# TABLE OF CONTENT

About the Journal........................................................................................................3
ASGC 22\textsuperscript{nd} annual symposium agenda......................................................4

**Featured Articles**

Tristan Odekirk, Jacob Teffs, and Debra Burris: A Preliminary Study of Lighter Neutron-Capture Elements in Galactic Halo Stars: Abundance Results.................................................................5

Matthew J. Hankins, Debra Burris, and Donald P. Higgins: The Point Remove Mound Complex: A Study in Archaeoastronomy.................................................................9

Caleb Parks: Use of Time as a Quantum Key...............................................................15

Nathan L Dunn: Quantum Key Distribution Simulation and Implementation for Aerospace Applications.........................................................................................................26

Lindy Roberts, Bethany Miller, Jacob Pinkerton, Travis Reimer, Jesse Van Gorkom, and Will Holmes: Lunar Regolith Excavator.................................................................33

**Information for Authors**......................................................................................43

**List of ASGC Affiliates**.......................................................................................44

**List of Funded Grants by ASGC during 2013-2014**..............................................46

The Arkansas Space Grant Consortium is a proud member of the National Space Grant Program
About the Journal

Publication of the first issue of the *Arkansas Aerospace Proceedings* is the result of a long range desire by the Arkansas Space Grant Consortium to publicize the amazingly wide variety of NASA related research that is being done by investigators and students in the State of Arkansas. NASA research is comprehensive in that there is almost no area of science investigation that doesn’t impinge on topics related to the Mission of NASA.

A second desire of the ASGC is to give undergraduate and graduate students as well as senior investigators the opportunity to see their work published. The process from laboratory research notebooks to a fully developed research manuscript involves development of a range of skills and experiences. This journal will give young people the opportunity to hone these skills and also use the final manuscript to use when interviewing for that first professional position or graduate school.

The third reason for this publication is to use the Arkansas Aerospace Proceedings to summarize the activities of the ASGC each year. In future issues we would like to include pictures and news about the people who make up ASGC to build interest in our program and generate interest in the science and research community of this great State.

We believe it will increase awareness in Arkansas of the aspects that shape scientific knowledge and the scientific process. It will also be a showcase of the breadth of research interests and expertise in our State.

Abdel Bachri, Southern Arkansas University

Edmond Wilson, Harding University
**Twenty-second Annual**  
**ARKANSAS SPACE GRANT SYMPOSIUM**  
**Hot Springs Convention Center**  
**Hot Spring, Arkansas**  
**April 7, 2014**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30-8:00</td>
<td>Registration – 200 Concourse</td>
</tr>
</tbody>
</table>
| 8:00-8:30 | Welcome  
Dr. Keith Hudson, ASGC Director, University of Arkansas at Little Rock |
| Room 203 | Session  
Chemistry  
Chaired by:  
Dr. Andrew Williams |
| Room 204 | Session  
General Science  
Chaired by:  
Dr. Nawab Ali |
| Room 205 | Session  
Spectrography  
Chaired by:  
Dr. Shannon Clardy |
| 8:30-8:45 | R. Bowman (8) ATU                                                        |
| 8:45-9:00 | K. Carter (10) ATU                                                       |
| 9:00-9:15 | M. Fuller (11) ATU                                                      |
| 9:15-9:30 | MORNING BREAK                                                            |
| 9:30-9:45 | K. Ward (13) UAPB                                                      |
| 9:45-10:00 | K. Buckholts (9) HSU                                                   |
| 10:00-10:15 | P. Chowdhury (23) UAMS                                            |
| 10:15-10:30 | Poster Session  
Pages 45-60  
Concourse |
| 11:00-11:45 | Buffet Lunch  
Room 207-208 |
| 11:45-12:45 | Keynote Speaker  
Astronaut Duane “Digger” Carey |
| Room 203 | Session  
Physics  
Chaired by:  
Dr. Rick McDaniels |
| Room 204 | Session  
Space Grant Meeting |
| Room 205 | Session  
Engineering  
Chaired by:  
Dr. Adam Huang |
| 1:00-1:15 | A. Bachri (30) SAU                                                      |
| 1:15-1:30 | J. White/A. Paschle (36) HSU                                           |
| 1:30-1:45 | V. Kunets (35) UAF                                                     |
| 1:45-2:00 | R. Evans (33) ATU                                                       |
| 2:00-2:15 | AFTERNOON BREAK                                                         |
| 2:15-2:30 | S. Clardy (31) HSU                                                     |
| 2:30-2:45 | P. Galla (34) ATU                                                      |
| 2:45-3:00 | C. Clark (32) ATU                                                      |
| 3:00-3:15 | B. Fong (attachment) ASU                                               |
| 3:15-3:30 | A. Huang (18) UAF                                                      |

ASGC will have a brief meeting beginning at 1 pm in 204
A Preliminary Study of Lighter Neutron-Capture Elements in Galactic Halo Stars: Abundance Results

Tristan Odekirk¹, Jacob Teffs¹ and Debra L. Burris¹

Department of Physics and Astronomy, University of Central Arkansas Conway, AR, 72035

Corresponding Author: dburris@uca.edu

Abstract

Elements are created in stars through a variety of processes including fusion and neutron-capture (n-capture). Some of these processes have been well studied and the source of these processes is believed to be known with some confidence. The elements strontium (Sr), yttrium (Y) and zirconium (Zr) reside in the mass range where there is uncertainty about the production mechanism in the early history of the Galaxy. Initially, the rapid n-capture process (r-process) was believed to be responsible for their production in this period due to its ability to model the production of elements Z\geq56 well. No study as yet has been able to use the r-process abundances to match the lighter n-capture mass range. It has been suggested by several authors there may be secondary r-process responsible for this mass range. We have performed new abundance calculations for the lighter n-captures elements Sr, Y and Zr as well the higher Z elements La, Ba and Eu as a preliminary step to observing trends in the abundances of these elements.

Introduction

The primary process for creating elements beyond the the iron peak in stars is the neutron-capture (n-capture) process. In this process an atomic nucleus acquires a free neutron from its surroundings increasing the atomic mass. Unstable nuclei then undergo beta decay raising the atomic number. This process has been divided into at least two primary processes named the rapid-process (r-process) and the slow-process (s-process). The main difference between these is the time taken to accomplish these processes; the r-process takes less than a second in cataclysmic conditions, while the s-process takes thousands of years in AGB stars.

The s-process is a well studied process. Occurring in the shell burning phase of low to medium mass AGB stars, the process is of low enough energy to be studied on earth. (Käppeler et al. 1982, Käppeler, Beer & Wisshak 1989) The s-process contributions come from two components—main, and weak—each contributing a range of isotopes. (Busso, Gallino & Wasserburg 1999). The r-process is more difficult to quantify as it occurs only at extreme energies and densities (Woosley et al. 1994, Wheeler, Cowan & Hillenbrant 1998). Some events have been suggested to be responsible for the r-process including type II supernova of stars exceeding eight solar masses, and merging binary neutron stars (Sneden et al 2000, Qian & Wasserberg 2001, Goriely, Bauswein & Janka 2011).

The mechanism of the r-process is not well understood, and details concerning the complexities of the process are only recently being studied. Abundances of n-capture elements Z\geq56 early in
the Galaxy’s history follow the predicted distribution of the r-process for those elements. Studies of evolved Galactic halo giants are good study objects of pre-s-process enriched stars. There comes a problem with the r-process distribution of lighter \((Z \geq 56)\) stars (Burris et al. 2000; Travaglio et al. 2004; Cowan et al. 2005). The elements studied in this range are Sr, Y, and Zr because they have transitions that are observable in visible wavelengths. These elemental abundances show neither agreement with predicted abundances for any single component of the s- or r-process, nor do they agree with any combination of these processes. Based upon this, it has been suggested that the r-process is not a single-component process (Travaglio et al. 2004; Cowan et al. 2005; Sneden and Cowan 2003; Cowan and Thielemann 2004). This work focuses on abundance determinations of these three elements of interest using new atomic transition data available for Zr (Malcheva et al. 2006) and Y.

**Experimental Procedure**

The goal of this work is to obtain elemental abundances, which is done by analyzing spectral data using the spectral synthesis code MOOG (Sneden 1973) and is an expansion of small sample of Zr and Y abundances presents in Burris, Lusk and Jones (2009). The spectra used in this study were acquired from the McDonald observatory by Jennifer Simmerer and had previously been used in her study of Eu and La (Simmerer et. al. 2004). The main instrument was the 2.7 m telescope using the 2d coude cross-dispersed echelle spectrograph configured to a2 pixel resolving power of \(R \sim 60,000\) and a Tektronix 2048 × 2048 CCD. This had a S/N \(\approx 100\) pixel−1 at 4100°A. Full details of the spectra characteristics can be found in Simmerer et al. (2004).

MOOG creates four possible fits to observed data by the parameters of model atmosphere, metallicity, and spectral line atomic data. The model atmospheres and metallicity values were the same as used by Simmerer et al (2004). Atomic data were taken from Kurucz line lists. Initial values for the synthesis were centered around the solar abundance of the elements and fitting followed from there. The dependence of the spectral synthesis is dependent upon the assumed values for the atmosphere. The sensitivity of these parameters to changes in these values was explored by Lusk and Burris (2011) so as to improve confidence in the results obtained for the abundances. For the program stars, a total of four Zr lines, two Y lines and two Sr lines were available in the wavelength range of the spectra.

**Results**

The results of the abundance analysis are found in Table 1. The second column, \([\text{Fe/H}]\), is the metallicity value for each star and is calculated as the average of the \([\text{Fe I/H}]\) and \([\text{Fe II/H}]\) values found in the Simmerer et al. (2004) paper. Each abundance value is an average of all of its individual line abundances. Elements with no abundance value are denoted by an ellipsis and were not found due to the weakness of the line or contamination due to other species was too strong in that particular object. The abundance values are in traditional spectroscopic notation of \(\log \varepsilon[X]\) which is defined as the number of atoms of element X and is the number of Hydrogen atoms.

**Discussion**
The results found of these elements are in agreement with previously published values where available. In some instances no abundances were available from other authors. With this survey, the next step of the project would be to compare the elemental abundances to each other to find trends. In Burris et al. (2000), a bimodal trend was found in the comparison of Ba and Eu. Our current focus is to model this comparison for the light n-capture elements using both data acquired from this work and also from current literature. Early on in the Galaxy’s history, it appears that Sr, Y, and Zr do not fall solely into the r- or s-process. We can compare these to the behaviors of known s-process elements (La, Ba) and r-process elements (Eu) in hope of observing some trend. If these comparisons produce noticeable trends it should help shed light on the processes that create these light n-capture elements.

Table 1: n-capture abundance results for program stars

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BD+173248s</td>
<td>-2.02</td>
<td>0.95</td>
<td>0.09</td>
<td>...</td>
<td>0.58</td>
<td>-0.4</td>
<td>-0.67</td>
</tr>
<tr>
<td>HD006755</td>
<td>-1.625</td>
<td>0.62</td>
<td>0.07</td>
<td>1.17</td>
<td>...</td>
<td>-0.193</td>
<td>-0.775</td>
</tr>
<tr>
<td>HD108317</td>
<td>-2.13</td>
<td>0.055</td>
<td>0.01</td>
<td>0.62</td>
<td>-0.41</td>
<td>-1.02</td>
<td>-1.15</td>
</tr>
<tr>
<td>HD110184</td>
<td>-2.61</td>
<td>0.815</td>
<td>-0.27</td>
<td>0.36</td>
<td>-0.91</td>
<td>-1.57</td>
<td>-2.02</td>
</tr>
<tr>
<td>HD115444</td>
<td>-2.805</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>-0.7</td>
<td>-1.41</td>
<td>-1.81</td>
</tr>
<tr>
<td>HD122956</td>
<td>-1.82</td>
<td>1.13</td>
<td>0.29</td>
<td>...</td>
<td>-0.1</td>
<td>-0.64</td>
<td>-1.125</td>
</tr>
<tr>
<td>HD126587</td>
<td>-2.85</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>-0.54</td>
<td>...</td>
</tr>
<tr>
<td>HD128279</td>
<td>-2.07</td>
<td>-0.62</td>
<td>-0.58</td>
<td>0.305</td>
<td>-0.74</td>
<td>-1.29</td>
<td>-1.8875</td>
</tr>
<tr>
<td>HD135148</td>
<td>-2.12</td>
<td>0.94</td>
<td>-0.18</td>
<td>0.49</td>
<td>-0.53</td>
<td>-0.93</td>
<td>-1.5175</td>
</tr>
<tr>
<td>HD186478</td>
<td>-2.5</td>
<td>0.29</td>
<td>...</td>
<td>0.49</td>
<td>-0.318</td>
<td>-1.11</td>
<td>-1.4</td>
</tr>
<tr>
<td>HD204543s</td>
<td>-1.765</td>
<td>1.21</td>
<td>0.07</td>
<td>0.84</td>
<td>...</td>
<td>-0.515</td>
<td>-1.23</td>
</tr>
<tr>
<td>HD221170</td>
<td>-2.19</td>
<td>0.81</td>
<td>-0.18</td>
<td>...</td>
<td>...</td>
<td>-0.69</td>
<td>-1.3475</td>
</tr>
<tr>
<td>HD74462</td>
<td>-1.515</td>
<td>1.24</td>
<td>0.03</td>
<td>...</td>
<td>-0.195</td>
<td>-0.59</td>
<td>...</td>
</tr>
<tr>
<td>HD3008</td>
<td>-2.08</td>
<td>1.1</td>
<td>0.19</td>
<td>0.5</td>
<td>-0.37</td>
<td>-0.79</td>
<td>-1.09</td>
</tr>
<tr>
<td>HD44007s</td>
<td>-1.72</td>
<td>1.25</td>
<td>0.01</td>
<td>...</td>
<td>0.03</td>
<td>-0.517</td>
<td>-0.89</td>
</tr>
<tr>
<td>HD119516s</td>
<td>-1.98</td>
<td>1.075</td>
<td>0.39</td>
<td>...</td>
<td>...</td>
<td>-0.505</td>
<td>...</td>
</tr>
<tr>
<td>HD006833</td>
<td>-0.85</td>
<td>...</td>
<td>1.39</td>
<td>2.05</td>
<td>...</td>
<td>0.285</td>
<td>-0.84</td>
</tr>
<tr>
<td>HD008724</td>
<td>-1.91</td>
<td>1.21</td>
<td>0.395</td>
<td>1.1</td>
<td>0.2</td>
<td>-0.563</td>
<td>-0.84</td>
</tr>
<tr>
<td>HD021581s</td>
<td>-1.71</td>
<td>1.38</td>
<td>0.565</td>
<td>1.3</td>
<td>-0.17</td>
<td>-0.42</td>
<td>-1.69</td>
</tr>
<tr>
<td>HD023798s</td>
<td>-2.26</td>
<td>0.53</td>
<td>-0.81</td>
<td>0.7</td>
<td>-0.57</td>
<td>-1.056</td>
<td>-1.49</td>
</tr>
<tr>
<td>HD025329s</td>
<td>-1.67</td>
<td>1.54</td>
<td>-0.51</td>
<td>0.8</td>
<td>...</td>
<td>-1.02</td>
<td>...</td>
</tr>
<tr>
<td>HD026297s</td>
<td>-1.98</td>
<td>1.03</td>
<td>0.44</td>
<td>1.05</td>
<td>-0.22</td>
<td>-0.93</td>
<td>-0.94</td>
</tr>
<tr>
<td>HD029574s</td>
<td>-2</td>
<td>1.23</td>
<td>0.59</td>
<td>1</td>
<td>0.23</td>
<td>-0.43</td>
<td>-0.69</td>
</tr>
<tr>
<td>HD037828s</td>
<td>-1.62</td>
<td>1.7</td>
<td>0.54</td>
<td>1.4</td>
<td>1</td>
<td>-0.2266</td>
<td>-0.49</td>
</tr>
<tr>
<td>HD063791s</td>
<td>-1.9</td>
<td>1.15</td>
<td>0.2</td>
<td>1.15</td>
<td>...</td>
<td>-0.526</td>
<td>...</td>
</tr>
<tr>
<td>HD101063s</td>
<td>-1.33</td>
<td>1.6</td>
<td>0.74</td>
<td>1.8</td>
<td>...</td>
<td>0.293</td>
<td>...</td>
</tr>
<tr>
<td>HD103036s</td>
<td>-2.04</td>
<td>...</td>
<td>0.09</td>
<td>1.1</td>
<td>...</td>
<td>-0.605</td>
<td>...</td>
</tr>
<tr>
<td>HD103545s</td>
<td>-2.45</td>
<td>0.28</td>
<td>-0.46</td>
<td>0.5</td>
<td>...</td>
<td>-1.07</td>
<td>...</td>
</tr>
<tr>
<td>HD105755s</td>
<td>-0.83</td>
<td>2.225</td>
<td>1.175</td>
<td>1.91</td>
<td>-0.04</td>
<td>0.48</td>
<td>0.79</td>
</tr>
<tr>
<td>Star Name</td>
<td>n/Capture</td>
<td>[Fe/H]</td>
<td>[M/H]</td>
<td>[α/Fe]</td>
<td>[Fe/H]</td>
<td>[α/Fe]</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>-----------</td>
<td>--------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>HD106516s</td>
<td>-0.81</td>
<td>2.355</td>
<td>1.41</td>
<td>1.67</td>
<td>0.93</td>
<td>0.55</td>
<td>-0.05</td>
</tr>
<tr>
<td>HD107752s</td>
<td>-2.78</td>
<td>-0.29</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>HD121135</td>
<td>-1.54</td>
<td>1.68</td>
<td>0.77</td>
<td>0.93</td>
<td>0.56</td>
<td>-0.215</td>
<td>-0.51</td>
</tr>
<tr>
<td>HD124358</td>
<td>-1.91</td>
<td>0.49</td>
<td>-0.3</td>
<td>0.96</td>
<td>...</td>
<td>-0.61</td>
<td>...</td>
</tr>
<tr>
<td>HD132475</td>
<td>-1.86</td>
<td>0.97</td>
<td>...</td>
<td>1.32</td>
<td>...</td>
<td>-0.185</td>
<td>-0.67</td>
</tr>
<tr>
<td>HD141531</td>
<td>-1.79</td>
<td>0.98</td>
<td>0.17</td>
<td>1.03</td>
<td>0.01</td>
<td>-0.575</td>
<td>-0.71</td>
</tr>
</tbody>
</table>

**Acknowledgements**

We would like to thank Dr. Jennifer Simmerer for the spectra from the McDonald Observatory, Dr. Chris Sneden for helpful conversation and support of the MOOG software, and Dr. John Cowan for helpful. We would also like to thank the University of Central Arkansas College and Natural Science and Mathematics for support and the Arkansas Space Grant Consortium for financial support.

**References**


The Point Remove Mound Complex: A Study in Archaeoastronomy

Matthew J. Hanks1, Debra Burris1, Donald P. Higgins2

1Department of Physics, University of Central Arkansas, Conway, AR, 72035, 2Arkansas Archeological Society

Correspondence: mjhanks44@gmail.com

Abstract

The use of artificial astronomical markers is a common theme across many cultures. People groups throughout the world are thought to have used artificial solstice and lunar markers to form basic calendars. There are many advantages in being able to predict the changing seasons that would have been of interest to early peoples. The Point Remove Mound Complex (site 3CN4) is an archeological site near Petit Jean Mountain near Morrilton, Arkansas. Early reports of the site claim mounds that bear cardinal alignments, which may indicate some level of advanced site planning; however, the site has never been analyzed for astronomical alignments before due to the poor condition of the site. The purpose of this analysis is to determine the presence of any potential astronomical alignments based off available evidences, as well as qualifying the results of any alignments found in order to assess their statistical significance. In all, only a few alignments were found on site, which does not speak well to the intentionality of the site. Though the methods for analyzing this site may prove useful in analyzing other badly damaged sites.

Introduction
The practice of astronomy is a common thread across many civilizations (Evans 1998). Numerous people groups throughout history are thought to have used observations of the sky to benefit and enrich their everyday lives (Krupp 2003). While these observations are often thought of as being associated with religious practices; to early peoples, these observations were highly practical because they could be used to form the basis of a calendar system (Pannekoek 1961). While many cycles of detailed observations of astronomical objects are necessary to understand the movement of the heavens, many people groups across the ancient world have left record of their observations (Krupp 2003). The purpose of this research project is to determine the possibility of any astronomical significance at the Point Remove Mound Complex (located near Morrilton, AR). If a statistically significant number of astronomical alignments can be found at the Point Remove Site, it would suggest that the site’s builders planned the site design with intention of tracking the heavens with the mound structures. This would further suggest a higher level of technological innovation of the site’s builders, of which very little is known due to their lack of written records.

While searching for astronomical alignments in earthen mounds may seem a little farfetched, there are numerous examples of Native American sky watching practices. Much is known of the native peoples of the southwest (Williamson 1987); however, much less is known about their eastern counterparts. There are several mound sites throughout the country that have evidence of astronomical significance. Many of the large cultural centers of the Mississippian peoples, such as Cahokia Mounds, Toltec Mounds, as well as others, have been reported as having features that could have posed some form of astronomical significance (Sherrod and Rollingson 1987).

The Point Remove Mound Complex (sometimes referred to as site 3CN4) is located just outside of Morrilton, AR, in the shadow of Petit Jean Mountain. Carbon dating of the site places the construction of Mound A around 1400 C.E. (Beta Analytic 2008). Artifacts recovered from the site along with the site’s proximity to Toltec Mounds (Scott, AR) suggest possible trade ties between these peoples (Sabo et al 1990). With the exchanging of goods, it does not seem unreasonable to think that information, possibly of an astronomical nature, may have spread from one people to the other. Very little is known about the builders of the Point Remove Site. The site has been badly damaged over years of historic and agricultural land use, which has left only the remnant of one mound visible on the site today (Vogel 2005). The poor condition of the site has hindered study of the site, and previous studies of the have not explored the possibility of astronomical significance.

Methods

The methodological approach taken in this work was largely based on the work of Clay Sherrod and Martha Ann Rolingson in Surveyors of the Ancient Mississippi Valley (1987), and the more rigorous statistical methods of Lionel Sims in “Which Way Forward for Archaeoastronomy? West Kennet Avenue as a Test Case” (2010). First, it was necessary to determine the kinds of alignments to search for in this analysis. The choice of the Sun and Moon seems rather obvious at first. They are practical, in that the patterns of their motions are easily adapted into a calendar system (Evans 1998). Additionally, the Sun and Moon are thought to be culturally important to ancient peoples (Krupp 2003). Their prominence in the sky, in terms of their angular size compared with other astronomical objects, also makes them the two most noticeable objects in the sky. For use in this analysis, solar alignments were preferred over lunar alignments for reasons that will become clear later.
In order to search for solar alignments on the site, it was necessary determine the kinds of observations that might have been taken on the site, and what their value was for the site. Due to the smoothly transitioning periodic behavior of the sun, the turning points in its northward and southward rising and setting was a natural choice. These events, known as the summer and winter solstice, were culturally significant for many ancient peoples, as these turning points marked the changing seasons (Krupp 2003).

The moon follows a very similar path to the sun; however, it has a few noticeable differences. For one, the moon’s transition from a northernmost rising and setting point to a southernmost rising and setting point and back takes around a month to complete. The sun does this over the course of a year. Additionally, the monthly extrema in the rising and setting of the moon varies month to month. With careful record keeping, an observer can discover a subtle pattern in the change of monthly extrema, which reach a northernmost and southernmost extreme during an 18.6 year cycle (Aveni 1997). This event, known as the major lunar standstill, may have been of interest to Mississippian peoples, as evidence for one of these kinds of alignments is present at Toltec Mounds (Sherrod and Rollingson 1987). There is a second event, known as the minor lunar standstill, corresponding to the southernmost northern moonrise and moonset, and the northernmost southern moonrise and moonset (Aveni 1997). The purpose of tracking such an alignment is unclear; however, an alignment of this nature would speak a great deal as to the level of sophistication of the observations. Because the range of lunar rising and setting is very close to the sun, it is difficult to distinguish from solar alignments at low accuracy sites.

For these reasons, six solar alignments (winter solstice sunrise, winter solstice sunset, summer solstice sunrise, summer solstice sunset, equinox sunrise, and equinox sunset) were selected for this analysis. The additional eight lunar alignments (four affiliated with the major lunar standstill and four affiliated with the minor lunar standstill) were not considered due to their apparent lack of distinguishability given the uncertainty present on the site.

To determine the angular values for alignments between mounds for these events, NASA JPL’s Horizons System was used to generate ephemeris (Giorgini et al 1996). Data generated for this analysis was done using the RTS Flag (Rise-Transit-Set) in the Horizons System. All Data were elevation corrected and refraction corrected. In considering alignments to the southwest and west of the site, it was necessary to adjust the value for setting objects because the true setting position is obscured by Petit Jean Mountain. This can cause up to a 3° difference between true setting position and the visual setting position observed by Mound A on the site. To overcome this, more detailed ephemeris were used to determine the visible setting position behind the mountain.

In order to study the possible alignments, it was necessary to determine the original layout of the site. For an ideal site, it would have been preferable to take measurements on site; however, the lack of visible physical evidence of mound locations on the site severely limits this kind of analysis. Instead of relying on physical measures, the choice was made to use historic maps, surveys, and supporting documentation of the site to determine mound locations as accurately as possible. While the location of each mound is somewhat imprecise, the lack of a more robust method made this a necessary evil.

Once mound locations were determined, their data was input into Google Earth. Using the measuring tool within Google Earth, it was possible to determine the angles in between the
mounds on the site. These values could then be compared with the calculated values for astronomical alignments on the site.

Figure 1: The Point Remove Mound Site. Mound labels are not indicative of mound size.

Handling the error calculations for a site of this nature is rather complicated. The complexity stems from two main issues. First, the precision that the builders may have built alignments into the site is unknown. This issue is compounded by the relative uncertainty in mound positions on the site. With these two issues, it is difficult to determine a ‘good’ estimate of the uncertainties on the site. To get around this issue, the method of Monte Carlo Simulations was employed (Sims 2010).

The Monte Carlo Method is essentially a test of the null hypothesis, which for this study, produces a false positive rate of alignments, which can be compared with the number of alignments present at the site (Sims 2010). To perform this analysis, a c++ program ‘mounds.cpp’ was created. The mounds program takes in physical data, such as the length and width of the site, the number of mounds on the site, the uncertainty of the site, and values for alignments of interest. The program then generates random (x,y) coordinates for mound locations based off the length and width user input. Next, trigonometric functions are used to determine the angle values between the mounds. These values are then passed through a filter that counts the occurrences of alignments of interest that are within the given uncertainty. This process is iteratively looped to repeat the process, simulating a number of sites that is specified by the user. For each site, the number of alignments of interest is output to a text file for analysis. In practice the numeric accuracy of the angle calculations is within ±0.2°, which should not have an effect given the relative error present on site.

Using this approach, a various levels of accuracy and precision could be tested for the site. From the data generated in the Monte Carlo, an error function of the number of false positive counts from the random data versus the uncertainty of those alignments was created. This was compared with the number of alignments at the Point Remove site with various levels of error. While this
method cannot conclusively prove the existence of all kinds of alignments (high precision, low accuracy alignments would be harder to make a case for without additional evidence), it can at least test for the possibility of various kinds of alignments. While there are several simplifying assumptions that go into the Monte Carlo, given the extent of damage on the site and the limited information available, this simple test allows the site to be checked for these kinds of alignments in a very general manner. With additional information, it would be desirable to factor the angular size of each mound into calculations; however, the size of many mounds is unclear. Additionally, information about the angular size of each mound would affect the uncertainties in the alignment. For this test, uncertainties were considered the same for each mound.

Results

In testing the alignments on site versus various levels of error, no data fell outside of the standard deviation of the random data generated by the Monte Carlo. The random data is based off of 1000 simulations of each level of uncertainty (±3°, ±6°, ±9°, ±12°).

![Figure 2: Monte Carlo & Site Data](image)

Conclusions

While a few solar alignments were found at the Point Remove site, comparing the random Monte Carlo data and the number of alignments found, there is no evidence to support the intentionality of solar alignments at the site. This would seem to suggest that the builders of the Point Remove site were not considering solar alignments when constructing the mounds. However, due to the poor condition of the site, it is difficult to make this claim with absolute certainty. Early reports of the site list as many as 11 mounds rather than the 8 studied in this work (Vogel 2005). The addition of these unknown mounds in certain locations could completely change the results of this analysis.

In addition to this work, it would be interesting to look at other alignments. Because the moon’s path closely follows the sun, it would appear that lunar alignments would also be unsubstantial (but it would be nice to check); however, this does not rule out the possibility of various stellar alignments that could be present.
Acknowledgements

Maps generated for this project were produced using Google Earth in conjunction with a USGS topographic map package from ArcGIS ESRI. Solstice Position calculations were made using NASA JPL’s Horizons Calculator. Funding for this project was provided by the UCA College of Natural Sciences and Mathematics and the UCA Honors College. A special thanks to the Arkansas Archeological Survey and Arkansas Archeological Society, in particular Dr. Skip Stewart-Abernathy and Alan Smith for their assistance with the project. Additionally, a special thanks to Daniel Doolabh for his assistance in constructing the ‘mounds.cpp’ program. Individuals wishing to use the mounds program for research purposes may contact the author to receive a copy.

References


Use of Time as a Quantum Key

Caleb Parks
Southern Arkansas University, Magnolia AR 71753
Corresponding Author: cparks1000000@gmail.com

Abstract:
Conventional and quantum cryptography, which relies on a secure channel, face a common problem: given enough time a cryptanalyst can decrypt the message. A cryptosystem which no one can crack after a given time is more secure. Assuming that one can manipulate the polarization of photons with respect to time, one can construct such an algorithm. The algorithm can and will be sufficiently random such that, without prior knowledge of the key, the attacker would be as well off picking a random binary string as attempting to decrypt a message. The construction of the functions which will allow this must be part of the algorithm.

Background:
In recent history, people have been racing to ensure that encryptions will continue to remain secure. The advent of the quantum computer has put a time limit on the amount of time that traditional cryptosystems will suffice. Some of the methods include quantum key distribution, random angle photons, and entanglement generated keys.

In September 2013, Zi proposed a quantum algorithm that is composed of random rotation angles using assistance from a semi-honest third party. These random angles make the protocol safer. Furthermore, the algorithm may save many computer resources. Furthermore the protocol does not yield any information regarding the sender and receiver [1].

One group in Los Alamos recently demonstrated this method over ten kilometers through the atmosphere. “[They] report the first demonstration of the transfer of cryptographic-quality secret keys at practical rates during both day and night using QKD across a 10 km air path whose extinction, optics and background are representative of potential applications” [8]. The group also demonstrates the inability of an eavesdropper to acquire information from the communication without causing disturbance in the messages. Upon noticing these disturbances, the parties exchanging messages were able to successfully discard the information and reestablish a secure connection. According to the publication, the communications can occur across ranges of up to thirty kilometers [8]. The study also concludes that night-time communications are much faster and travel over significantly longer distances than day-time...
communications [8]. Figure 1 is a figure from the article [8] which demonstrates a sender, Alice, sending a message to Bob using a quantum one-time-pad. As one can see, the keys of Alice and Bob are almost identical. The picture Bob receives is almost identical to the original. This demonstrates the feasibility of general quantum algorithms; therefore, there is a high probability that someone can successfully implement the algorithm described herein in a quantum scenario.

![Image of Encrypted Image and Keys](image)

Figure 1: Using a one-time-pad key sent via a quantum encryption algorithm, Alice securely sends a picture to Bob. The "encrypted image" is what any eavesdropper will discover without access to the one-time-pad key.

Some alternative algorithms use an already existing secret key to generate a larger one-time pad for communication using classical methods. “Lomonaco describes the basics of classical and quantum cryptography as well as the problems faced by each discipline. He talks of the famous Catch 22 of classical cryptography, namely: ... There are perfectly good ways to communicate in secret provided we can communicate in secret. Classical cryptography is subject to this catch and according to the literature to date, quantum cryptography falls in the same category” [2].

Many other such algorithms rely on entangled qubits such as the algorithm of NAGY. NAGY’s algorithm does not use an existing secret key. This algorithm generates a secret one-time-pad independently of any non-public communication. Public communication in this case refers to any communication which cannot be altered by anyone but can be read by everyone. In particular, this algorithm does not have a classical channel available for communication. The key distribution, however, takes a time which grows linearly with the number of recipients of the encrypted message, not including preparing each bit [1].
While there exist many algorithms for secure, quantum communication. All of the described methods require time which must take into account the number of participants in the following manner for n bits to be sent to p recipients:

\[ O(n*p) + O( f(p) ) \]

where f is a non-constant increasing function representing the amount of time the algorithm spends per recipient.

If one assumes that encryption of a one byte segment of data and a request for a public encryption key takes a negligible amount of time, then the algorithm proposed herein eliminates f(p). In other words, f(p) becomes a constant number not dependent on p. The only factor in the efficiency of this algorithm is the number of bits that must be sent out plus some constant. Furthermore this algorithm uses time as its key. This ensures that even given an infinite amount of time, the cryptanalyst can not break the encryption. Additionally, this method transfers data directly as opposed to sending a private key such as a one-time-pad which then requires one to send the actual data separately. Lastly, only one classical public-key encryption is required per each recipient. It does not require any other classical encryption. One can contrast this encryption style with the following style of multi-recipient encryption by Ruigang Du and associates:

First suppose a sharer Alice wants to share some string A. Then Alice puts some “check” bits and some “ping” bits onto the string to form a new string A’. Now Alice distributes the length of A’. Say this length is n. Now one of the recipients Bob sends n polarized photons to another recipient Charlie. Each one of the photons is in a random state (either from rectangular basis or from diagonal basis). Bob then stores the state of the photons he sent. Charlie then “inserts a filter in front of his devices to filter out the photon signals with an illegitimate wavelength [which will be generated when a computer is eavesdropping]. [6]” This prevents any Trojan horse attacks. Charlie then randomly flips some qubits received from Bob. Charlie then stores which bits he flipped. Charlie then uses the Hadamard operation to change the encoding basis to stop eavesdropping. Charlie then sends the qubits from Bob to Alice. Alice then prevents an IPE (eavesdropping) attack. Now Alice restores the qubits to the original order[6].

Now Alice will proceed to check for any eavesdropping. Bob then tells Alice the polarization his photon he sent Charlie (in the paragraph above), then Charlie tells if he took the Hadamard operation. Given any “ping” bit a’ of A' knowing weather or not Charlie applied the Hadamard and the basis from Bob, Alice can know what the encoded a’ should be. If a’ is not as it should be, an error is noted. If too many errors are found, the protocol is aborted. There is additional error checking too[6].

Finally, Alice will encode each of the qubits of A and “check” with the with unitary operations (“flipping”) based on Charlie's actions. Alice then sends the qubits to Bob. Bob then measures the photon in his basis if Charlie did not perform a flip. Else if Charlie did perform a unitary operation, then Bob will measure the qubit in the other. Alice, Bob, and Charlie then work together to determine if any errors in the “check” string exist. If too many errors exist in the check string, the protocol aborts. Lastly, Bob and Charlie work together to extract the message[6].
According to the authors, “Intuitively, our scheme is just a variant to the following classical secret sharing scenario with one-time pad: The agent Bob and Charlie choose two random strings B and C, and deliver them to Alice in a secure manner. Alice then uses the bitwise XOR result of B and C to encode her message (also through the bitwise XOR operation), and sends cipher back to Bob. Obtaining C from Charlie, Bob can then restore Alice’s secret. In our scheme, quantum cryptography is employed to protect B from being eavesdropped by Charlie, and C By Bob before Alice’s encoding phase. [6]”

Due to the fact that “pure entangled multi-qubit states with decoy photons” are difficult to produce, Shi has proposed a modification of Zi’s cryptosystem. This cryptosystem is the “Multiparty Quantum Secret Sharing with the Pure Entangled Two-Photon States” which, as one can assume, utilizes qubits with two states as opposed to Zi’s algorithm which requires three or four entangled photons.

Theory

Using quantum cryptography, one has the ability to encode information in photons which no outsider can discover. Using this principle information can be encoded with time as the key to the cryptosystem. Some thought is necessary regarding the exact equations by which the photons will change in order to reduce a cryptanalyst’s probability of extracting the meaning of the message. One must also have an appropriate way to communicate the time key to a recipient.

In classical cryptography, a cryptanalyst has unlimited time to decrypt a message because the message remains constant within time. However, assuming one has an apparatus by which he or she can manipulate the value of theta as a function of time in the following equation concerning the polarization of a photon, then one would be able to make the information contained in an encrypted message variant over time:

$$|\psi\rangle \overset{\text{def}}{=} \begin{pmatrix} \psi_x \\ \psi_y \end{pmatrix} = \begin{pmatrix} \cos \theta \exp(i\alpha_x) \\ \sin \theta \exp(i\alpha_y) \end{pmatrix}. \quad [1]$$

Additionally, the electric field of the photon is described by this:

$$E(r, t) = |E| \text{ Re} \{ |\psi\rangle \exp[i(kz - \omega t)] \} \quad [2]$$

While the magnetic field of the photon is given by this:

$$B(r, t) = \hat{z} \times E(r, t) \quad [3]$$

Such apparatus may exist in the near future. One group of scientists have been working on a method to control photons using an entanglement feature and have demonstrated some promising experimental results [9]. One could use the entangled photons to induce a simulated time-dependent photon polarization. Another, possibly more promising result, is controlling photon polarization by exploiting a link between the polarization of a photon and its angular momentum.
“[The scientists] introduce and test experimentally a series of simple optical schemes for the coherent transfer of quantum information from the polarization to the orbital angular momentum of single photons and vice versa. All [their] schemes exploit a newly developed optical device, the so-called “q-plate”, which enables the manipulation of the photon orbital angular momentum driven by the polarization degree of freedom” [10]. This could allow for a photon whose state is directly dependent of the time since one generated the photon. One also needs some form of quantum memory in order to hold the photons until the appropriate measurement time. This was shown to be within the laws of physics for the case of photons [4]. Now, all a person needs to decrypt a received message is the angle for the measurement basis, which will be called theta, and the time at which one should measure the photon, which will be called t₀. This time and basis pair shall be named the key. Ideally, each photon would have a different equation for theta so that no photon will have the same value at any given time. While this would require too much calculation, one can have a set number of equations proportional to the data amount. If at least ten percent of the photons have different equations, then in the best case scenario without knowledge of the correct time to measure the photon, a cryptanalyst has one out of ten the bits correct with any given certainty. The analyst cannot even know which bits are correct. Also, the analyst will not be able to determine the function which determines theta because measuring the photon causes its state to become constant in time and collapses its superposition.

One may ask, how does one safely transfer the key to the recipient? One can use any traditional or quantum key distribution system. For simplicity, examine the RSA encryption. Although one can break the RSA encryption with approximate speed of

\[ \sim O((\log N)^3) \] (where n is the number of bits in the key), [5].

Given n sufficiently large one can make the decryption time of the RSA encryption in the order of minutes. Call this time T. This will give sufficient time for photons to be charged and sent before a cryptanalyst can discover the key. One can manipulate the photons in such a way that the time at which the recipient will decrypt the quantum message less than or equal to half the time it takes for the largest possible computer to decrypt the RSA message. After t₀, one cannot recover the message because after this time, the angles will never be equal again.

To reduce the chance of any theta being equal to another, one wants to construct theta-functions (the functions that denote the value of theta for each photon) such that they satisfy the following: (1) the value of the theta-functions is easily known for a given time, (2) all the theta-functions intersect in exactly one point which will be called theta-zero, (3) the functions are all of degree 5. Now, let f represent a theta function. Suppose

\[ f = At^5 + Bt^4 + Ct^3 + Dt^2 + Et + F \]

Now set \( f(t) = \theta_0 \), then suppose that

\[ f(t) - \theta_0 = (t-ai)(t+ai)(t-bi)(t+bi)(t-t_0) \quad EQ: A \]
where \( i \) is the imaginary number. This ensures that \( f(t) - \theta_0 \) will have exactly one zero. Thus the addition of all the theta functions will have one zero. By multiplying the right side of \( A \) out and substituting the form of \( f \), one gets

\[
A t^5 + B t^4 + C t^3 + D t^2 + E t + (F - \theta_0) = t^5 + (t_0) t^4 + (a^2 + b^2) t^3 + (-t_0(a^2 + b^2)) t^2 + (a^2 b^2) t + (-t_0(a^2 b^2))
\]

By identification of variables, one can determine the following:

\[
A = 1; \quad B = -t_0; \quad C = a^2 + b^2; \quad D = -t_0 C; \quad E = a^2 b^2; \quad \text{and} \quad F = \theta_0 - t_0(E)
\]

Since \( a \) and \( b \) are arbitrary numbers, then \( C \) and \( E \) are random numbers. Furthermore it is obvious that \( f(t_0) = \theta_0 \). This fulfills all the requirements.

**Algorithm:**

Suppose that Alice is attempting to send a quantum message to Bob and his friends securely. Call this group delta which has \( N \) members.

Now Alice must to determine the longest amount of time it takes for a message to go from Alice to any computer in delta. This will be the minimal time Alice can have the computers measure the quantum bits they will get. Alice must be completely certain that this time will not be exceeded or else the message will be permanently lost. Call this minimum time \( M \).

Next, Alice distribute to all the computers in delta the name of an public key cryptosystem with which Alice would like to communicate. Each computer in delta must send Alice a public key. Additionally, the chosen cryptosystem should take a minimum time \( T \) to be broken by the fastest computer which can exist. This time \( T \) must be less than \( M \) or else an eavesdropper, Eve, will be able to decrypt the key then read the qubits.

Alice will use the public-key cryptosystem to tell all the computers in delta the basis and time they will need to decrypt the message. times for each computer to check it's quantum message.

Append check bits to the message in some fashion. These bits must be sufficient to check for an error in transmission of the photons. Also the check must ensure that if Eve tampered with the bits, the recipient computer can disregard the message. This will also expose any small differences in the ideal and actual times for which the photons are to be measured. One could use a number of overlapping check-sums for this purpose and parity bits.

Alice will now construct \( F \) functions \( f(t) \) such that the following using a calculated pattern which includes random variables (this is described in more detail above):

a.) \( f_i(t) \neq y_0 \) for all \( t \) in \([0,T]\) such that \( t \neq t_0 \) and for all integers \( i \) in \([0,F]\).

b.) \( f_i(t_0) = y_0 \) for all integers \( i \) in \([0,F]\).

c.) \( f_i'(t_0) = 0 \) for all integers \( i \) in \([0,F]\).

d.) Given \( f_i'(t_1) \) and \( t_1 \), \( f_i(t) \) can not be reconstructed.

e.) \( f \) is of degree 4.
Alice then uses a machine, part of her quantum computer, to force a photon's polarization to be a specified value at a given time. Each photon must have the same value for its polarization at some time between M and T. The $A^{th}$ photon should change in a manner given by $f_{A \mod F}$. $F$ should also be at least 10% of the number of photons Alice will send to the N computers in delta.

Lastly, Bob and his friends will test the check bits to verify that the message is correct. If one computer finds that the message does not pass the check test, then that computer will ask the Alice to restart the algorithm.

**Simulation:**

Although there seems to be no problem with the theory behind this algorithm, one still should simulate the algorithm to demonstrate its function. This simulation must simulate the photons using a vector in two-space. Additionally, it must represent the probabilistic nature of photons. Lastly, the test should demonstrate an inability for an eavesdropper to obtain a message without knowing the correct time and theta pair. Note that, in this simulation, the Uncertainty Principle is not considered. The classical part of the algorithm is assumed to be handled before the execution of the quantum part of the algorithm; the classical part is not in the simulation since there exist many examples of cyphers like RSA.

The first problem is simulating the change in the photon with respect to time. The most intuitive simplification of reality makes use of linear algebra in two dimensions. Let us let the exponential parts to be one in the following equation:

$$ |\psi\rangle \overset{\text{def}}{=} \begin{pmatrix} \psi_x \\ \psi_y \end{pmatrix} = \begin{pmatrix} \cos \theta \exp(i \alpha_x) \\ \sin \theta \exp(i \alpha_y) \end{pmatrix}. $$

This is the basis for the general representation of the polarization of a photon in this simulation. Furthermore in the simulation, the vector $i = <1,0>$ denotes the $<0>$ state and the vector $j = <0,1>$ denotes the $<1>$ state. Once again, this is a slight simplification from an actual photon. Now to find the general $<0>$ state in terms of theta, one simply needs to multiply the rotational matrix with $i$. One can find the $<1>$ state similarly. After applying the rotation, one gets

$<0> = <\cos(\theta), \sin(\theta)>$ then denote this by $<\theta_x>$

$<1> = <-\sin(\theta), \cos(\theta)>$ then denote this by $<\theta_y>$

The one remaining problem is determining how to ensure that the final polarization of the photon will be the correct value given an angle theta. The simple solution is to set the initial vector to $i$ or $j$ then rotating the initial vector by an angle determined by the photon’s theta-function. Denote the initial vector by $<x,y>$ (note that the square root of $x^2+y^2$ must be one). After performing the rotation, one gets the following value for the final state:

$<x*\cos(\theta) - y*\sin(\theta), x*\sin(\theta) + y*\cos(\theta)>$

The following java code calculates the state:
private double[] getState(double time) {
    if (finalState == null) {
        double theta = formula.evaluate(time); // formula is an object containing the theta-function
        double[] newState = new double[2];
        double x = initialState[X];
        double y = initialState[Y];
        newState[X] = x * cos(theta) - y * sin(theta);
        newState[Y] = x * sin(theta) + y * cos(theta);
        finalState = newState;
    }
    return finalState;
}

After calculating the state of the photon, one must simulate the measurement of the photon using a basis. In general, given basis elements \(<\theta_x^>\) and \(<\theta_y^>\) and a photon state of \(<x, y^>\), one simply needs to find \(a\) and \(b\) such that

\[
a<\theta_x^> + b<\theta_y^> = <x, y^>
\]

One can simply check the following two solutions:

\[
a = x \cos(\theta) + y \sin(\theta)
b = -x \sin(\theta) + y \cos(\theta)
\]

For the first component, \(a \cos(\theta) + b \sin(\theta) = x \cos^2(\theta) + x \sin^2(\theta) + y \sin(\theta) \cos(\theta) - y \sin(\theta) \cos(\theta) = x\). For the second component, \(a \sin(\theta) + b \cos(\theta) = y \cos^2(\theta) + y \sin^2(\theta) + x \sin(\theta) \cos(\theta) - x \sin(\theta) \cos(\theta) = y\). This confirms that \(a\) and \(b\) are appropriate measures of the basis \(<\theta_x^>\) and \(<\theta_y^>\). Now, the value of \(a^2\) is the probability that the photon is in the 0 state while the value \(b^2\) is the probability that the photon is in the 1 state. The following code “measures” the photon:

public int measure(double time, double theta) {
    int value = 0;
    double[] state = getState(time);
    double[] basisCoordinates = new double[2];
    double x = state[X];
    double y = state[Y];
    basisCoordinates[X] = x * cos(theta) + y * sin(theta);
    basisCoordinates[Y] = -x * sin(theta) + y * cos(theta);
    if (basisCoordinates[X] >= .9999) { value = 0; }
    else if (basisCoordinates[Y] >= .9999) { value = 1; }
    else {
        int value0 = -1;
        int value1 = -1;
        do{
final int MAX = 400000000;
int part0 = (int) (MAX * basisCoordinates[0]);
int part1 = (int) (MAX * basisCoordinates[1]);
if(random.nextInt(MAX) < part0) { value0 = 0; }
else { value0 = 1; }
if(random.nextInt(MAX) < part1) { value1 = 1; }
else { value1 = 0; }
while(value0 != value1 && value0 != -1 && value1 != -1);
value = value0;
return value;

Finally, the simulation is ready for a test. Suppose one wants to send the message, “Quantum encryption is very important,” to a recipient. One will input the message into the interface as shown in figure 2. Suppose in figure 1 that Alice is sending to Bob and Eve is trying to intercept the message.

Figure 2: After establishing a time-key, Alice sends Bob a message. Bob then decrypts the message at the time Alice told him.

In a one hundred trial run, no character was ever incorrect using the appropriate key. Furthermore, in a 264 character trial, the text was totally intact. Now suppose that Eve has intercepted Alice’s message to Bob. Eve will receive text similar to figure 3. Note that Eve cannot know the correct time to read the message until after the time has already passed.
Figure 3: An eavesdropper, Eve, tries to intercept the message that Alice sends to Bob. Although Eve attempts to decrypt the message only one tenth of a second after the correct time, Eve cannot decipher the message.

The following are the different random values of eve’s interception of the string, “AAAAAAA…(20 times),”: ÜB¡sFf5NÁ,‰^@q]Bá|Gù; ÇdM÷Kx%ÔieÔaâÔ; 4UlëiX• réé&äà; öñ;Ê!'S€<dAÔ*FeÇ^; K•TêÉj A iAiH ÚGö. As one can see, the strings are completely random. The difference between the time Eve is reading the message and Bob reading it is 0.00005ms. This supports the theoretical findings that the encryption is very secure.

Summary and Conclusion:

A successful cryptosystem can be created using time as the key. The algorithm has a number of features as follows:

Firstly, this cryptosystem relies on traditional cryptography and channels a minimal amount. The only traditional channel use occurs when the sender, Alice, notifies the recipient group delta that she will be sending a message, the members of delta respond to Alice, and Alice sends the key using traditional cryptography. This reduces the amount of useless translations between Alice and delta – the communication using traditional channels is useless because it can only be used in assisting the quantum algorithm and can be decrypted relatively easily with quantum machines.

Secondly, this cryptosystem is relatively fast for sending to multiple computers simultaneously. While many cryptosystems requires security steps for a set of bits (a set can vary in size) being transferred for each recipient in addition to the actual encryption, this system needs only three security operations per recipient. This method also preserves almost all bits being sent. Alice
only needs to insert extra, check, bits as in the TCP or UDP protocols. There need to exist no security bits or any communication from a member of delta except for acknowledge messages as in TCP protocol if one wishes.

Finally, this algorithm is completely secure provided Alice requires each recipient to measure the message in a time small enough that no eavesdropper can decrypt the traditional encryption in a time less than the time Alice specified. Since Alice will have ensured that no cryptanalyst can determine the appropriate measurement time, no eavesdropper will be able to read the message properly. Furthermore, the functions by which the photons follow ensure that the basis-angle of the photons will never again be equal to one-another, although they may be equal modulo 360. The probability of this is required to be very low during the construction of the functions controlling the basis-angle of the photons. Additionally, even when all the photons are equal modulo 360, a cryptanalyst cannot know about this since the functions cannot be recreated without a minimum of 5 measurements. This is 4 more measurements than is possible.

All that remains is the ability to manipulate the state of a photon with respect to time. If this obstacle can be overcome, secure communication will be an easier task. The time constraints placed on the cryptanalyst almost force the analyst to look for the function which the photon follows in order to reveal any information. This is very difficult if not impossible due to the collapsing of the photon into a certain state upon measurement. Finally, this kind of cryptosystem is fast. There is no need to constantly share information to create a key or any such thing.

Acknowledgments

This work has been supported by Arkansas Space Grant Consortium. Special thanks to Dr. Khalil Dajani for valuable guidance, and for the opportunity to do this project.

References


Quantum Key Distribution Simulation and Implementation for Aerospace Applications

Nathan L. Dunn

Southern Arkansas University, Magnolia, AR 71753

Corresponding Author: NLDunn9306@muleriders.saumag.edu

Abstract

With increasing computer power and an ever growing need for organizations to secure their data the subject of quantum cryptography has gained much attention. Presently quantum cryptography experiments are still in their infancy yet there exists a supply of photonic based cryptography systems that are commercially available. Photonic based Quantum Key Distribution (QKD) for cryptography systems has the potential of being utilized and or integrated into current and future WAN and LAN networks. Yet with ongoing advances in mobile and wireless computing there exists a gap for QKD to be utilized in these devices. Wireless communication is used widely in
aerospace systems ranging from communication satellites to drone aircraft. Some of the wireless aerospace systems fail to incorporate cryptographic standards because security is not seen as a priority in the overall design of the system. This has led to aerospace systems being compromised and millions spent on fixing the vulnerabilities. Cryptographic QKD systems could potentially eliminate these vulnerabilities and provided added security. Cryptographic free space QKD systems are a viable option in bridging the gap between QKD and wireless communication, and could feasibly be utilized in aerospace systems. This paper will discuss the initial steps in modeling and implementing a cryptograph system utilizing a free space QKD system and the challenges ahead.

Background

Today’s quantum computers and cryptography systems are utilized in laboratories and government agencies to solve complex problems and transmit confidential data. There exists experiments and systems that focus on the utilizations of polarized lasers that transmit q-bits thru a quantum channel in a QKD based system. Most of these systems have the ability to utilize fiber optic channels for long distance tamper proof QKD channels and have the added benefit of supplying securely encrypted data thru existing data links. Photonic based QKD supplies added security in the fact that intruders can easily be detected on such a system. Currently electronic based communication can be breached because of the elementary fact that data cables and or wires emit electromagnetic waves that can easily be patched into without warning. In photonic based communication, photons do not emit electromagnetic waves thus making it virtually tamper proof. Yet the simple act of breaching such a communication system leads to a breakdown in communication. Figure 1 displays a classic flow chart on how Quantum key distribution works and the protection it offers. As displayed in figure 1 Alice wants to communicate encrypted information with Bob but wants to distribute an encryption key on a secure quantum channel. If Eve the intruder disturbs any of the quantum information that is being transmitted Bob and Alice will be able to pick up on the disturbance by comparing quantum information. Thus if their quantum information does not have a certain degree of accuracy it is safe to assume that there exists an intruder in the system and that communication should-come-to-a-halt
Currently quantum key distribution systems consist of fiber optic and or photonic optical equipment that is hardwired into a network system and are presently being used in small networks to encrypt sensitive data. Though the hard wired implementation of QKD has been solved and is currently used there currently exists a gap for QKD for wireless communication. With continuing advancements in mobile and wireless technology there currently exists a gap in utilizing QKD in these devices. Currently NIST has made progress in utilizing lasers for free space QKD over distances up to 730 meter. The NIST QKD system transmits a stream of individual photons to generate a verifiably secret key. The photos are utilized as q-bits and are utilized to encrypt and decrypt digital information. What makes this system fascinating is that it is able to identify a photon from the sender amongst a large number of photons from other sources, such as the sun (Porter, 2009). As well scientists at Los Alamos have made progress in utilizing BB84 and OTP algorithms in free space QKD. There system similar to the NIST system utilizes a combination of lasers and optical equipment for a BB84 QKD algorithm. What sets this system apart from NIST is its ability to communicate over a 10km range and adjust for environmental variables such as air density and daylight (Hughes, 2002). Both of these free space QKD systems bridge the gap of wirelessly supplying a cryptography key, and could allow for aerospace systems such as satellites and aircraft to have the ability to encrypt communication and control data that is critical and or strategically important. In Afghanistan and Iran there were reported incidents of drone aircraft being compromised simply because of the fact that the aircraft were communicating over analog signals which were easily intercepted with conventional off the shelf electronics. These compromises have led to the capture of a drone in Iran and video transmission interceptions of drone video footage in Afghanistan. Though free space QKD is promising there is a limitation for systems that utilize photonic based communication. Overcast skies and changes in air density over long distances can cause a multitude of communication problems or can render photonic communication useless. Thus it is critical to takes these matters into account when developing a wireless communication systems that utilizes free space QKD.

**Simulation**

In order to model a cryptography system utilizing a QKD algorithm MATLAB/SIMULINK was selected as a modeling software because of its ease of use, abundance of Digital Signal Processing libraries, Simulink libraries, and its embedded code/Software libraries for microcontrollers. The Simulink model blocks listed in table 1 were utilized in the creation of a cryptography model utilizing One-Time Pad (OTP) QKD algorithm.

<table>
<thead>
<tr>
<th>Block Models</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Sine Wave Block" /></td>
<td>The Sine Wave block outputs a sinusoidal waveform. The block can operate in time-based or sample-based mode.</td>
</tr>
<tr>
<td><img src="image" alt="Zero-Order Hold Block" /></td>
<td>The Zero-Order Hold block holds its input for the sample period you specify. The block accepts one input and generates one output. Each signal can be scalar or vector. If the input is a vector, the</td>
</tr>
</tbody>
</table>
The cryptography model utilizing OTP OKD algorithm is displayed in figure 2. A sine wave was chosen to be used in this cryptography model as a general baseline since they are mathematically predictable and do not require FFT filters and error analysis. In the future reiteration of this model a random signal generator will be utilized in order to simulate voice and radio communication that go thru an Analog to Digital and Digital to Analog conversion process.

**Table 1. Simulink Model Blocks.** Adapted from Simulink Documentation at [www.mathworks.com](http://www.mathworks.com), 2014, Mathworks Documentation Center.

<table>
<thead>
<tr>
<th>Block</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integer to Bit Converter</td>
<td>The Integer to Bit Converter block maps each integer (or fixed-point value) in the input vector to a group of bits in the output vector.</td>
</tr>
<tr>
<td>Bit to Integer Converter</td>
<td>The Bit to Integer Converter block maps groups of bits in the input vector to integers in the output vector. M defines how many bits are mapped for each output integer.</td>
</tr>
<tr>
<td>First-Order Hold</td>
<td>The First-Order Hold block implements a first-order sample-and-hold that operates at the specified sampling interval.</td>
</tr>
<tr>
<td>Interpreted MATLAB Function</td>
<td>The Interpreted MATLAB Function block applies the specified MATLAB® function or expression to the input. The output of the function must match the output dimensions of the block or an error occurs.</td>
</tr>
<tr>
<td>Scope</td>
<td>The Scope block displays inputs signals with respect to simulation time.</td>
</tr>
<tr>
<td>MATLAB Function</td>
<td>With a MATLAB Function block, you can write a MATLAB® function for use in a Simulink® model. The MATLAB function you create executes for simulation and generates code for a Simulink Coder™ target.</td>
</tr>
</tbody>
</table>

Figure 2: Cryptography QKD Model
In the 10 second simulation run the sine wave is input into a Zero-order Hold. The Zero-Order Hold creates stepped sine wave which is outputted to a MATLAB function block. The MATLAB function block entitled Integer to Bit Converter converts the doubled floating point numeric information into an integer which is multiplied by 100. The integers are multiplied by 100 so that the numeric information may be later converted into 8 bit binary which has a max vale of 225. Next the Integer to 8 Bit Converter turns all the numeric information of the sine wave into an 8 bit binary array. The MATLAB function block Encrypt does a simple XOR operation and outputs the One Time Pad Key information thru channel K and the encrypted information thru channel C to the Decrypt MATLAB function block. The One Time Pad Key in the Encrypt function block utilizes a random bit generator function that produces 8 q-bits that are place in an array. Once the 8-bit streams of cryptic information coming thru the C channel is decrypted through the Decrypt MATLAB function block the information goes thru a reverse operation just as before the information made it to the Encrypt function block. Figure 3 thru 5 shows the results of the simulation with the first plot representing the original sine wave, the second representing the encrypted digital information, and the last plot representing the reconstructed sine wave utilizing the First-Order Hold function block.

Figure 3: Original Sine Wave
Figure 4: Encrypted Digital Sine Wave Information

Figure 5: Decrypted Reconstructed Sine Wave

The First-Order Hold block displays a sine wave similar to the one that was originally created yet there exists some errors. This is due to sampling and filtering errors and will require additional frequency and sampling analysis to reconstruct the sine waves without any errors. Yet the simple cryptography model presented in this MATLAB/SIMULINK proves that the OTP OKD algorithm can be simulated and improved upon by utilizing this software.

Experimentation

To physically implement a cryptography system utilizing a QKD algorithm the experimental set up displayed in figure 6 was designed. The experimental set up consists of a signal generator, USB Oscilloscope, two Arduino Microcontrollers and a laptop which is utilized as a data acquisition and control system. The experiment is similar to the MATLAB/SIMULINK model where Alice digitizes, and encrypts an analog signal and transmits the encrypted information via serial data link to Bob. The second serial data link mimics a QKD channel which can later be retrofitted utilizing free space photonics and or fiber optics. The microcontrollers are opensourced hardware that allows for the implementation and development of new QKD algorithms and current BB84 and OTP algorithms and since. The Arduino microcontroller boards were selected to represent Alice and Bob because of their vast functionality. The Arduino Mega 2560 microcontroller board is an open source microcontroller board that allows for rapid prototyping of electronic devices, robotic controls, and communication systems.
Figure 6: Tentative experimental setup

It has 54 digital input/output pins, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The Arduino boards are based off of the ATmega2560 microcontrollers which contain an onboard 6 channel analog-to-digital (A/D) converter. The converters have a 10 bit resolution, returning integers from 0 to 1023. As well the ATmega chips have the capability to convert digital data back into analog data. The A/D and D/A functionality along with the chips programmable C/C++ architecture allows for many communication and encryption algorithms to be simulated between the two boards (Arduino, n.d.). The USB Oscilloscope allows for the computer to monitor and collect data that is transmitted over this system, and also displays the communication data over a COM terminal. The collection of the transmitted data throughout the system will aid in data error analysis and integration issues.

The development and use of this wired systems lays the foundation for continued experimentation with multiple QKD algorithms that can be utilized in a cryptography communication system. After a multitude of algorithms are implemented they can be tested by replacing the Serial QKD Link with a photonic based free space QKD system.
Conclusion and Outlook

The first simulation run utilizing an OTP QKD algorithm provides the base line for configuring and implementing the physical cryptography system. The next step in the development of the cryptography system is to validate physical cryptography system with the MATLAB /Simulink model. This will allow the proper system settings and architecture to be implemented properly on the microcontrollers. Clearing this milestone will allow for the implementation and testing of a free space QKD by replacing the serial QKD link with a photonic based QKD system. The planned system will incorporate polarized lasers, beam splitters, wave plates, and photo diodes. Similar to Hughes QKD system this setup can easily be implemented and integrated into the physical microcontroller systems. A photonic based system would require 2 computer systems that implement a DAQ module with a high sampling rate. Yet the micro controllers are sufficient enough for encrypting small amounts of data that can easily be handled by the microcontroller.

Acknowledgments

This work has been supported by Arkansas Space Grant Consortium. Special thanks to Dr. Khalil Dajani for valuable guidance, and for the opportunity to do this project.

References


Lunar Regolith Excavator

Lindy Roberts, Bethany Miller, Jacob Pinkerton, Travis Reimer, Jesse Van Gorkom, and Will Holmes

John Brown University, Siloam Springs, AR 72761

Corresponding Author: WHolmes@jbu.edu
Abstract

Throughout the 2011-2012 school year, the team from John Brown University (JBU) hosted and participated in several outreach events. The JBU team (the Eaglenauts) had three primary goals for their outreach activities: encourage students of all ages to participate in STEM by linking technical knowledge to Lunabot experience, recruit high school students to pursue STEM majors in college, and encourage minorities to pursue careers in STEM. These goals supported an ultimate goal of encouraging participation in science, technology, engineering and mathematics (STEM). Because JBU is a return competitor to the NASA Lunabotics competition, the Eaglenauts had a functional robot to enhance outreach while the 2012 Lunabot was still in the design and manufacturing phases. As a result, the team was able to demonstrate the functions of the Lunabot and give students hands-on experience with robotics.

Introduction

The Eaglenauts participated in ten total outreach events, reaching roughly 2300 students. They hosted events on the JBU campus, visited local schools, and traveled to demonstrate in classrooms and conventions. The team modified their approach and content as necessary for each recipient group as they interacted with 4th graders through high school seniors. Through presentations, hands on activities, and question-and-answer sessions, the Eaglenaut team promoted STEM disciplines and encouraged the students to pursue activities in technical fields.

The Eaglenauts planned and executed their outreach events for four distinct groups: elementary students, middle school students, high school students, and minority students. The team desired to encourage young students to begin a serious STEM education in high school. Further, they hoped to inspire high school students and minority groups to major in a STEM discipline in college. The Eaglenauts believe a diverse community of scientists and engineers is essential to the development of technical fields, as collaboration and diverse understanding foster a superior product. Further, the team understands that development of skill and interest at all age levels will encourage contributions from a variety of groups, both now and in future endeavors.

Each event targeted one or more of the team’s outreach goals, as shown in Table 1. The following sections of this paper describe the outreach activities designed for each objective.
Encourage Students to Pursue STEM, Link Learning to Lunabot Experience. The Eaglenauts held several outreach events for elementary and middle school students. Through these events, the team hoped to inspire students to pursue education in science in high school and prepare to enter STEM majors at a university level. To promote this goal, the team held outreach events at two different middle schools in Kansas, a local 4th grade enrichment program, and local 4th and 5th grade classrooms.

Figure 1: Team members quizzing students in Meade, KS

**Fall 2011: Kansas Middle Schools**

In October 2011, two members of the JBU Lunabot team traveled to Meade and Plains, Kansas to present the Lunabot to middle school students. The team began by giving a brief presentation about the competition, NASA’s involvement, and the desire to return to the moon and eventually continue on to Mars. Following each presentation, the team asked a series of questions, some...
from selected math and science topics, and others directly related to the presentation. The team tailored their questions to the skill level of the junior high students, seeking to appropriately challenge their math and problem-solving skills, as shown in Table 2.

Students who answered correctly were given an opportunity to drive the Lunabot through a small obstacle course. The Eaglenauts facilitated a driving competition to increase student interest via a hands-on activity. The students learned to control the robot using the Xbox controller and competed with their teachers and classmates to complete the course. The Eaglenauts observed a marked increase in excitement and involvement during these competitions. Questions about operation and fabrication of the robot and the Lunabotics competition increased exponentially as students participated and cheered on their classmates.

At both locations, the students were encouraged to gather around and inspect the robot and ask further questions after the event.

Table 2: Question Content by Grade Level

<table>
<thead>
<tr>
<th>Targeted Audience</th>
<th>Question Content</th>
</tr>
</thead>
</table>
| 4<sup>th</sup> grade | • Calculations for area and volume, including units  
|                     | • Purpose of lunar research  
|                     | • Purpose of lunabot  
|                     | • Weight concepts  
|                     | • Collection rates  
|                     | • Simple motion (translation, reflection, rotation) |
| 5<sup>th</sup> grade | • Purpose of lunar research  
|                     | • Calculations for area and volume, including units  
|                     | • Orbiting bodies  
|                     | • History of space program  
|                     | • Competition concepts |
In Meade, the robot was presented to a 6th grade Robotics Club, consisting of 30 students. During the presentation, the team discussed the possibility of a future moon base, and the need for engineers and scientists to create such a facility. The students in the club were learning about simple systems. To integrate with this unit, the Eaglenauts asked students to point out simple machines on the robot and then to discuss applications of the skills they had learned. The students were very interested in the possibility of involvement in building a robot that would operate on the moon and asked many good questions, such as why wheels were chosen instead of tracks for the robot. They also asked about sensors, giving the electrical engineer on the team a chance to explain infrared and sonic sensors and their lunar applications. The team encouraged the students to continue learning about math, science, and robotics, so they can be involved with Lunabotics or other exciting engineering projects.

**Figure 2: Middle school students looking at simple machines on the Lunabot**

In Plains, KS the team demonstrated the Lunabot to the entire 5th grade class. This group of students had no specialized focus on robotics, thus the team focused on the general ideas behind the competition and design process instead of design specifics. The team engaged the students through appropriate questions regarding the Lunabotics Mining Competition and the practical
application of their math and science skills. Throughout this presentation, the students asked questions regarding the robot and the design and manufacturing processes.

A week after the team presented to the 5th grade students, they received a stack of letters. Each student had written a thank-you note to the team which included their favorite part of the presentation, things they learned, and suggestions for the project. Figure 3 shows one such letter.

Figure 3: Thank-you note from student in Plains, KS

Fall 2011: 4th Grade Enrichment

In Arkansas, elementary school students do not complete standardized “bench mark” tests in science until they reach the 5th grade. As a result, local elementary schools do not focus heavily on science education until that year. To ease the transition into more intensive science education, an education major at JBU started an after school enrichment program for 4th grade boys at Southside Elementary School. The Eaglenauts took the 2011 Lunabot to Southside to participate in this program in October, 2011.

The format of the event was similar to that of the Kansas presentations, with a presentation, brief “quiz,” interactive driving competition, and question-and-answer session. The boys were very excited about the project, and due to the small class size (15 students), each student was able to drive the Lunabot. The students were involved, very interested, and asked questions until the last minute. The program facilitator thanked the team for their participation, saying that the boys loved the presentation and were excited about science and robotics applications for several subsequent program sessions.
Spring 2012: Local 4th & 5th Grades

In April 2012, the Eaglenauts were invited to hold an outreach event at Southside Elementary School on two separate occasions, for 4th and 5th grade classes. The team followed their standard presentation format, including the questions and hands-on opportunities. The team enjoyed the enthusiasm of each class—nearly all of the students raised their hands, eager to answer every “quiz question” and offering many questions of their own. These presentations were especially meaningful for the Eaglenaut team, because they had completed fabrication of their own Lunabot and were able to share their own work and experience with the students.

Recruit High School Students to Pursue STEM Majors in College
The afore-mentioned goals and activities were aimed at retaining the STEM pipeline into the high school years. The Eaglenauts also designed the JBU Lunabotics outreach program to encourage high school students to pursue STEM majors in college. For this activity, the team targeted high school junior and seniors taking high school courses in drafting, pre-calculus, calculus, and physics. This subset of the high school population has the necessary background to succeed in a college engineering and/or technology program. Educational outreaches directed towards this goal had two forms. First, the Eaglenauts brought high school students to the JBU campus to demonstrate the project. Second, the team took the 2011 Lunabot to local high schools for college/career fairs.

For the on-campus events, the JBU engineering department invited classes of local high school students to the JBU campus, demonstrated the various ongoing engineering projects, and introduced the students to university level engineering and mathematics. The primary goal of these presentations was to get the students excited to study STEM in college.

The Eaglenauts were involved with the execution of each of these events, and the Lunabot was highlighted during the on-campus presentations. As in previous presentations, the Lunabot team would first describe the Lunabotics competition, NASA’s involvement, and desire to return to the moon and Mars. The team then described the robot design process so the students could see engineering as a creative problem solving activity and also learn practical applications for the technical knowledge they were acquiring in their current coursework. Finally, the team held an interactive, hands on portion in which at least two female and male students had a driving competition. The students were very excited to compete, as evidenced by their enthusiasm when volunteering, cheering throughout the competition, and their eagerness to participate and improve. Through these on-campus events, the team interacted with approximately 500 students and received very positive feedback from the high school teachers.

In addition to the events on the JBU campus, the Eaglenauts took the robot to a STEM career fair at nearby Bentonville High School on November 15th, 2011. The career fair was structured like
an exposition, so the team set up an area in which high school students could drive the 2011 JBU Lunabot. The unique nature and interactive demonstration of the 2011 Lunabot attracted many of the high school students. The JBU team initiated conversations with the students in which they described their Lunabot experience. Through these individual conversations, the Eaglenaunts were able to convey their excitement about the Lunabot project to the students and discuss the benefits of higher education in engineering or technology. Finally, the team gave a card with information about the Lunabot project and the JBU Lunabotics Facebook page to each visiting student and encouraged them to watch for competition times and information.

At the event, the Eaglenaunts were able to interact with approximately 100 students. The team later received positive feedback from the high school pre-engineering teacher that it was an educational, beneficial experience for the students. The team was invited to return the following year to present again and further encourage students to investigate and contribute to STEM fields.

**Encourage Minorities to Pursue Careers in STEM**

Seven JBU Engineering Students took the 2011 Lunabot to a NASA exhibit at the Hispanic Engineering Science and Technology Week in South Texas. At this event, the JBU team used hands-on robot demonstrations to encourage junior high and high school students to pursue careers in engineering, science and mathematics.

![Figure 8: JBU team at HESTEC event](image1)

![Figure 9: Interaction with HESTEC students](image2)

As in the career fair presentations in Bentonville, the JBU team used students’ attraction to the Lunabot to start conversations about the project and the benefits of STEM disciplines. Throughout the course of the two-day event, the team was able to reach roughly 1000 students, inspiring them to pursue STEM careers.

**Conclusion**
Through the ten outreach events hosted by the JBU Eaglenauts, the team was able to reach over 2000 students, from ages 8 to 18. Through the information, interaction, integration of the audience’s technical ability, and hands-on activities, the Eaglenauts helped to “promote the development of interest in space activities and STEM (Science, Technology, Engineering, and Mathematics) fields [1].

References

Arkansas Space Grant Consortium (ASGC) is pleased to announce the creation of the *Arkansas Aerospace Proceedings* (AAP), a journal published annually to coincide with the ASGC Symposium. The journal will provide opportunities for students to publish research funded by the ASGC after peer review, thus enriching the undergraduate experience by directly involving them in this important scientific process. The annual publication will focus on archiving undergraduate research in science, engineering, and mathematics in the State of Arkansas. Each submission must be sponsored by a full-time faculty member of an ASGC member institution; where the research was completed. In recommending the article, the faculty approves the scholarship and manuscript style. Manuscripts should be submitted, in standard one column MS word format to one of the journal editors below. Additional formatting requirements can be found on the ASGC website. Once a manuscript is accepted for publication, it will undergo language copyediting, typesetting, and reference validation in order to provide the highest publication quality possible. AAP will be considered an internal publication for the Arkansas Space Grant Consortium, and should not preclude the student’s work from being published in other journals. However, faculty mentors should discuss this with their students and jointly decide if the research paper should be submitted for publication in the Arkansas Aerospace Proceedings.

We invite electronic submissions from the 22nd ASGC Symposium attendees and all of ASGC past grant recipients. For consideration please submit your manuscripts electronically by the date of the symposium or no later than June 30, 2014. Submit it to one of the journal editors below. The reports will be made available online once accepted.

**Note:** For questions not addressed here, please contact the *Journal* editors: Abdel Bachri; [AbdelBachri@saumag.edu](mailto:AbdelBachri@saumag.edu), and Ed Wilson: [wilson@harding.edu](mailto:wilson@harding.edu)
<table>
<thead>
<tr>
<th>Affiliation</th>
<th>Name</th>
<th>Email Address</th>
<th>Phone No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkansas State University</td>
<td>R: Dr. Tillman Kennon</td>
<td><a href="mailto:jkennon@astate.edu">jkennon@astate.edu</a></td>
<td>(870)972-3256</td>
</tr>
<tr>
<td></td>
<td>A: Dr. Andrew Sustich</td>
<td><a href="mailto:sustich@astate.edu">sustich@astate.edu</a></td>
<td>(870)972-3079</td>
</tr>
<tr>
<td>Arkansas Tech University</td>
<td>R: Dr. Mostafa Hemmati</td>
<td><a href="mailto:mhemmati@atu.edu">mhemmati@atu.edu</a></td>
<td>(479)968-0340</td>
</tr>
<tr>
<td>108 McEver Hall, Russellville 72801</td>
<td>A: Dr. Frank Hardcastle</td>
<td><a href="mailto:fhardcastle@atu.edu">fhardcastle@atu.edu</a></td>
<td>(479)280-4310</td>
</tr>
<tr>
<td>Harding University</td>
<td>R: Dr. Edmond Wilson</td>
<td><a href="mailto:wilson@harding.edu">wilson@harding.edu</a></td>
<td>(501)279-4513</td>
</tr>
<tr>
<td>915 East Market Ave., Searcy 72149</td>
<td>A: Dr. James Mackey</td>
<td><a href="mailto:jmackey@harding.edu">jmackey@harding.edu</a></td>
<td>(501)279-4512</td>
</tr>
<tr>
<td>Henderson State University</td>
<td>R: Dr. Basil Miller</td>
<td><a href="mailto:millerb@hsu.edu">millerb@hsu.edu</a></td>
<td>(870)230-5317</td>
</tr>
<tr>
<td>1100 Henderson St., Arkadelphia 71999</td>
<td>A: Dr. Rick McDaniel</td>
<td><a href="mailto:mcdanir@hsu.edu">mcdanir@hsu.edu</a></td>
<td>(870)230-5170</td>
</tr>
<tr>
<td>Hendrix College</td>
<td>R: Dr. Bob Dunn</td>
<td><a href="mailto:dunn@hendrix.edu">dunn@hendrix.edu</a></td>
<td>(501)450-1234</td>
</tr>
<tr>
<td>1600 Washington, Conway 72032</td>
<td>A: Dr. Jennifer Peszka</td>
<td><a href="mailto:peszka@hendrix.edu">peszka@hendrix.edu</a></td>
<td>(501)450-1323</td>
</tr>
<tr>
<td>John Brown University</td>
<td>R: Dr. Larry Bland</td>
<td><a href="mailto:lbland@jbu.edu">lbland@jbu.edu</a></td>
<td>(479)238-8637</td>
</tr>
<tr>
<td>2000 W University St, Siloam Springs 72761</td>
<td>A: Dr. Will Holmes</td>
<td><a href="mailto:wholmes@jbu.edu">wholmes@jbu.edu</a></td>
<td>(479)524-7462</td>
</tr>
<tr>
<td>Lyon College</td>
<td>R: Dr. David Thomas</td>
<td><a href="mailto:david.thomas@lyon.edu">david.thomas@lyon.edu</a></td>
<td>(870)307-7269</td>
</tr>
<tr>
<td>2300 Highland Road, Batesville 72501</td>
<td>A:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ouachita Baptist University</td>
<td>R: Dr. Joe Bradshaw</td>
<td><a href="mailto:bradshawj@obu.edu">bradshawj@obu.edu</a></td>
<td>(870)245-5218</td>
</tr>
<tr>
<td>PO Box 3726 Arkadelphia 71998</td>
<td>A: Dr. Jim Taylor</td>
<td><a href="mailto:taylorj@obu.edu">taylorj@obu.edu</a></td>
<td>(870)245-5531</td>
</tr>
<tr>
<td>Southern Arkansas University</td>
<td>R: Dr. Abdel Bachri</td>
<td><a href="mailto:agbachri@saumag.edu">agbachri@saumag.edu</a></td>
<td>(870)235-4283</td>
</tr>
<tr>
<td>100 E. University, Magnolia 71753</td>
<td>A: Dr. Sam Heintz</td>
<td><a href="mailto:sfheintz@saumag.edu">sfheintz@saumag.edu</a></td>
<td>(870)235-4398</td>
</tr>
<tr>
<td>University of Arkansas at Little Rock</td>
<td>R: Dr. Mariya Khodakovskaya</td>
<td><a href="mailto:mvkhodakovsk@ualr.edu">mvkhodakovsk@ualr.edu</a></td>
<td>(501)371-7506</td>
</tr>
<tr>
<td>2801 S. University, Little Rock 72204</td>
<td>A: Dr. Julian Post</td>
<td><a href="mailto:jwpost@ualr.edu">jwpost@ualr.edu</a></td>
<td>(501)569-8041</td>
</tr>
<tr>
<td>University of Arkansas at Monticello</td>
<td>R: Dr. Marvin Fawley</td>
<td><a href="mailto:fawleym@uamont.edu">fawleym@uamont.edu</a></td>
<td>(870)460-1165</td>
</tr>
<tr>
<td>PO Box 3480, Monticello 71656</td>
<td>A: Dr. Morris Bramlett</td>
<td><a href="mailto:bramlett@uamont.edu">bramlett@uamont.edu</a></td>
<td>(870)460-1116</td>
</tr>
<tr>
<td>University of Arkansas at Pine Bluff</td>
<td>R: Dr. Ebo Tei</td>
<td><a href="mailto:teie@uapb.edu">teie@uapb.edu</a></td>
<td>(870)575-8175</td>
</tr>
<tr>
<td>1200 N. University Drive, Pine Bluff 71601</td>
<td>A: Dr. Mansour Mortazavi</td>
<td><a href="mailto:mortazavim@uapb.edu">mortazavim@uapb.edu</a></td>
<td>(870)575-8789</td>
</tr>
<tr>
<td>University of Arkansas For Medical Sciences</td>
<td>R: Dr. Parimal Chowdhury</td>
<td><a href="mailto:chowdhuryparimal@uams.edu">chowdhuryparimal@uams.edu</a></td>
<td>(501)686-5443</td>
</tr>
<tr>
<td>4301 W. Markham, Little Rock 72205</td>
<td>A: Dr. Maxim Dobretsov</td>
<td><a href="mailto:mdobretsov@uams.edu">mdobretsov@uams.edu</a></td>
<td>(501)526-7150</td>
</tr>
<tr>
<td>University of Arkansas, Fayetteville</td>
<td>R: Dr. Larry Roe</td>
<td><a href="mailto:lar@uarl.edu">lar@uarl.edu</a></td>
<td>(479)575-3750</td>
</tr>
<tr>
<td>ADMN 205, Fayetteville 72701</td>
<td>A: Dr. Cindy Sagers</td>
<td><a href="mailto:csagers@uark.edu">csagers@uark.edu</a></td>
<td>(479)575-5624</td>
</tr>
<tr>
<td>University of Arkansas At Ft. Smith</td>
<td>R: Dr. Kevin R Lewelling</td>
<td><a href="mailto:kevin.lewelling@uafs.edu">kevin.lewelling@uafs.edu</a></td>
<td>(479)788-7736</td>
</tr>
<tr>
<td>5210 Grand Avenue, Fort Smith 72913</td>
<td>A: Dr. Michael Reynolds</td>
<td><a href="mailto:michael.reynolds@uafs.edu">michael.reynolds@uafs.edu</a></td>
<td>(479)788-7719</td>
</tr>
<tr>
<td>University of Central Arkansas</td>
<td>R: Dr. Carl Frederickson</td>
<td><a href="mailto:carlf@uca.edu">carlf@uca.edu</a></td>
<td>(501)450-5900</td>
</tr>
<tr>
<td>201 Donaghey, Conway 72035</td>
<td>A: Dr. Stephen R. Addison</td>
<td><a href="mailto:saddison@uca.edu">saddison@uca.edu</a></td>
<td>(501)450-3199</td>
</tr>
<tr>
<td>University of the Ozarks</td>
<td>R: Dr. Shyma Al-Shukri</td>
<td><a href="mailto:sashukri@ozarks.edu">sashukri@ozarks.edu</a></td>
<td>(479)979-1363</td>
</tr>
<tr>
<td>415 N. College Ave, Clarksville 72830</td>
<td>A: Dr. Salomon Itza</td>
<td><a href="mailto:sitza@ozarks.edu">sitza@ozarks.edu</a></td>
<td>(479)979-1365</td>
</tr>
</tbody>
</table>
Arkansas Space Grant Consortium - Phone List

AR Aviation Historical Society  R: Mr. Ken Hiegel  kmbhiegel@att.net  (501) 681-8599
3301 E. Roosevelt Rd., Little Rock 72206  A: Ms. Cathe Crews  cathe.crews@gmail.com  (501) 256-6052

Arkansas Aerospace Training Consortium  R: Mr. Stephen Paull  spaull@uaccb.edu  (870) 612-2149
PO Box 3350, Batesville 72503  A:

Arkansas Department of Aeronautics  R: Mr. John Knight  deptaero@mail.state.ar.us  (501) 376-6781
One.Airport Drive-3rd Floor, LR 72206  A: Mr. Jerry Chism  jerry.chism@arkansas.gov  (501) 376-6781

Ark. Science and Technology Authority  R: Dr. Gail McClure  gail.mcclure@arkansas.gov  (501) 682-8186
900 W. Capitol Ave Sut.400, LR 72201  A: Ms. Marta Collier  marta.collier@arkansas.gov  (501) 683-4400

Arkansas Department of Higher Educatio  R:Ms. Lillian Williams  Lillian.Williams@adhe.edu  (501) 371-2038
423 Main Street Suite 400, LR 72201  A: Ms. Jeanne Jones  Jeanne.Jones@adhe.edu  (501) 371-2039

AR Economic Development Commission  R: Ms. Robin Pelton  rpelton@arkansasedc.com  (501) 837-9674
900 W. Capitol Ave Sut.400, LR 72201  A:

BEI Systems and Space Division  R: Mr. John Beasley  jbeasley@beiprecision.com  (501) 851-4000
1100 Murphy Drive, Maumelle 72113  A:

Civil Air Patrol  R: Lt. Chuck Bishop  cgbishopjr@aol.com  (501) 565-9185
2201 Crisp Drive, Little Rock 72202  A:

Conestoga-Rovers & Associates  Dr. Robert Sproles  rsproles@CRAworld.com  (501) 224-1926
11719 Hinson Road Suite 100  A:
Little Rock, AR 72212

Arkansas Space Grant Consortium
2801 S. University Ave ETAS 329
Little Rock, AR 72204
asgc@ualr.edu

Director  Keith Hudson  mkhudson@ualr.edu  (501) 569-8212
Assistant Director  Julian Post  jwpost@ualr.edu  (501) 569-8041
Finance Coordinator  Laura Holland  ldholland@ualr.edu  (501) 569-8212
Education & Outreach Coordinator  Schyler Cannatella  ns cannatella@ualr.edu  (501) 569-8213
List of Funded Grants by ASGC during 2013-2014

***Lyon College***
Type: Research Infrastructure  
Title: “Biological Diversity of Ozark Caves”  
Student: Natalie McFarland  
Student: Anna Mickler  
Mentor: Dave Thomas  
Amount: $10,000.00

***Southern Arkansas University***
Type: Research Infrastructure  
Title: “Application of Quantum Computation Algorithms for Network Communications and Space-based Devices”  
Student: Jared Jones  
Student: Caleb Parks  
Mentor: Khalil Dajani  
Amount: $9,905.00

***University of Arkansas at Pine Bluff***
Type: Research Infrastructure  
Title: “Development of Intermediate Bank Quantum Wires Solar Cell for NASA Space Explorations”  
Student: Matthew Wilkins  
Mentor: Mansour Mortazavi  
Amount: $3,430.00

Type: Research Infrastructure  
Title: “Evaluation of Antioxidant Zinc Complexes for Ability to Prevent Lipid Peroxidation”  
Mentor: Richard Walker  
Mentor: Abul Kazi  
Amount: $3,500.00

***University of Central Arkansas***
Type: Research Infrastructure  
Title: “Acoustic Properties of Metallic Foams and Flight Materials Cont.”  
Student: Matt Sisson  
Mentor: William Slaton  
Amount: $5,686.00

Type: Collaborative Research Grant  
Title: “Novel High Efficiency Nanorod Electrodes for Polymer Electrolyte Membrane Fuel Cell”  
Student: TBD  
Student: TBD  
Mentor: Ali Shaikh-UALR  
Mentor: Tansel Karabacak-UALR  
Mentor: Aslam Chowdhury-UAPB  
Amount: $15,000.00
<table>
<thead>
<tr>
<th>University</th>
<th>Type</th>
<th>Title</th>
<th>Student</th>
<th>Mentor</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Arkansas at Little Rock</td>
<td>Work Force Development</td>
<td>“Heteroaton doped carbons nanostructures for photocatalytic energy production and energy storage”</td>
<td>Saad Azam</td>
<td>Tito Viswanathan</td>
<td>$6,500.00</td>
</tr>
<tr>
<td>Henderson State University</td>
<td>Work Force Development</td>
<td>“Ground Penetrating Radar important in search for water”</td>
<td>Kristopher Buckholz</td>
<td>Basil Miller</td>
<td>$6,500.00</td>
</tr>
<tr>
<td>Arkansas Tech University</td>
<td>Work Force Development</td>
<td>“Breakdown Waves with a Significant Current behind the Shock Front”</td>
<td>Haley Morris</td>
<td>Mostafa Hemmati</td>
<td>$6,500.00</td>
</tr>
<tr>
<td>University of Arkansas at Little Rock</td>
<td>Work Force Development</td>
<td>“The Effect of Microgravity of Expression of the G-Protein Coupled Receptor the CR5 in Human Coronary Artery Endothelial Cells(HCAEC) grown in HARV culture vessel”</td>
<td>Bukola Odeniyi</td>
<td>Nawab Ali</td>
<td>$6,500.00</td>
</tr>
<tr>
<td>Henderson State University</td>
<td>Work Force Development</td>
<td>“Investigation of the properties of Simulated Martian Soil Using Ground Penetrating Radar”</td>
<td>Bryant Pierce</td>
<td>Basil Miller</td>
<td>$6,500.00</td>
</tr>
<tr>
<td>Southern Arkansas University</td>
<td>Work Force Development</td>
<td>“Chandra X-Ray Laboratory – Summer Research Internship 2013”</td>
<td>Zachary Pinson</td>
<td>Abdel Bachri</td>
<td>$6,500.00</td>
</tr>
<tr>
<td>University of Arkansas at Monticello</td>
<td>STEM Minority Award – Stipend</td>
<td>“Understanding Ribosome Biogenesis”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Student: Shana Chancellor  
Mentor: Mary Stewart  
Amount: $1,500.00

***John Brown University***

Type: STEM Minority Award – Stipend  
Title: “NASA Lunabotics Mining Competition”  
Student: Ariel Forret  
Mentor: Will Holmes  
Amount: $1,500.00

***University of Arkansas at Little Rock***

Type: STEM Minority Award – Stipend  
Title: “The Effect of Microgravity of Expression of the G-Protein Coupled Receptor the CR5 in Human Coronary Artery Endothelial Cells(HCAEC) grown in HARV culture vessel”  
Student: Bukola Odeniyi  
Mentor: Nawab Ali  
Amount: $1,500.00

Type: K-12 Mini-Grant  
Title: “NSTA Conference”  
Requestor: Michelle Green  
School: Blevin High School  
Amount: $500.00  
Match: $545.00

Type: K-12 Mini-Grant  
Title: “Star Gazing Family Night”  
Requestor: Janie Hill  
School: Gardner Math & Science Magnet  
Amount: $500.00  
Match: $500.00

Type: K-12 Mini-Grant  
Title: “Ocean ‘Waves’ to Arkansas”  
Requestor: Kathy Rusert  
School: Acorn High School  
Amount: $500.00  
Match: $10,200.00

***Hendrix College***

Type: Research Infrastructure  
Title: “Application of FHH-Adsorption Activation Theory to water adsorption measurements”  
Student: Rebecca Meredith  
Mentor: Coutney Hatch  
Amount: $4,020.00

Type: Research Infrastructure  
Title: “Incorporation Computation at Large Landau Levels”  
Student: Anna Reine  
Mentor: Todd Tinsley  
Amount: $3,150.00

Type: Research Infrastructure  
Title: “Infrasound/Ground Coupling”  
Student: Konstantin Gruenwald
### University of Arkansas at Fort Smith

**Type:** Research Infrastructure  
**Title:** “Developing a Motor Drive Used for Large Electric Vehicles and Rovers”  
**Student:** Robert Murphree  
**Mentor:** Kevin Lewelling  
**Amount:** $10,000.00

### University of Arkansas at Pine Bluff

**Type:** Research Infrastructure  
**Title:** “Nematodes of Zea mays: Ecological Considerations”  
**Mentor:** Martin Matute  
**Amount:** $2,500.00

### University of Central Arkansas

**Type:** STEM Minority Award – Stipend  
**Title:** “STEM Minority Award”  
**Student:** Shelby Burns  
**Mentor:** William Slaton  
**Amount:** $1,500.00

### Lyon College

**Type:** STEM Minority Award – Stipend  
**Title:** “Performing Research within Sandtown Cave”  
**Student:** Kayla Ford  
**Mentor:** David Thomas  
**Amount:** $1,500.00

**Type:** K-12 Mini-Grant  
**Title:** “Understanding Sun Earth Connection”  
**Requestor:** Jerri Emrick  
**School:** Ozark Junior High School  
**Amount:** $500.00  
**Match:** $0.00

**Type:** K-12 Mini-Grant  
**Title:** “Straw Rockets”  
**Requestor:** Charlotte Cook  
**School:** Carver Magnet School  
**Amount:** $500.00  
**Match:** $0.00

**Type:** K-12 Outreach-Grant  
**Title:** “Destination Space”  
**Requestor:** Curtis Varnell, Brett Stone  
**School:** Western Arkansas Education Service Cooperative  
**Amount:** $5,000.00  
**Match:** $6,230.00

**Type:** K-12 Outreach-Grant  
**Title:** “Destination Science Challenge”
Requestor: Brian Schuller
Requestor: Lisa Schuller
School: DeQueen Mena Educational Cooperative
Amount: $5,000.00
Match: $5,000.00

***University of the Ozarks***

Type: Research Infrastructure
Title: “Annalysis of GTT1 and GTT2 in cell life cycles”
Student: Sean Colemen
Mentor: Emily Toombs
Amount: $7,202.00

***University of Central Arkansas***

Type: STEM Minority Award – Stipend
Title: “STEM Minority Award”
Student: Shelby Burns
Mentor: William Slaton
Amount: $1,500.00

***University of Arkansas at Pine Bluff***

Type: STEM Minority Award – Stipend
Title: “STEM Minority Award”
Student: Eleni-James Becton
Mentor: Mansour Mortazavi
Amount: $1,500.00

***University of Arkansas at Little Rock***

Type: STEM Minority Award – Stipend
Title: “STEM Minority Award”
Student: Katie Hart
Mentor: Nawab Ali
Amount: $1,500.00

Type: STEM Minority Award – Stipend
Title: “STEM Minority Award”
Student: Nicole Schartz
Mentor: Nawab Ali
Amount: $1,500.00

***University of Arkansas, Fayetteville***

Type: STEM Minority Award – Stipend
Title: “STEM Minority Award”
Student: Erika Kohler
**University of Arkansas at Pine Bluff FY23 Funds**

- **Type:** STEM Minority Award – Stipend
- **Title:** “STEM Minority Award”
- **Student:** Rebecca Mickol
- **Mentor:** Timothy Kral
- **Amount:** $1,500.00

- **Type:** STEM Minority Award – Stipend
- **Title:** “STEM Minority Award”
- **Student:** Amanda Schilling
- **Mentor:** Julia Kennefick
- **Amount:** $1,500.00

- **Type:** STEM Minority Award – Stipend
- **Title:** “STEM Minority Award”
- **Student:** Patrice Brown
- **Mentor:** Richard Walker
- **Amount:** $1,500.00

- **Type:** STEM Minority Award – Stipend
- **Title:** “STEM Minority Award”
- **Student:** Britney McBride
- **Mentor:** Richard Walker
- **Amount:** $1,500.00

---

**Arkansas State University**

- **Type:** Research Infrastructure
- **Title:** “Development of Li-ion Battery Research Program at ASU”
- **PI:** Ross Carroll & Koushik Biswas
- **Amount:** $5,000.00
- **Match:** $6,000.00

---

**Hendrix College**

- **Type:** Research Infrastructure
- **Title:** “Hurricanes and Tornadoes”
- **PI:** Bob Dunn
- **Student:** Tessa Cook
- **Amount:** $2,000.00
- **Match:** $23,609.00

---

**University of Arkansas at Little Rock**

- **Type:** STEM Minority Award
- **Title:** “STEM Minority Award”
- **Student:** Muntaha Yousef
- **Mentor:** Keith Hudson
- **Amount:** $1,500.00

---

- **Type:** K-12 Outreach Grant
- **Title:** “Planetarium and Astronomy Activates for STEM Education”
- **Requestor:** Basil Miller
- **School:** Henderson State University
**Arkansas Tech University**

- **Type:** Research Infrastructure
- **Title:** “Breakdown Waves: Current Range”
- **PI:** Mostafa Hemmati
- **Student:** Ryan Evans
- **Amount:** $2,000.00
- **Match:** $0.00

---

**Southern Arkansas University**

- **Type:** Research Infrastructure
- **Title:** “High Pressure Xenon Time Projection Chamber Background for Neutrino-less Double Beta Decay Experiment”
- **PI:** Abdel Bachri
- **Student:** Zachary Pinson
- **Amount:** $2,000.00
- **Match:** $4,400.00

---

**John Brown University**

- **Type:** Research Infrastructure
- **Title:** “Eaglenaut Aerospace Club”
- **PI:** Will Holmes
- **Student:** Brain Plank, Karl Anderson, Lindsey Davis, Zach Huffaker, & Zach Lee
- **Amount:** $5,000.00
- **Match:** $44,000.00

- **Type:** Research Infrastructure
- **Title:** “NASA Lunabotics Mining Competition”
- **PI:** Will Holmes
- **Amount:** $5,000.00
- **Match:** $29,000.00

---

**Ouachita Baptist University**

- **Type:** Research Infrastructure
- **Title:** “Horizontal Electric Confinement due to a Glass Box in Complex Plasma”
- **PI:** Angela Douglass
- **Student:** Jace Bradshaw
- **Amount:** $2,000.00
- **Match:** $6,500.00

---

**Ouachita Baptist University**

- **Type:** Research Infrastructure
- **Title:** “Elucidation of Signaling Mechanism Associated with Oxidative Stress Defense and its Implications to Long Term Space Travel”
- **PI:** Nathan Reyna
- **Student:** TBD
- **Amount:** $3,300.00
- **Match:** $5,500.00

- **Type:** Research Infrastructure
- **Title:** “Germination and Growth of Plants in Hypobaria”
PI: Jim Taylor
Student: TBD
Amount: $3,300.00
Match: $2,100.00

***Arkansas Tech University***

**Type:** Student Scholarship  
**Title:** “Targeting DNA-Protein Kinase for Cancer Therapy”  
**Student:** Taylor Freeman  
**Mentor:** Ivan Still/Mostafa Hemmati  
**Amount:** $2,000.00  
**Match:** $500.00

**Type:** Research Infrastructure  
**Title:** “Bond Valence/Length Relationship for Fe-Fe, Fe-S, Fe-C and S-D Bonds”  
**PI:** Franklin Hardcastle  
**Student:** Caitlyn Rofkahr-Bowman  
**Amount:** $2,000.00  
**Match:** $0.00

**Type:** Research Infrastructure  
**Title:** “Intra-Cavity Generation of Laguerre-Gauss Laser Beams”  
**PI:** Jessica Young  
**Student:** Katelyn Hinman  
**Amount:** $2,000.00  
**Match:** $0.00

**Type:** Research Infrastructure  
**Title:** “Preparation and Characterization of Hydrogen Producing Catalysts”  
**PI:** Charles Mebi/Anwar Bhuiyan  
**Student:** Megan Fuller  
**Amount:** $2,000.00  
**Match:** $0.00

**Type:** Research Infrastructure  
**Title:** “Interacting Dark Energy Models and Observation”  
**PI:** Hamed Shojael/Vrege Amirkhanian  
**Student:** Joshua Heathcock  
**Amount:** $2,000.00  
**Match:** $0.00

**Type:** STEM Minority Award  
**Campus:** University of Arkansas at Little Rock  
**Student:** Virginia Boyett  
**Mentor:** Mariya Khodakovskaya  
**Amount:** $1,500.00

**Type:** STEM Minority Award  
**Campus:** Arkansas Tech University  
**Student:** Carerabas Clark  
**Mentor:** Mostafa Hemmati  
**Amount:** $1,500.00

**Type:** STEM Minority Award  
**Campus:** Lyon College  
**Student:** Alexandria Gillins
Mentor: David Thomas  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: Arkansas Tech University  
Student: Shakeena Johnson  
Mentor: Charles Mebi  
Amount: $1,500.00

Mentor: Charles Mebi  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: Lyon College  
Student: Javier Moreno  
Mentor: David Thomas  
Amount: $1,500.00

Mentor: Patricia Buford  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: Henderson State University  
Student: Ramona Martin  
Mentor: Shannon Clardy  
Amount: $1,500.00

Mentor: Basil Miller  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: Henderson State University  
Student: Marissa Otwell  
Mentor: Basil Miller  
Amount: $1,500.00

Mentor: Basil Miller  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: University of Arkansas at Pine Bluff  
Student: Eleni-James Becton  
Mentor: Mansour Mortizavi  
Amount: $1,500.00

Mentor: Andrew Williams  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: University of Arkansas at Monticello  
Student: Kiara Newhouse  
Mentor: Andrew Williams  
Amount: $1,500.00

Mentor: Jennifer Franklin  
Amount: $1,500.00  
Type: STEM Minority Award  
Campus: Arkansas State University  
Student: Jennifer Franklin
Type: STEM Minority Award
Mentor: Hashim Ali
Amount: $1,500.00
Campus: Arkansas State University
Student: Jerry Jones
Mentor: Hashim Ali
Amount: $1,500.00

Type: STEM Minority Award
Campus: Harding University
Student: Shelby Sorrells
Mentor: Ed Wilson
Amount: $1,500.00

Type: K-12 Mini Grant
Title: “Valley View 6th Grade Rocket Show”
Requestor: Curtis Adams
School: Valley View Public Schools – Jr. High
Amount: $500.00
Match: $500.00

Type: K-12 Mini Grant
Title: “Valley View 6th Grade Rocket Show”
Requestor: Linda Shepherd
School: Valley View Public Schools – Jr. High
Amount: $500.00
Match: $500.00

***Arkansas Tech University***

Type: Research Infrastructure
Title: “Breakdown Waves: Current Range”
PI: Mostafa Hemmati
Student: Ryan Evans
Amount: $2,000.00
Match: $0.00

***Southern Arkansas University***

Type: Research Infrastructure
Title: “High Pressure Xenon Time Projection Chamber Background for Neutrino-less Double Beta Decay Experiment”
PI: Abdel Bachri
Student: Zachary Pinson
Amount: $2,000.00
Match: $4,400.00

***John Brown University***

Type: Research Infrastructure
Title: “Eaglenaut Aerospace Club”
PI: Will Holmes
Student: Brain Plank, Karl Anderson, Lindsey Davis Zach Huffaker, & Zach Lee
Amount: $5,000.00
<table>
<thead>
<tr>
<th>Match:</th>
<th>$44,000.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“NASA Lunabotics Mining Competition”</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Will Holmes</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$5,000.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$29,000.00</td>
</tr>
</tbody>
</table>

***Ouachita Baptist University***

<table>
<thead>
<tr>
<th>Match:</th>
<th>$29,000.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Horizontal Electric Confinement due to a Glass Box in Complex Plasma”</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Angela Douglass</td>
</tr>
<tr>
<td><strong>Student:</strong></td>
<td>Jace Bradshaw</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$2,000.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$6,500.00</td>
</tr>
</tbody>
</table>

***Ouachita Baptist University***

<table>
<thead>
<tr>
<th>Match:</th>
<th>$5,500.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Elucidation of Signaling Mechanism Associated with Oxidative Stress Defense and its Implications to Long Term Space Travel”</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Nathan Reyna</td>
</tr>
<tr>
<td><strong>Student:</strong></td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$3,300.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$5,500.00</td>
</tr>
</tbody>
</table>

***Ouachita Baptist University***

<table>
<thead>
<tr>
<th>Match:</th>
<th>$2,100.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Germination and Growth of Plants in Hypobaria”</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Jim Taylor</td>
</tr>
<tr>
<td><strong>Student:</strong></td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$3,300.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$2,100.00</td>
</tr>
</tbody>
</table>

***Arkansas Tech University***

<table>
<thead>
<tr>
<th>Match:</th>
<th>$500.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Student Scholarship</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Targeting DNA-Protein Kinase for Cancer Therapy”</td>
</tr>
<tr>
<td><strong>Student:</strong></td>
<td>Taylor Freeman</td>
</tr>
<tr>
<td><strong>Mentor:</strong></td>
<td>Ivan Still/Mostafa Hemmati</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$2,000.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Match:</th>
<th>$0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Bond Valence/Length Relationship for Fe-Fe, Fe-S, Fe-C and S-D Bonds”</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Franklin Hardcastle</td>
</tr>
<tr>
<td><strong>Student:</strong></td>
<td>Caitlyn Rofkahr-Bowman</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$2,000.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Match:</th>
<th>$0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Intra-Cavity Generation of Laguerre-Gauss Laser Beams”</td>
</tr>
<tr>
<td><strong>PI:</strong></td>
<td>Jessica Young</td>
</tr>
<tr>
<td><strong>Student:</strong></td>
<td>Katelyn Hinman</td>
</tr>
<tr>
<td><strong>Amount:</strong></td>
<td>$2,000.00</td>
</tr>
<tr>
<td><strong>Match:</strong></td>
<td>$0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Match:</th>
<th>$0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong></td>
<td>Research Infrastructure</td>
</tr>
<tr>
<td><strong>Title:</strong></td>
<td>“Preparation and Characterization of Hydrogen Producing Catalysts”</td>
</tr>
</tbody>
</table>
PI: Charles Mebi/Anwar Bhuiyan
Student: Megan Fuller
Amount: $2,000.00
Match: $0.00

Type: Research Infrastructure
Title: “Interacting Dark Energy Models and Observation”
PI: Hamed Shojael/Vrege Amirkhanian
Student: Joshua Heathcock
Amount: $2,000.00
Match: $0.00

Type: STEM Minority Award
Campus: University of Arkansas at Little Rock
Student: Virginia Boyett
Mentor: Mariya Khodakovskaya
Amount: $1,500.00

Type: STEM Minority Award
Campus: Arkansas Tech University
Student: Carerabas Clark
Mentor: Mostafa Hemmati
Amount: $1,500.00

Type: STEM Minority Award
Campus: Lyon College
Student: Alexandria Gillins
Mentor: David Thomas
Amount: $1,500.00

Type: STEM Minority Award
Campus: Arkansas Tech University
Student: Shakeena Johnson
Mentor: Charles Mebi
Amount: $1,500.00

Type: STEM Minority Award
Campus: Lyon College
Student: Javier Moreno
Mentor: David Thomas
Amount: $1,500.00

Type: STEM Minority Award
Campus: Arkansas Tech University
Student: Kelsey Ledbetter
Mentor: Patricia Buford
Amount: $1,500.00

Type: STEM Minority Award
Campus: Henderson State University
Student: Ramona Martin
Mentor: Shannon Clardy
Amount: $1,500.00

Type: STEM Minority Award
Campus: Henderson State University
Student: Marissa Otwell
<table>
<thead>
<tr>
<th>Mentor</th>
<th>Amount</th>
<th>Type</th>
<th>Campus</th>
<th>Student</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basil Miller</td>
<td>$1,500.00</td>
<td>STEM Minority Award</td>
<td>Henderson State University</td>
<td>Abigail Wilhite</td>
<td>$1,500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Basil Miller</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>University of Arkansas at Pine Bluff</td>
<td>$1,500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Eleni-James Becton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mansour Mortizavi</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>University of Arkansas at Monticello</td>
<td>$1,500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Kiara Newhouse</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Andrew Williams</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Arkansas State University</td>
<td>$1,500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jennifer Franklin</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hashim Ali</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Arkansas State University</td>
<td>$1,500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Jerry Jones</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hashim Ali</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Harding University</td>
<td>$1,500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shelby Sorrells</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ed Wilson</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,500.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>K-12 Mini Grant</td>
<td>“Valley View 6th Grade Rocket Show”</td>
<td>Curtis Adams</td>
<td>$500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Valley View Public Schools – Jr. High</td>
<td>Match: $500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>K-12 Mini Grant</td>
<td>“Valley View 6th Grade Rocket Show”</td>
<td>Linda Shepherd</td>
<td>$500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Valley View Public Schools – Jr. High</td>
<td>Match: $500.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*** Harding University ***
Type: Research Infrastructure
Title: “High Resolution Solar Spectrograph for 2014 NSSSC”
PI: Edmond Wilson
Student: Stephanie Inabnet
Amount: $2,956.00
Match: $6,000.00

***University of Central Arkansas***

Type: Research Infrastructure
Title: “Acoustic Properties of 3D Printed Porous Media”
PI: William Slaton
Student: John Ferrier
Amount: $4,994.00
Match: $4,139.00

***Arkansas Tech University***

Type: Research Infrastructure
Title: “Breakdown Waves: Current Range”
PI: Mostafa Hemmati
Student: Ryan Evans
Amount: $2,000.00
Match: $0.00

***Southern Arkansas University***

Type: Research Infrastructure
Title: “High Pressure Xenon Time Projection Chamber Background for Neutrino-less Double Beta Decay Experiment”
PI: Abdel Bachri
Student: Zachary Pinson
Amount: $2,000.00
Match: $4,400.00

***John Brown University***

Type: Research Infrastructure
Title: “Eaglenaut Aerospace Club”
PI: Will Holmes
Student: Brain Plank, Karl Anderson, Lindsey Davis Zach Huffaker, & Zach Lee
Amount: $5,000.00
Match: $44,000.00

Type: Research Infrastructure
Title: “NASA Lunabotics Mining Competition”
PI: Will Holmes
Amount: $5,000.00
Match: $29,000.00

***Ouachita Baptist University***

Type: Research Infrastructure
Title: “Horizontal Electric Confinement due to a Glass Box in Complex Plasma”
PI: Angela Douglass
Student: Jace Bradshaw
Amount: $2,000.00
### ***Ouachita Baptist University***

<table>
<thead>
<tr>
<th>Type: Research Infrastructure</th>
<th>Title: “Elucidation of Signaling Mechanism Associated with Oxidative Stress Defense and its Implications to Long Term Space Travel”</th>
<th>PI: Nathan Reyna</th>
<th>Student: TBD</th>
<th>Amount: $3,300.00</th>
<th>Match: $5,500.00</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type: Research Infrastructure</th>
<th>Title: “Germination and Growth of Plants in Hypobaria”</th>
<th>PI: Jim Taylor</th>
<th>Student: TBD</th>
<th>Amount: $3,300.00</th>
<th>Match: $2,100.00</th>
</tr>
</thead>
</table>

### ***Arkansas Tech University***

<table>
<thead>
<tr>
<th>Type: Student Scholarship</th>
<th>Title: “Targeting DNA-Protein Kinase for Cancer Therapy”</th>
<th>Student: Taylor Freeman</th>
<th>Mentor: Ivan Still/Mostafa Hemmati</th>
<th>Amount: $2,000.00</th>
<th>Match: $500.00</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type: Research Infrastructure</th>
<th>Title: “Bond Valence/Length Relationship for Fe-Fe, Fe-S, Fe-C and S-D Bonds”</th>
<th>PI: Franklin Hardcastle</th>
<th>Student: Caitlyn Rofkahr-Bowman</th>
<th>Amount: $2,000.00</th>
<th>Match: $0.00</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type: Research Infrastructure</th>
<th>Title: “Intra-Cavity Generation of Laguerre-Gauss Laser Beams”</th>
<th>PI: Jessica Young</th>
<th>Student: Katelyn Hinman</th>
<th>Amount: $2,000.00</th>
<th>Match: $0.00</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type: Research Infrastructure</th>
<th>Title: “Preparation and Characterization of Hydrogen Producing Catalysts”</th>
<th>PI: Charles Mebi/Anwar Bhuiyan</th>
<th>Student: Megan Fuller</th>
<th>Amount: $2,000.00</th>
<th>Match: $0.00</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Type: Research Infrastructure</th>
<th>Title: “Interacting Dark Energy Models and Observation”</th>
<th>PI: Hamed Shojael/Vrege Amirkhanian</th>
<th>Student: Joshua Heathcock</th>
<th>Amount: $2,000.00</th>
<th>Match: $0.00</th>
</tr>
</thead>
</table>

<p>| Type: STEM Minority Award | Campus: University of Arkansas at Little Rock | Student: Virginia Boyett | Mentor: Mariya Khodakovskaya | | |</p>
<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Arkansas Tech University</td>
</tr>
<tr>
<td>Student:</td>
<td>Carerabas Clark</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Mostafa Hemmati</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Lyon College</td>
</tr>
<tr>
<td>Student:</td>
<td>Alexandria Gillins</td>
</tr>
<tr>
<td>Mentor:</td>
<td>David Thomas</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Arkansas Tech University</td>
</tr>
<tr>
<td>Student:</td>
<td>Shakeena Johnson</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Charles Mebi</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Lyon College</td>
</tr>
<tr>
<td>Student:</td>
<td>Javier Moreno</td>
</tr>
<tr>
<td>Mentor:</td>
<td>David Thomas</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Arkansas Tech University</td>
</tr>
<tr>
<td>Student:</td>
<td>Kelsey Ledbetter</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Patricia Buford</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Henderson State University</td>
</tr>
<tr>
<td>Student:</td>
<td>Ramona Martin</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Shannon Clardy</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Henderson State University</td>
</tr>
<tr>
<td>Student:</td>
<td>Marissa Otwell</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Basil Miller</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Henderson State University</td>
</tr>
<tr>
<td>Student:</td>
<td>Abigail Willhite</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Basil Miller</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>University of Arkansas at Pine Bluff</td>
</tr>
<tr>
<td>Student:</td>
<td>Eleni-James Becton</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Mansour Mortizavi</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>
Type: STEM Minority Award  
Campus: University of Arkansas at Monticello  
Student: Kiara Newhouse  
Mentor: Andrew Williams  
Amount: $1,500.00

Type: STEM Minority Award  
Campus: Arkansas State University  
Student: Jennifer Franklin  
Mentor: Hashim Ali  
Amount: $1,500.00

Type: STEM Minority Award  
Campus: Arkansas State University  
Student: Jerry Jones  
Mentor: Hashim Ali  
Amount: $1,500.00

Type: STEM Minority Award  
Campus: Harding University  
Student: Shelby Sorrells  
Mentor: Ed Wilson  
Amount: $1,500.00

Type: K-12 Mini Grant  
Title: “Valley View 6th Grade Rocket Show”  
Requestor: Curtis Adams  
School: Valley View Public Schools – Jr. High  
Amount: $500.00  
Match: $500.00

Type: K-12 Mini Grant  
Title: “Valley View 6th Grade Rocket Show”  
Requestor: Linda Shepherd  
School: Valley View Public Schools – Jr. High  
Amount: $500.00  
Match: $500.00

***Henderson State University ***

Type: Research Infrastructure  
Title: “Mapping Subsurface Anomalies Using GPR: Potential for Water Detection on Mars”  
PI: Basil Miller  
Student: William Goodin  
Amount: $5,000.00  
Match: $5,000.00

***University of the Ozarks***

Type: Research Infrastructure  
Title: “Analysis of GTT1 & GTT2 in Cell Life Cycles”  
PI: Sean Coleman  
Student: Emily Toombs  
Amount: $7,201.93  
Match: $400.00

***University of Arkansas, Fayetteville***
<table>
<thead>
<tr>
<th>Type:</th>
<th>Student Fellowship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>“Methanogen Growth and Survivability at Low Pressure”</td>
</tr>
<tr>
<td>Student:</td>
<td>Rebecca Mickol</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Tim Kral</td>
</tr>
<tr>
<td>Amount:</td>
<td>$2,000.00</td>
</tr>
<tr>
<td>Match:</td>
<td>$1,100.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>Research Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>“Evaluation and Initial Development of CubeSat Electrical Power Systems (EPS)”</td>
</tr>
<tr>
<td>PI:</td>
<td>Adam Huang</td>
</tr>
<tr>
<td>Amount:</td>
<td>$2,000.00</td>
</tr>
<tr>
<td>Match:</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>Research Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>“Interactions of Tholins with Titan’s Surface Hydrocarbons”</td>
</tr>
<tr>
<td>PI:</td>
<td>Vincent Chevrier</td>
</tr>
<tr>
<td>Student:</td>
<td>Amanda Wagner and Sandeep Singh</td>
</tr>
<tr>
<td>Amount:</td>
<td>$3,000.00</td>
</tr>
<tr>
<td>Match:</td>
<td>$0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>Student Scholarship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>“Advance Propulsion Physics Intern at JSC Eagleworks”</td>
</tr>
<tr>
<td>Student:</td>
<td>Tyler Scogin</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Larry Roe</td>
</tr>
<tr>
<td>Amount:</td>
<td>$3,000.00</td>
</tr>
<tr>
<td>Match:</td>
<td>$9,600.00</td>
</tr>
</tbody>
</table>

***Harding University***

<table>
<thead>
<tr>
<th>Type:</th>
<th>Research Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>“Field Studies for a Mobile Science Laboratory”</td>
</tr>
<tr>
<td>PI:</td>
<td>Edmond Wilson</td>
</tr>
<tr>
<td>Student:</td>
<td>Brennan Thomason &amp; Stephanie Inabnet</td>
</tr>
<tr>
<td>Amount:</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Match:</td>
<td>$12,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>Research Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title:</td>
<td>“Development of Communications for Space Missions”</td>
</tr>
<tr>
<td>PI:</td>
<td>Edmond Wilson</td>
</tr>
<tr>
<td>Student:</td>
<td>Maurisa Orona</td>
</tr>
<tr>
<td>Amount:</td>
<td>$5,000.00</td>
</tr>
<tr>
<td>Match:</td>
<td>$10,000.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>University of Arkansas at Pine Bluff</td>
</tr>
<tr>
<td>Student:</td>
<td>Redmond Floyd</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Jessie Walker</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>University of Arkansas at Pine Bluff</td>
</tr>
<tr>
<td>Student:</td>
<td>Kevrick Watkins</td>
</tr>
<tr>
<td>Mentor:</td>
<td>Jessie Walker</td>
</tr>
<tr>
<td>Amount:</td>
<td>$1,500.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type:</th>
<th>STEM Minority Award</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus:</td>
<td>Arkansas Tech University</td>
</tr>
<tr>
<td>Student:</td>
<td>Skye Heckman</td>
</tr>
</tbody>
</table>
Mentor: Rosemary Burk
Amount: $1,500.00

Type: STEM Minority Award
Campus: University of Arkansas at Little Rock
Student: Charlette Felton
Mentor: Anindya Ghosh
Amount: $1,500.00

Type: STEM Minority Award
Campus: University of Arkansas at Monticello
Student: Danielle Cook
Mentor: Jeff Taylor
Amount: $1,500.00

Type: STEM Minority Award
Campus: University of Arkansas at Monticello
Student: Chris Roberts
Mentor: Marvin Fawley
Amount: $1,500.00

Type: STEM Minority Award
Campus: John Brown University
Student: Courtney Smith
Mentor: Will Holmes
Amount: $1,500.00

Type: K-12 Outreach Grant
Title: “CAAS Robotic Telescope Project”
Requestor: Darrell Heath
School: Central Arkansas Astronomical Society
Amount: $2,000.00
Match: $12,600.00

***Hendrix College***

Type: Research Infrastructure
Title: “Hurricane Internal Dynamics”
PI: Robert Dunn
Student: Angela Lamb
Amount: $3,800.00
Match: $25,893.00

Type: Research Infrastructure
Title: “Convective Storms-internal Dynamics”
PI: Robert Dunn
Student: Elijah Kessler
Amount: $3,800.00
Match: $27,974.00

***Lyon College***

Type: Research Infrastructure
Title: “Biological Diversity of Ozark Caves”
PI: David Thomas
Co PI: Cassia Oliveria
Student: Bobie Jo Cooper
Student: Alexandria Gillins
Student: Javier Moreno
Amount: $10,000
Match: $57,550.00

***University of Arkansas at Little Rock***

Type: Research Infrastructure
Title: “Novel metal complexes in developing electrocatalysts”
PI: Anindya Ghosh
Student: Charlette Felton
Amount: $2,000.00
Match: $2,000.00

Type: Research Infrastructure
Title: “Establishment of Stress-Tolerant Rice for Advanced Life Support System”
PI: Mariya Khodakovskaya
Student: Virginia Boyett(Johnson)
Amount: $2,000.00
Match: $2,000.00

Type: Research Infrastructure
Title: “Heteroatom doped mesoporous carbons for supercapacitor application”
PI: Tito Viswanathan
Student: Zach Hicks
Amount: $2,000.00
Match: $2,000.00

***University of Arkansas at Fort Smith***

Type: Research Infrastructure
Title: “Characterizing a Motor Drive for Electric Vehicles and Rovers”
PI: Kevin Lewelling
Student: Osman Martinez
Student: Drew Caple
Amount: $10,000.00
Match: $10,545.00

***John Brown University***

Type: Research Infrastructure
Title: “Eaglenaut Aerospace Club”
PI: Will Holmes
Student: Brian Plank
Student: Karl Anderson
Student: Lindsey Davis
Student: Zach Huffaker
Student: Zach Lee
Amount: $2,000.00
Match: $33,950.00

Type: Research Infrastructure
Title: “JBU Lunabot”
PI: Will Holmes
Student: Brian Plank
Student: Zach Huffaker
Amount: $8,000.00
Match: $26,000.00
***Southern Arkansas University***

Type: Research Infrastructure  
Title: “Carbon nanotube reinforced polymer composites”  
PI: Mahbub Ahmed  
Student: Justin Vanhoose  
Student: Joshua Grant  
Amount: $10,000.00  
Match: $5,000.00

***University of Arkansas at Pine Bluff***

Type: Research Infrastructure  
Title: “New Biological countermeasures for Protection of Astronauts”  
PI: Richard Walker  
Co PI: Abul Kazi  
Student: Dominecia Foots  
Student: TBA  
Amount: $6,500.00  
Match: $2,500.00

Type: WFD Award  
Campus: University of Arkansas at Little Rock  
Student: Saad Azam  
Mentor: Tito Viswanathan  
Amount: $6,500.00

Type: WFD Award  
Campus: John Brown University  
Student: Zachary Huffaker  
Mentor: Will Holmes  
Amount: $6,500.00

Type: WFD Award  
Campus: University of Arkansas at Little Rock  
Student: John Minton  
Mentor: Nawab Ali  
Amount: $6,500.00

Type: WFD Award  
Campus: Arkansas Tech University  
Student: Hunter Newberry  
Mentor: Mostafa Hemmati  
Amount: $6,500.00

Type: WFD Award  
Campus: John Brown University  
Student: Brian Plank  
Mentor: Will Holmes  
Amount: $6,500.00