the dome.

The SciDome Fulldome Curriculum, powered by Starry Night, turns your dome into an interactive digital classroom. Created by binary star astronomer and educator Dr. David H. Bradstreet, each lesson uses the dome’s unique environment to teach challenging astronomy concepts at every grade level.

Lessons like moon phases, seasons, and planetary motion become fun, engaging group explorations. With SciDome’s Fulldome Curriculum you don’t just demonstrate how the universe functions, you engage students with inquiry-based activities that reexamine how the universe really works.

The Fulldome Curriculum is provided with SciDome and SciDome HD systems. It includes:

- Fulldome Starry Night simulations for all subjects - each with student/teacher interactives, customizable for all grade levels - includes “mini lessons” on a variety of topics
- Detailed teaching outlines, presentation suggestions
- “WHAT I FS?”: original, lesson-specific sky objects and data to simulate non-standard conditions, motions, and observations
- Automated ATM-4 scripts for easy presentation of lesson elements
Feature Comparisons of Portable Digital Planetarium Systems
Full Dome, Fisheye Lens Systems Only

- Compiled by Digitalis Education Solutions, Inc. Please independently verify information with vendors and inform us if you find any errors.
- We have limited our comparison to the most affordable fisheye lens systems with full dome coverage. Visit our FAQ page (DigitalisEducation.com/faq.html) for details about how any fisheye lens system easily outperforms a spherical mirror system.
- While we believe these feature comparisons provide helpful information, nothing compares to seeing the systems in action before deciding which best meets your specific needs.
- Prices shown are US prices in US dollars.

<table>
<thead>
<tr>
<th>Seller</th>
<th>Digitalis</th>
<th>Digitalis</th>
<th>Digitalis</th>
<th>Science First</th>
<th>E-Planetarium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Digitarium® Alpha 2</td>
<td>Digitarium® Gamma</td>
<td>Digitarium® Epsilon</td>
<td>Digital Starlab®</td>
<td>Elumenati ZOOM SX3</td>
</tr>
<tr>
<td>Estimated set up time (w/out dome)</td>
<td>Two minutes</td>
<td>Unknown</td>
<td>Unknown</td>
<td><a href="http://DigitalisEducation.com">http://DigitalisEducation.com</a></td>
<td><a href="http://www.starlab.com">http://www.starlab.com</a></td>
</tr>
<tr>
<td>User interface</td>
<td>Backlit, handheld remote control from anywhere in dome</td>
<td>Laptop (Mac)</td>
<td>Laptop (Windows)</td>
<td><a href="http://DigitalisEducation.com">http://DigitalisEducation.com</a></td>
<td><a href="http://www.starlab.com">http://www.starlab.com</a></td>
</tr>
<tr>
<td>Resolution</td>
<td>768 pixel diameter circle</td>
<td>1050 pixel diameter circle</td>
<td>1200 pixel diameter circle or truncated 1344 x 1200</td>
<td>1080 pixel diameter circle</td>
<td>1050 pixel diameter circle or truncated 1400 x 1050</td>
</tr>
<tr>
<td>Projection type</td>
<td>DLP</td>
<td>DLP</td>
<td>LCOS</td>
<td>DLP</td>
<td>LCOS</td>
</tr>
<tr>
<td>Base projector brightness (with non-fisheye lens)</td>
<td>3500 lumens</td>
<td>6500 lumens</td>
<td>5700 lumens</td>
<td>1000 lumens</td>
<td>3500 lumens</td>
</tr>
<tr>
<td>Contrast ratio</td>
<td>900:1 measured minimum</td>
<td>2100:1 measured minimum</td>
<td>2200:1 measured minimum</td>
<td>12000:1 claimed</td>
<td>1000:1 claimed</td>
</tr>
<tr>
<td>Planetarium software</td>
<td>Stellarium, Digitalis edition, open source *</td>
<td>Starry Night Small Dome, proprietary</td>
<td>Stellarium, open source</td>
<td>Starry Night Small Dome, proprietary</td>
<td>Stellarium, open source</td>
</tr>
<tr>
<td>Number of stars in database</td>
<td>100,000 +</td>
<td>16,000,000</td>
<td>100,000 +</td>
<td>16,000,000</td>
<td>100,000 +</td>
</tr>
<tr>
<td>Scriptable planetarium features</td>
<td>Yes, including audio, video, and image manipulation</td>
<td>No</td>
<td>Maybe (depends on Stellarium version)</td>
<td>Yes, including audio, video, and image manipulation</td>
<td>No</td>
</tr>
<tr>
<td>Seller</td>
<td>Digitalis</td>
<td>Digitalis</td>
<td>Digitalis</td>
<td>Science First</td>
<td>E-Planetarium</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Model</td>
<td>Digitalis Alpha 2</td>
<td>Digitalis Gamma</td>
<td>Digitalis Epsilon</td>
<td>Digital Starlab®</td>
<td>Elumenati ZOOM SX3</td>
</tr>
<tr>
<td>Integrated multimedia viewer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Easily switch between planetarium software and multimedia viewer</td>
<td>Yes</td>
<td>Unknown</td>
<td>Unknown</td>
<td>No—must quit Stellarium to view media</td>
<td></td>
</tr>
<tr>
<td>Seller is developer of system’s planetarium software</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Seller maintains-updates all system software (OS, planetarium, multimedia)</td>
<td>Yes. Automated software updates free for life of system.</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Free technical support for life of system</td>
<td>Yes</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Lease to own program</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Grant writing assistance offered</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Warranty period</td>
<td>Two years</td>
<td>One year (three years on laptop)</td>
<td>90 days on fisheye lens; one year on other parts *</td>
<td>90 days on fisheye lens; one year on other parts *</td>
<td></td>
</tr>
<tr>
<td>Return policy</td>
<td>Full refund (less shipping charges) if returned within 30 days of purchase</td>
<td>Returns allowed only if company makes an error</td>
<td>No published policy</td>
<td>No published policy</td>
<td></td>
</tr>
<tr>
<td>Cost of full system (USD)</td>
<td>$20,950 portable; $19,550 fixed</td>
<td>$43,230 portable; $41,350 fixed</td>
<td>$53,230 portable; $51,350 fixed</td>
<td>$39,950</td>
<td>$35,310 **</td>
</tr>
<tr>
<td>Cost of full portable system and 5m inflatable dome (USD)</td>
<td>$28,900</td>
<td>$51,180</td>
<td>$61,180</td>
<td>$45,750</td>
<td>$54,000 **</td>
</tr>
<tr>
<td>Notes</td>
<td>* Digitalis maintains a customized version of Stellarium for our customers. This includes enhancements and bug fixes not available in the standard version. Details at: <a href="http://DigitalisEducation.com/products-stellarium.html">http://DigitalisEducation.com/products-stellarium.html</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>** Extended warranty may be available with package price.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>** See their website for what these prices include.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Company also sells truncated, lower resolution fisheye system.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Feature comparison, Digitalis Education Solutions, Inc.

May 6, 2009