Proposed Scouts BSA (formerly Boy Scouts) Optics/Photonics Merit Badge

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ABSTRACT

This paper summarizes the effort to date to develop a proposed Scouts BSA Optics/Photonics merit badge, suggests activities that can be done now, and recommends actions for the future. The paper also includes a description of merit badges from the author's point of view. The proposed Optics/Photonics merit badge would (1) Educate and expose potentially thousands of scouts and adult scout volunteers annually to the science, technology, manufacturing, and potential of optics and photonics; (2) List the organizations and academic institutions with optic, photonic, and photonic technician programs; (3) Help people make informed career decisions; (4) Advance the Scouts BSA STEM goals; and (5) Provide scouts with interesting and exciting activities.

Keywords: Scouts BSA, Boy Scouts, Cub Scouts, merit badge, STEM, education, outreach

1. INTRODUCTION

Scouts BSA currently offers 137 merit badges for scouts to earn, in a wide variety of hobby and career subjects[1]. In 2018, 1,822,136 total merit badges were earned, and on average over 13,000 scouts earned each merit badge (excluding Cinematography, which was replaced with Moviemaking)[2]. At the higher scout ranks, certain merit badges must be earned to advance in rank. Those merit badges are referred to as "Eagle Required", such as First Aid, which was the most popular merit badge in 2018 (69,565 were earned). However, any merit badge can be completed at any time just for fun or because the scout has an interest or curiosity in the subject matter (such as this proposed merit badge).

1.1 Merit Badges

Merit badges provide scouts the opportunity to explore hobbies and careers. Scouts BSA offers merit badges in a wide variety of topics, including Oceanography, Wood Carving, Astronomy, Backpacking, and many others (see Figure 1). To complete a merit badge the scout contacts a merit badge counselor, usually obtains the merit badge book, hopefully reads the book, and begins to complete the merit badge requirements in consultation with the merit badge counselor. Most merit badges can be completed in a month or less. The merit badge might require access to equipment or facilities (for instance, if you want to earn the Horsemanship merit badge, you will need access to a horse).

Figure 1. Scout Merit Badges Displayed at a Scout Store.

Optics Education and Outreach VI, edited by G. Groot Gregory, Anne-Sophie Poulin-Girard,
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0277-786X/20/$21 · doi: 10.1117/12.2567595

1.2 Merit Badge Book Organization

Merit badge books have a common organization. More recent editions have a color cover with relevant attention-getting photographs. Beginning on page 2 are the badge's requirements, which can be done in any order in consultation with a merit badge counselor. Then the book has a "Contents" page, which lists the title of each main section of the book (which I will refer to as chapters). In total, the entire book is about 75 pages, and the portion available for all of the chapters is between 30 and 80 pages. Each chapter contains many pictures, illustrations, tables, charts, graphs, and diagrams as required for clarity, which are listed (referenced) near the end of the book under "Photo and Illustration Credits". Also near the end of the book is a "Resources" section and an "Acknowledgements" section. The Resources section typically contains contact information for those interested in additional information, and are categorized under "Scouting Resources", "Books", "Organizations and Websites", "CDs, DVDs, and Videos", "Magazines", and occasionally a "Glossary". The "Veterinary Medicine" merit badge book has an additional section in the back titled "Veterinary Medical Schools and Colleges in the United States and Canada" listing the colleges and universities that offer a veterinary degree; an Optics/Photonics merit badge book could have a similar section listing the colleges and universities that offer optic and photonic programs. The Acknowledgements section gives thanks to the individuals and organizations responsible for the creation of the book. Finally, the inside back cover has an alphabetical list of all of the merit badges currently offered at the time of publication.

I have purchased (and read, cover to cover) three SPIE Field Guides: Radiology, Lens Design, and Geometrical Optics. I would say merit badge books are similar to SPIE Field Guides, but Field Guides have more pages, and are naturally much more detailed and specialized in content.

1.3 Merit Badge Requirements

Merit badge requirements are what the scout must learn, know, sketch, create, explain, demonstrate, build, and/or do to complete the merit badge.

In almost all merit badge books, the first two requirements begin with "Explain to your merit badge counselor the hazards you are most likely to encounter while …", and "Show that you know first aid for, and the prevention of, injuries and illnesses that could occur while …". One might discount the potential hazards of certain activities until "something happens". Best to be prepared. The author still vividly remembers the bitter cold weather on the windy mountaintop while trying to observe Halley's Comet.

Many merit badges require the scout to define, explain, draw, sketch, demonstrate, create, and/or build. For the proposed Optics/Photonics merit badge, a scout could say what the word "laser" stands for, explain the difference between visible light and infrared radiation, explain the difference between a concave and convex lens, create a poster, describe products or processes that are based on a laser (e.g., grocery store scanners and fiber optics), show light reflecting from a mirror, demonstrate total internal reflection, "Do this: While standing inside a lighted room take a picture of a window when it is dark outside.", and so forth. (These are only a few suggestions; I have many more.)

Frequently one is given a choice for a requirement: "Do ONE of the following:" (followed by multiple choices), or "Do TWO of the following:" (followed by multiple choices). Such choices are purposefully designed to provide flexibility to complete the badge. For instance, if the requirement states "Visit a laboratory …", or "Perform research using resources found at the library, in books, and on the internet,…", the scout can choose the requirement based on availability. There may not be a laboratory nearby (or a laboratory open to the public), in which case the scout could choose the research option. However, I have seen many individual scouts and scout troops make a day trip, or a weekend camping trip, that is close to the appropriate facility to complete a merit badge requirement. For instance, our troop made a day trip to the Sonoma County Airport to complete the Aviation merit badge, a two hour drive each way, and very worth it.

In addition, many merit badges require the scout to "Find out about three career opportunities in …", and "Find out the education, training, and experience required for this profession". Merit badges provide scouts (and adult scout volunteers) exposure to many professions. After completing the merit badge, if the potential career looks interesting, the scout might take classes that could lead to that career.

1.4 Merit Badge Challenges

Some merit badge requirements may be difficult or impossible to complete "close to home". Those badges might best be completed at a scout summer camp that is set up for that merit badge (e.g. if a scout camp offers the Horsemanship merit badge, they will have horses and qualified staff on-site). In addition, for certain summer camp merit badges, the scout can

complete some of the requirements ahead of time. In another example, if a scout chooses to visit an observatory to complete a requirement, and the closest observatory is far away (for instance, a two hour drive), the scout's troop can schedule a day trip or weekend campout near the observatory. A merit badge counselor must be available, but counselors can work with the scout virtually. Our troop has met via Zoom for three months now, and have completed merit badges virtually.

Our troop scheduled a weekend campout at the Robert Ferguson Observatory (see Figure 2). The Observatory is located at Sugarloaf State Park, California (coincidentally a two hour drive). Groups renting the observatory for the evening (we did) are required to camp next door to the observatory, which makes it very safe. After observing planets, stars, and galaxies late at night, courtesy of planetarium docents, we walked to our tents, maybe 100 feet away (see Figure 3).

Figure 2. Robert Ferguson Observatory, Sugarloaf State Park, California.

Figure 3. Camping near the Robert Ferguson Observatory, Sugarloaf State Park, California.

In addition to observing the nighttime stars and planets through three different telescopes, and observing the (filtered) sun in the morning, the scouts hiked the Planet Walk, which is a trail approximately 2-1/2 miles long. The Planet Walk shows the relative distances from the sun to the 8 planets, plus Pluto. Signs were set up along the trail for each planet at the appropriate distance from the sun. Mercury (the closest planet) was 81 feet from the sun (see Figure 4). Pluto (furthest from the sun) was about two and a half miles away walking (about 1.5 miles as the crow flies). In addition, each sign contained a circle that represented the planet's diameter to give one a sense of how big (or small) the planets are compared

to the sun. The sun was a circle about two feet in diameter, Mercury was a dot about the size of a pencil lead, and Jupiter was the size of a racquetball. I mention this to help the readers think of new and interesting optics/photonics activities that could be done at "who knows where?".

Figure 4. Hiking the Planet Walk at Sugarloaf State Park, California.

Another merit badge challenge could be the supplies or equipment needed to complete the badge. If the badge requires the scout to design and build a robot, then procuring the tools, supplies, and equipment to design and build a robot might be a task better suited for a summer camp, or possibly a troop can purchase it for the troop's use (e.g., a Lego robot).

It is my goal to borrow, modify, or create activities and projects that can be completed with low cost supplies. For instance, one can build a pinhole camera with a plastic restaurant ToGo container and a push pin. Shining three 500 lumen flashlights on the back cover of the March/April edition of the Photonics Focus magazine (again a laser magazine!) I could easily see the SPIE logo, and it was good enough such that my IPhone could make a picture (see Figure 5, left). One of the scouts in Troop 281 made an image (see Figure 5, right). If one is using low cost supplies, and mistakes are made during construction, then one can easily repair or replace and move on.

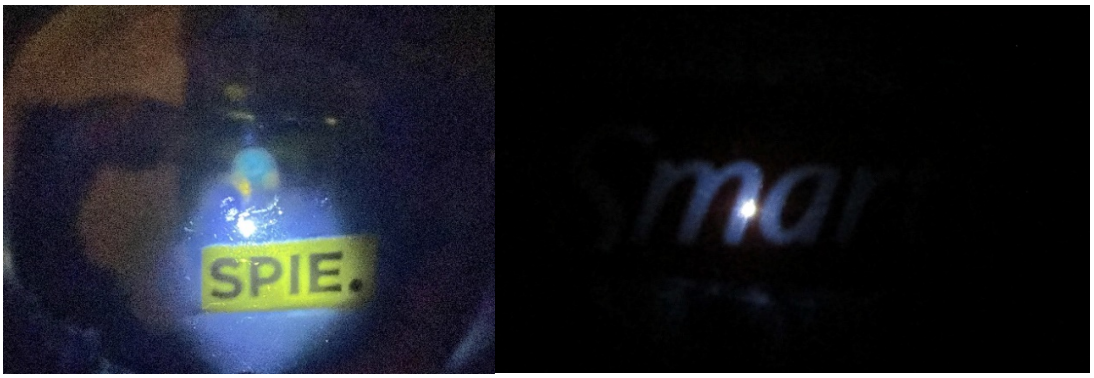


Figure 5. Pinhole Camera Images (Using a Circular Plastic "ToGo" Container)

2. PAST ACTIVITIES

2.1 Laser Magazines

It all started with laser magazines. It might have been 2012 when I began to subscribe to laser magazines, which I enjoyed reading then, and enjoy even more reading today. Especially the pictures! Reading the magazine articles eventually resulted in me contacting schools, organizations, colleges and universities, and staff in the laser field.

In 2014 I wondered if an OSA chapter was located in northern California (yes, the University of California at Davis had an active student OSA chapter). I asked if I could borrow their Optics Suitcase (yes!), and in addition the chapter graciously loaned me three fog machines.

2.2 Boy Scout Summer Camp

That summer I brought the Optics Suitcase to the Boy Scout summer camp our troop attended. We were amazed how well we could see a green laser beam shining on the trees on the other side of the lake at night (the trees were perhaps between 500 and 1,000 feet away). We set up a mirror on each side of the lake to see if we could reflect the beam multiple times across the lake (no). Too much divergence, plus we used ordinary household mirrors. I did not know lasers had divergence, or the importance of mirror flatness. The first, but not last, learning experience.

2.3 International Year of Light/Photonics Club

In the fall of 2014, while reading laser magazines, I discovered 2015 would be the International Year of Light. Without the laser magazines, I might never had known! I contacted my younger son's 7th grade science teacher at our local K-8 school to see what we could do, and she suggested we form a Photonics Club for the 6th, 7th, and 8th graders. We did, meeting almost every Tuesday at lunch, for the remainder of that school year, and most of the next year (with Ms. Cassandra Trevino). I scoured the OSA and SPIE websites, as well as any other resources I could find, for ideas what we could do. While wearing diffraction glasses (donated by SPIE) we looked at different colored light bulbs, watched fun videos, and once we had a "take apart day" The students disassembled a non-functioning microwave, an old electronic clock, and other "non-functioning" hardware – the kids loved it! One of the club members took a picture of a light bulb through diffraction glasses (see Figure 6).

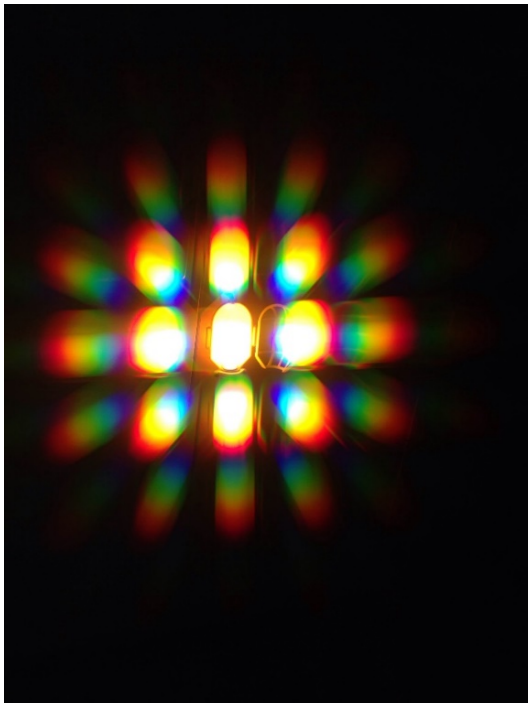


Figure 6. Picture of a Light Bulb Through SPIE Diffraction Glasses (Submitted by a Photonics Club Student).

2.4 Sacramento STEM Fair

In the spring of 2015 the Photonics Club was given the opportunity to exhibit at the Sacramento STEM Fair. We brought three tables full of hands-on activities, literature, and a bicycle equipped with a Monkey Light. For the bicycle equipped with the Monkey Light, we built a semi-dark "room" out of sheet plastic. The Photonics Club students staffed the tables, wearing complimentary Science Fair T-Shirts. Other than Intel, we were the most popular exhibitor, but Intel had give-away freebies (see Figure 7).

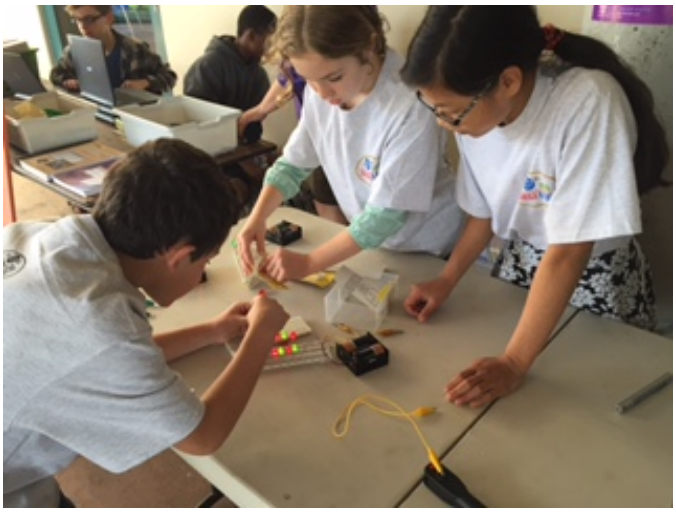


Figure 7. Photonics Club Members Staffing a Table at the 2015 Sacramento STEM Fair.

One of the most popular, interesting, and unique displays we brought was a device that could identify flying insects using a laser. The device, since commercialized, was invented by Dr. Eamonn Keogh, a computer science professor at the University of California at Riverside (UCR) Bourns College of Engineering, and two UCR students, Ms. Yanping Chen and Ms. Adene Why. The laser beam goes through a special lens to sculpt the beam into a thin diverging horizontal line, until it reaches a single sensor array. Initially Dr. Keogh purposefully used low cost parts and Legos. The array's output changes as an insect flies in front of all or a portion of the laser beam. The output is continuously recorded and then analyzed. Knowing in advance the wingbeat frequency of insects of interest, the device compares the analyzed output to those insect's frequencies. Using this device will help farmers and growers determine if and where certain insects are present. I found out the device existed when reading the article titled "Shining a Light on Pests" in the July/August issue of BioPhotonics (again, a laser magazine!). After reading the article, I emailed Dr. Keogh, who generously sent me a complete kit), which I now display at outreach events (see Figure 8). Could this device help in the effort to reverse declining Western Honeybee populations?

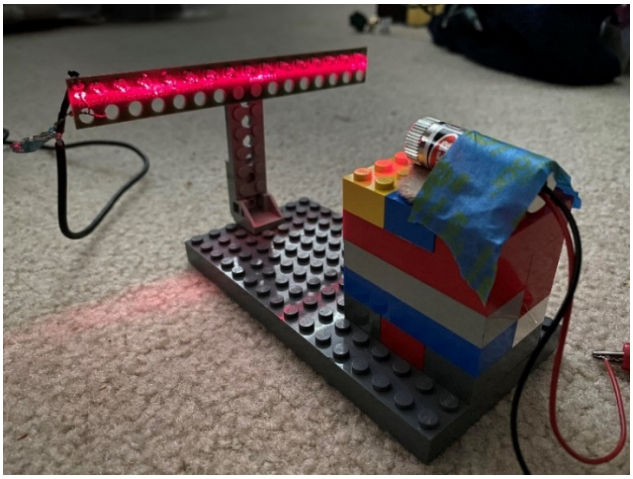


Figure 8. UCR Insect Identification Laser Device Kit (donated by Dr. Eamonn Keogh).

To operate the device, one wears headphones that are connected to a Sony Recorder, which is connected to the sensor array. If something blocks all or part of the beam, the person hears a brief sound (not unlike a thump). If something rapidly blocks/unblocks all or part of the beam (simulating beating wings), one hears a continuous humming sound. We brought an electric toothbrush to simulate insect wings (see Figure 9).

Figure 9. 2015 UCR Insect Identification Laser Device on Display at the 2015 Sacramento STEM Fair.

2.5 UC Davis Picnic Day

In the spring of 2015 the Photonics Club assisted the UC Davis OSA student chapter with their outreach efforts at the school's annual Picnic Day. Five different colored lights were set up on a table, with SPIE diffraction glasses for people to use while looking at the lights. The diffraction glasses would identify all of the individual colors the different bulbs actually emitted, irrespective of what color our eyes perceived. The red bulb emitted just red light, but other colored bulbs emitted two (or more) colors. To me, diffraction glasses are the equivalent of using a set of sieves to separate the larger wavelengths from the smaller wavelengths. And the diffraction glasses cannot be tricked.

We also brought polarizing plastic, CD cases, and three Lego robots. Each Lego robot would go forward, turn left, or turn right if the appropriate sensor was triggered. One robot was equipped with three color sensors, one with three light sensors, and one with three ultrasonic (distance) sensors (see Figure 10). We set up a large First Lego League competition table outdoors for people to operate the Lego robots. (Building four First Lego League tables was an Eagle Scout project.) The robot with the ultrasonic sensors worked great; the other two not at all. Outdoor light is different from indoor light. Who knew! Another learning experience (two makes a trend).

Figure 10. Lego Robots Controlled by Light (Left), Distance. (Middle), and Color (Right).

2.6 Hacker Lab

In 2016 I joined the Sacramento Hacker Lab, which is an all-in-one makerspace, coworking facility, and workforce incubator, full of equipment available for trained members. But I joined to use the laser cutter. For certain events, such as Wood Badge training, I made coasters for all of the staff and the four adult scouts in my troop (see Figure 11).

Figure 11. Laser Cut (and Etched) Wooden Coasters.

Hacker Lab members (and visitors, too) could sign up for a variety of training classes, such as how to solder electronics, or how to operate the laser cutter. Using the laser cutter I made wooden puzzles, coasters, signs, boxes, and a soccer ball.

I made a puzzle for a scout's Eagle Court of Honor (the puzzle was designed by the scout's younger sister). I made 44 puzzles for 44 Dr. Seuss books for a K-8 school's library to help them celebrate Dr. Seuss Day. I also provided colored pens for the children to add color to the puzzles (and have fun). I wanted people to know the laser could make anything they designed (to a point, of course).

The laser cutter made very accurate, very repeatable pieces. I wondered if I could make a soccer ball using the laser cutter. I found a website that gave me the dimensions of the pentagons and hexagons such that the assembled (glued) pieces would make a soccer ball. Individual pieces could be engraved with the coach's name and the names of the players. It worked, and I made two, one for the coach, and one for my son (see Figure 12). By inspection, the dimensions and accuracy was sufficient. In addition, the laser slightly "burned" the edges, which in my opinion enhances the effect.

Figure 12. Laser Cut (and Etched) Soccer Ball.

A simple coaster might take as little as 3 minutes to make. I needed 6 hours to laser cut and etch a scout "Trail to Eagle" puzzle.

2.7 Laser Conferences

Beginning in February 2018 I began attending California-based photonics-related conferences: Photonics West (San Francisco), SPIE Optics+Photonics (San Diego), SPIE Medical Imaging (San Diego), OFC (San Diego), and CLEO (San Jose). At the conferences I would spend all or most of my time in the Exhibition Halls, admiring the equipment set up in the booths and talking to people staffing the booths, looking for ideas applicable to a merit badge and for professional development. In addition, I took courses at some of the conferences, such as "Optiks: Outreach for Professionals who Teach in Informal Environments and K-12 Schools" (an excellent course, and absolutely related to this merit badge effort) and "Principles and Applications of Optical Coherence Tomography" (related to professional development, but which could also assist in this merit badge).

2.8 BSA Wood Badge

In the spring of 2018 I attended Wood Badge, the BSA's intensive 6-day adult leadership training course. In addition to attending the training, each participant had to create, obtain approval for, and complete five "tickets" (or tasks) during the following 18 months. My tickets were related to the Optics/Photonics merit badge. Originally one of my proposed tickets was to convince a photonics company representative to exhibit at Scout Expo, but my patrol guide, Mr. Chuck Brasfeild, changed it: I would be the exhibitor. In retrospect, that was a great decision Chuck made.

2.9 BSA GEC Scout Expo

In October 2018 I served on Scout Expo staff as a photonics exhibitor. The BSA Golden Empire Council (GEC) hosts Scout Expo once every three years. Scout Expo is held at Beale Air Force Base, and typically over 4,000 scouts and adult scout volunteers attend. As an exhibitor, which was one of my Wood Badge tickets, three tables were set up in a large aircraft hangar with hands-on photonics-related activities and displays, including samples of laser-peened metallic parts (donated by Curtiss Wright Surface Technologies), custom laser-cut Scout-themed wooden puzzles created for the event, a portable LCD inspection camera (the camera is mounted on the end of a 1 meter flexible cable and can go into hard-to-reach places), a portable thermometer that measures temperature using infrared, and much more. Nearby in the hangar was a simulated orbiting satellite measuring the Earth's "topography", five different colored lights with SPIE diffraction glasses to use with the lights, UV color-changing beads, and dozens of posters, donated by SPIE, which were laminated and displayed throughout the hangar (see Figure 13). In addition to the posters, many interesting laser magazine articles were laminated and displayed with the posters. The scouts used the infrared thermometer to measure the skin temperature of a fighter jet parked nearby in the sun: 89 degrees Fahrenheit on the shady side, 137 degrees Fahrenheit on the sunny side.

Figure 13. SPIE Posters on Display, 2018 Scout Expo.

For Scout Expo, I contacted a local sheet metal company that could cut metal (1/8 inch thick stainless steel) with a laser. The company designed and made two signs for me for the event. I gave one sign to the council approximately one month before the event; the other sign was on display at the event. In addition to cutting out the letters, the BSA logo was etched in the center of the sign (see Figure 14).

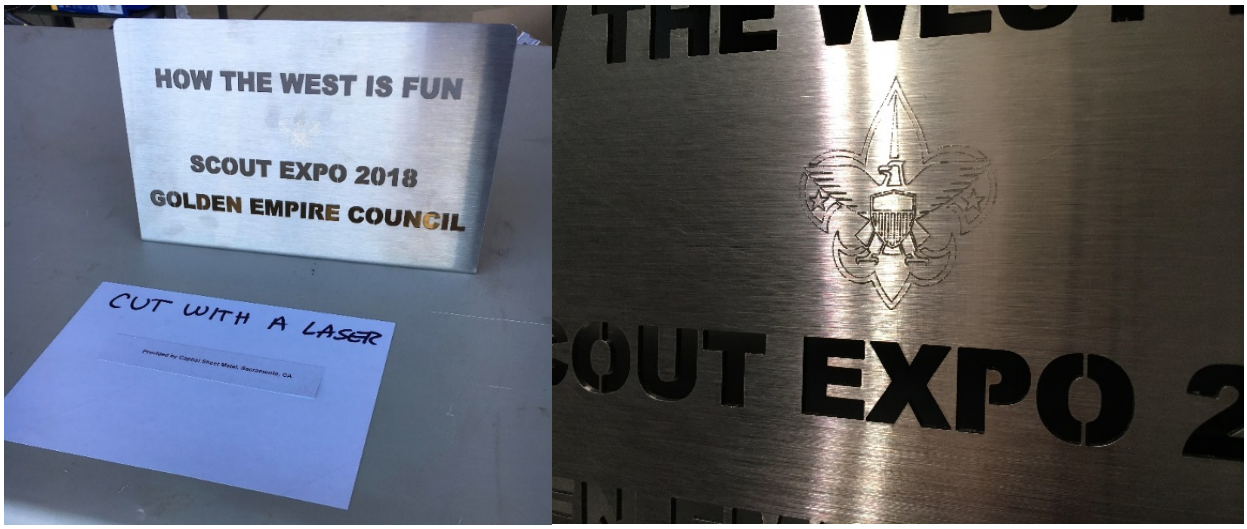


Figure 14. Laser-Cut and Laser-Etched Commemorative Sign courtesy of Capital Sheet Metal, 2018 Scout Expo.

I read an article in the January 2015 edition of the Smithsonian magazine which described a device that was going to be launched to the International Space Station that will measure the height of the earth's trees (the device is called the Global Ecosystem Dynamics Investigation, or GEDI). For Scout Expo I wanted to use modestly priced commercial off-the-shelf laser based products for activities both fun and practical for the scouts to do. Thus, three years after reading the story, I built a simulated orbiting satellite that measures the Earth's topography (the Smithsonian article gave me the idea).

For a modest price (about $50) I purchased a laser-based device that measures distances, mounted it in a wooden slider, and built a track that was supported by two sawhorses. The slider has a right-angle prism, donated by Edmund Optics. Underneath the track were wooden blocks that represented mountains. As the scouts slide the laser device back and forth along the track, the device outputs the changing distance between the track and the top of the wooden "mountains". The device did not always work on wood that had a rough surface texture, which was OK. But the scouts liked playing with blocks, too (see Figure 15).

Figure 15. Simulated Satellite Measuring the Earth's Topography at 2018 Scout Expo; ScoutMaster Carl Block (left).

2.10BSA GEC Klondike

Klondike is the name of a large winter cold-weather camping trip annually held in February near Truckee, California. Ten or more troops are invited. Hopefully there is snow on the ground, but with or without snow the weather is always cold. At the February 2019 Klondike I brought an infrared thermometer and a laser pointer. The scouts measured the temperature of snow, snow at depth, trees, tents, etc. Tunnels were made in three large piles of snow; the laser was used to ensure the tunnels were exactly collinear (simulating using lasers that align tunnels, such as the Chunnel). We were lucky that year: four feet of fresh soft snow was on the ground, not the usual one or two feet of crusty hard icy snow (commonly called Sierra cement). One of the scouts built a snow cave in one of the piles of snow and slept in it.

At the February 2020 Klondike I brought a FLIR IPhone infrared camera. There was almost no snow, but the weather was cold as always. Using the FLIR camera at night, a dark night with clear skies and no moon, a temperature of 25 degrees Fahrenheit and falling, we simulated searching for someone lost at night. Without the camera, one could only see what a flashlight could illuminate close by; with the infrared camera one could easily see someone 200 feet (or more) away.

2.11BSA GEC University of Scouting

In November 2019 the Boy Scout Golden Empire Council held its annual University of Scouting event, an all-day event that provides scouts the opportunity to complete most, or all, of the requirements of various merit badges. The combined title of my two sessions was “Lasers/Take Apart a Microwave! (not a merit badge)”. In the morning, laser concepts were discussed, combined with hands-on photonics activities (as if the material was for a merit badge). One of the activities was to take apart a one dollar laser pointer (the batteries were removed prior to the class). In the afternoon, 14 non-functioning microwaves were provided for the scouts to take apart (12 were disassembled). One scout brought a gigantic built-in microwave to be disassembled. In both the morning and afternoon sessions, scouts had tools in their hands, and learned how things are made or disassembled, very important skills.

3. CURRENT AND FUTURE ACTIVITIES

Many people in the optics and photonics industry have a background in the scouting program as a former scout, an adult scout volunteer, or both. In fact, I have discovered many people earned the rank of Eagle Scout. Coincidence?

I am currently developing photonics-related activities for the proposed merit badge, and activities for Scouts of all ages (first graders to age 17) to do as an individual or at a group scout event. Ideally the materials and equipment needed are safe, easy to obtain, and very low cost.

Or sometimes “no cost”: I made a pinhole camera out of a restaurant To Go plastic container and a pushpin (you can use a needle, a nail, or a drill instead of a pushpin) to make the hole (see Figure 16). The bottom portion of the container was opaque (black), and the top was clear plastic. Change the diameter of the hole and “see what happens”.

Figure 16. Some Sample Pinhole Cameras.

I made pinhole cameras from small and large pvc couplings. On the “pinhole side” of the coupling, I covered the end with a variety of materials: aluminum foil (traditional), the aluminum from the side of a soda can, thin plastic from a clear plastic file folder (painted black – spray paint that adheres to plastic is easily available), thin cardboard from a cereal box,

and 2” wide duct tape. To make the “Image Plane” I covered the other end of the coupling with “matte finish” Scotch Tape, clear plastic (some work well; others do not), wax paper, parchment, and a Ziploc baggie (see Figure 17). I bought ½”, ¾”, 1”, 1-1/4”, 1-1/2”, and 2” pvc couplings and pvc caps (caps can be used, and are superior, but the pinhole must be made with a drill). I also added short sections of pvc pipe to the cap to lengthen the camera’s “focal length”. If one gently assembles the pipe to the cap, one can easily disassemble the two pieces and install a pipe with a different length (to change the focal length again).

Figure 17. PVC Coupling and PVC Cap Pinhole Cameras (no Scotch Tape on Cap for Clarity)

Then I thought of simulating the ocelli found in some insects, such as a housefly. Their eyes are faceted. So I made a “multiple pinhole camera” to see the world “as an insect sees the world” (see Figure 18).

Figure 18. Multiple Pinhole Camera Under Construction (left), Object (Middle), and Image (Right).

When using a pinhole camera, try shining a powerful flashlight(s) on different objects. Shiny plastic containers with shiny colorful labels reflect light well. The flash drive worked, too, just not as well (see Figure 19).

Figure 19. Pinhole Camera Object and Image (Hand Sanitizer Only).

From a 12-pack box, I made what I refer to as a Light Box. I placed a 500 lumen flashlight inside the box and pointed it at the upside-down object (which was graciously given to me at the 2020 Photonics West conference). Close to the flashlight are three $1 magnifying glasses taped together, although one can use more (see what happens). To focus the image, slide the box closer or further away from the image plane (the wall) until the image is in focus. Try different objects; vary the size, color, and surface finish (see Figure 20).

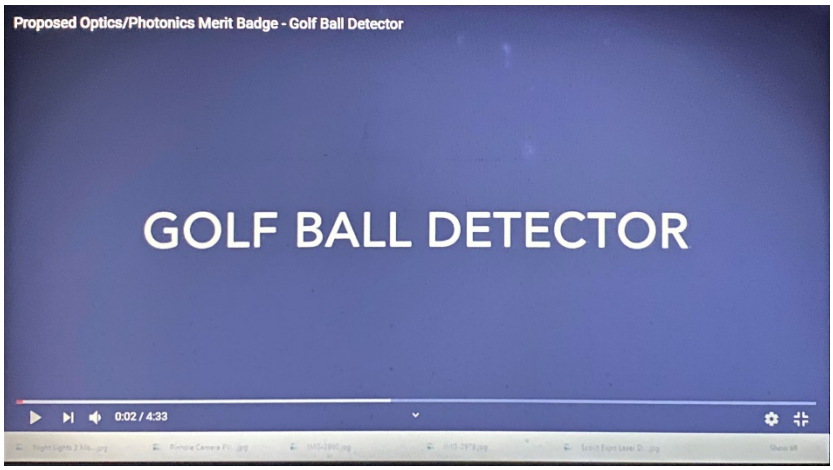
Figure 20. Light Box with Three $1 Magnifying Glasses and a 500 Lumen Flashlight.

Using a $2 night light, a $3 hot melt glue gun, and an old plastic pipe I made a "proof of concept" golf ball detector. "When I was growing up …" I played miniature golf. If someone made a hole-in-one on the 19th hole, one would win a free pass (no doubt an electro-mechanical device triggered the alarm). I simulated this with a night light and flashlight. When a golf ball slowly rolls down the pipe, it momentarily blocks the light from the flashlight. When it does, the light flashes on. A future version will have multiple night lights on the pipe. Thus, one can track the ball's progress. I made this using a flashlight instead of a laser light to make it safe for all ages (see Figure 21).

Figure 21. Night Light Detects a Golf Ball Rolling Slowly in a Pipe.

I built the future version – and it works well, provided one uses an appropriate light source. The powerful flashlights were replaced with solar-powered rechargeable outdoor night lights, which fit perfectly in a 1-1/2" pvc coupling, and the LED night light was used instead of the incandescent bulb (see Figure 22 and Video 1).

Figure 22. LED Night Light (left) Detects a Golf Ball Rolling Slowly in a Pipe.



Video 1: "Proposed Optics/Photonics Merit Badge – Golf Ball Detector". https://www.youtube.com/watch?v=tfSeajR1xZY

I noticed that a laser pointer's laser beam was simultaneously reflected, absorbed, and transmitted through a banana split banana boat's plastic. I thought they might nest rather well (yes), and I happened to have four at hand from a recent visit to an ice cream parlor. The test was successful (a rare event, and appreciated). I bought 50 plastic banana boats ($11 from Smart & Final), which would normally be used to make 50 banana splits, but I had a better use for them.

After I found out that the plastic sheets must be parallel and evenly spaced (although it still works), I glued the boats together separated with short 3/16" wooden dowels. I glued the dowels to the plastic using ordinary Elmer's glue (which is safe and water-soluble, and did not work "long term", but that's OK – safe failure can be good). I glued two, four, eight, and 15 boats together; one can stack them like blocks. I call the images "Reflections of Reflections" (see Figure 23).

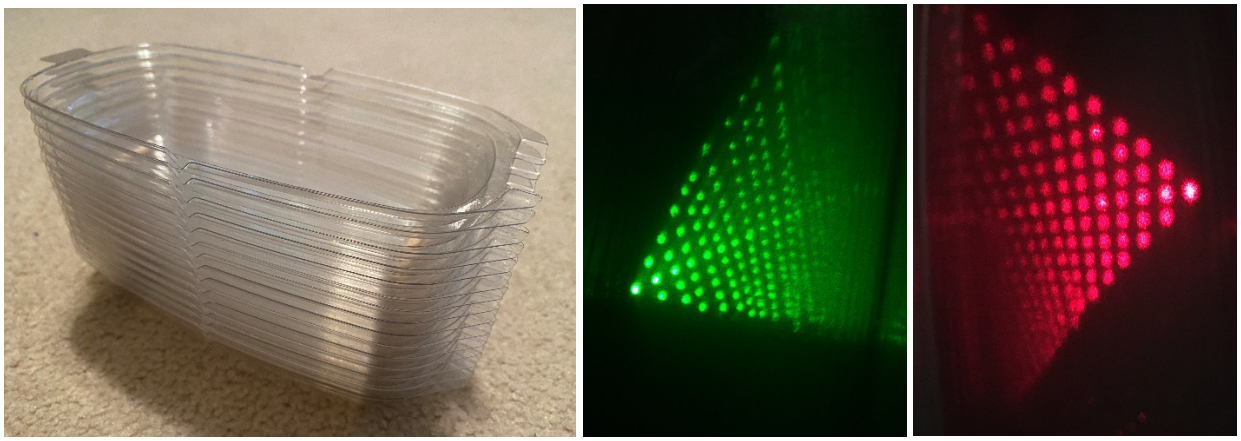


Figure 23. Reflections of Reflections Using 15 Plastic Banana Split Boats and Two Laser Pointers.

I am making and posting instructional YouTube videos using my IPhone's pictures and videos, utilizing the IPhone's IMovie app. My most important future video will explain how a laser works by playing a special game of soccer.

We attached a relatively inexpensive drone to the top of a radio-controlled truck. The scouts drove the truck on an obstacle course while wearing the drone's goggles – they could only see what the drone could see. This allowed the scouts to drive the obstacle course as if they were actually inside the truck. This was somewhat costly, but our troop also used the drone and goggles at a "Drone Day" (see Figure 24).

Figure 24. Drone Mounted on RC Truck and Troop 281's 2017 Drone Day.

One of the most rewarding activities of all occurred the day I brought an infrared camera into Ms. Trevino's seventh grade science class. The camera, a FLIR One Pro IPhone infrared camera, attaches to the bottom of an IPhone, and allows one to see the world in infrared. One can take pictures and video. I loaned the students the phone. That was by far the most expensive tool I purchased for this effort, but it was the most cost-effective in generating fun and enthusiasm. The students examined everything in the classroom, and posed for a group photo (see Figure 25).

Figure 25. Infrared Picture of Ms. Trevino's Science Class Students (2018)

4. RESULTS AND CONCLUSIONS

Based on the previous outreach efforts described above, and the many efforts conducted by others, it is apparent that optics and photonics generates interest, excitement, and enthusiasm from students, teachers, and parents; thus, one could predict this merit badge will succeed. When materials and hand tools are put in hands, especially hands that have possible barely used hand tools, learning, experimentation, creativity, satisfaction, and fun almost always result.

I am reminded of a passage in the book "City of Light the Story of Fiber Optics", in which the author is describing the work of two researchers, Dr. Peter Schultz and Dr. Donald Keck, who in 1967 were trying to create new glass fibers with far less optical losses. They had to deposit soot inside a glass fiber: "The soot couldn't go down the ¼-inch (6-millimeter) hole because no air was flowing through it. They needed to get air flowing down the tube to carry the soot and coat the inside uniformly. The frustrated pair looked around Schultz's lab, and their eyes fell on an old General Electric canister vacuum sitting in a corner, which Schultz used to clean up the mess inevitable in a glass lab. Inspiration struck…The vacuum didn't survive the nasty mixture of chemicals in the burner exhaust, but it did achieve a breakthrough."[5]

It is my hope that thousands of scouts learn knowledge and skills by "doing things" (by doing these merit badge activities), then later apply those skills to solve current and future technical challenges, either improvements or breakthroughs. Sometimes the simplest solution is the best.

I recommend the merit badge graphics be colorful, simple, and easily understood. To assist in this effort, I wish to highlight some examples below. Figure 26 very likely contains my favorite graphic of all time.

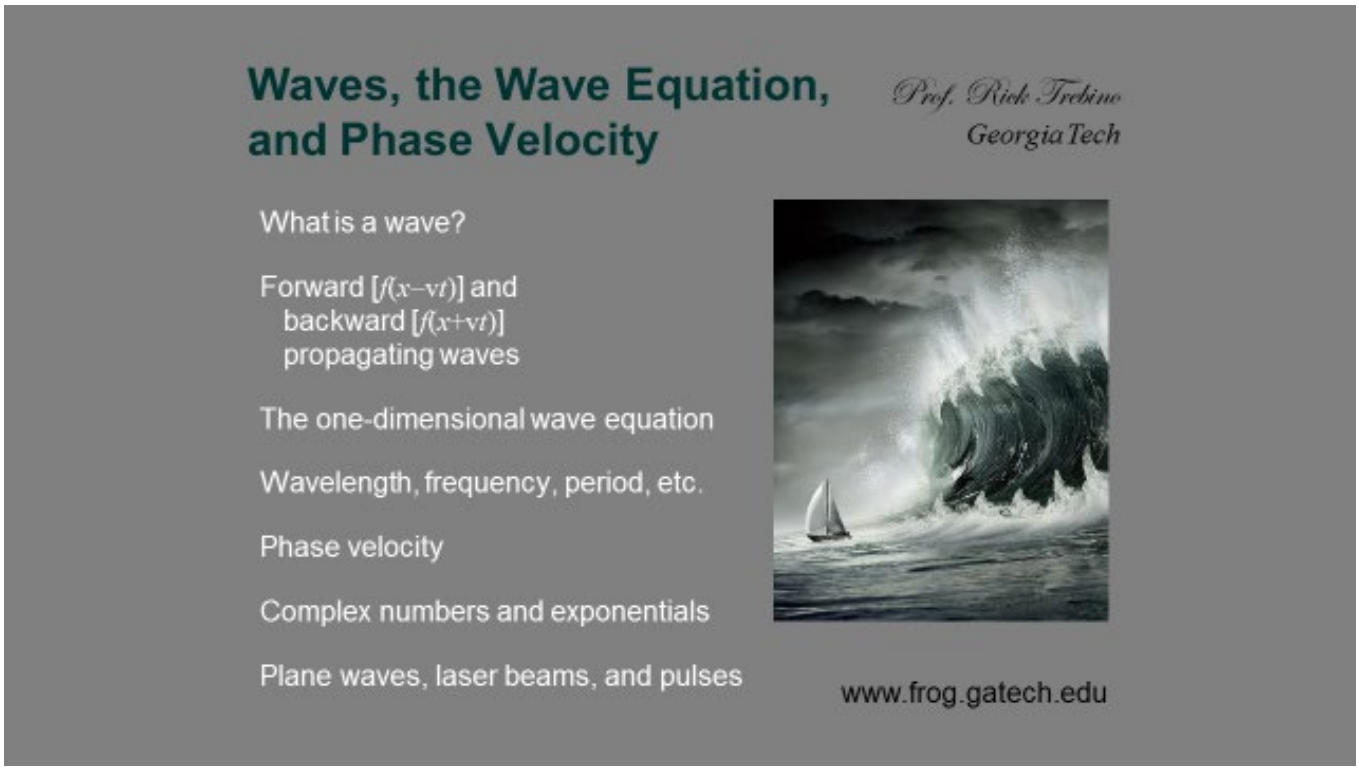


Figure 26. PowerPoint Slide Courtesy of Professor Rick Trebino of Georgia Institute of Technology

Figures 26 and 27 could be included in the merit badge to help people understand why they see a broad swath of color while looking at incandescent light bulbs when wearing diffraction glasses.

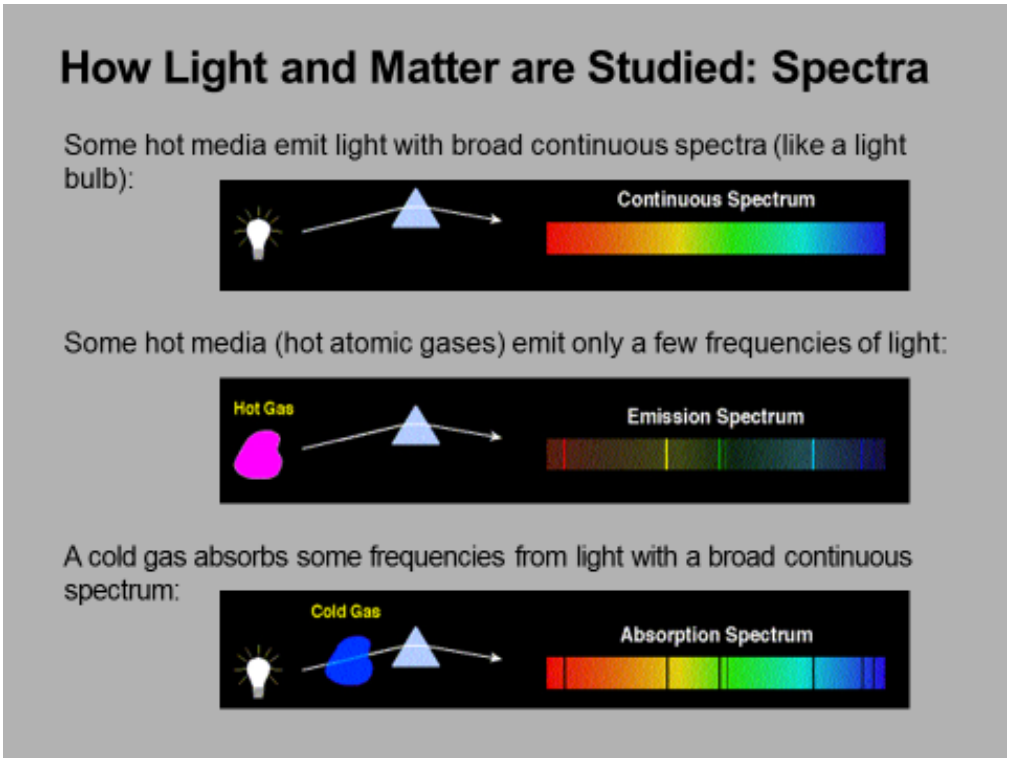


Figure 27. PowerPoint Slide Courtesy of Professor Rick Trebino of Georgia Institute of Technology

Five years ago I contacted Professor Emeritus Stephen Jacobs to buy Night Spectra Quest charts. The chart is good for examining the spectra of various light sources, which are unfortunately increasingly hard to find. Scouts could play a COVID-friendly game at home: each scout is given a Night Spectra Quest, then asked to take pictures using a cell phone when holding the cell phone lens close to the Night Spectra Quest "lens" (a diffraction grating). Many categories to earn points: most/least colors in one picture, most interesting, etc. (see Figure 28). They might get lucky and find a neon sign.

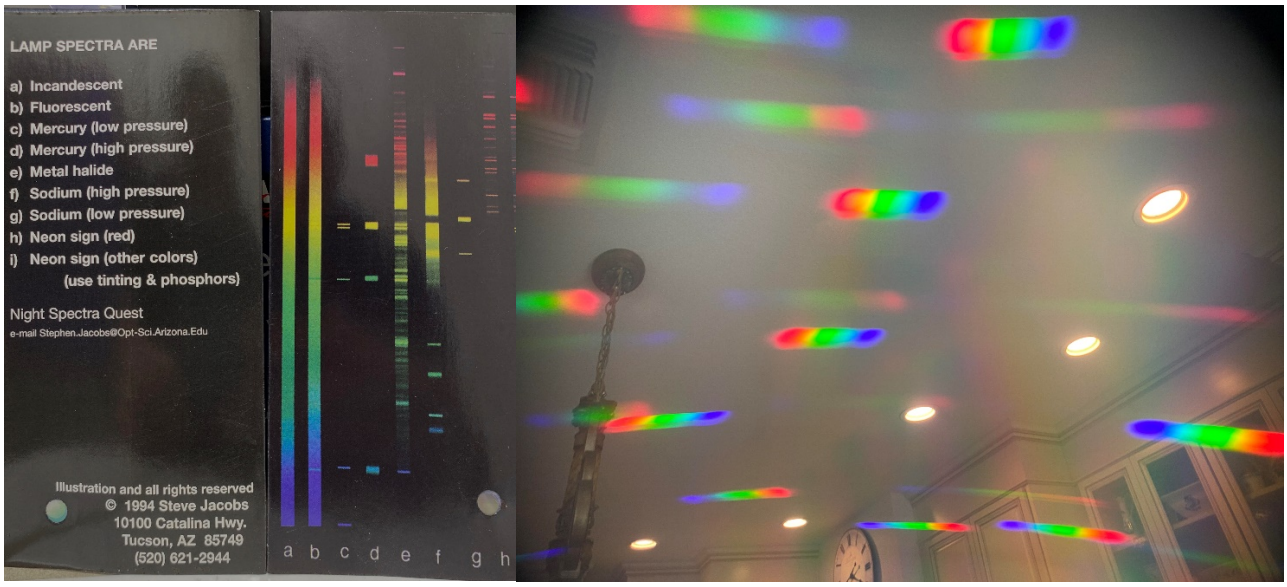


Figure 28. Night Spectra Quest and Picture of LED Kitchen Ceiling Lights.

If I had to bring one book to teach a scout the fundamentals of optics and photonics it would be "Light Introduction to Optics and Photonics", written by Judy Donnelly and Nicholas Massa[3]. If I wanted to show scouts a video to help explain the fundamentals of lasers, I would recommend Professor Shaoul Ezekiel's "Laser Fundamentals" videos available on MIT OpenCourseware[4]. Abundant resources are currently available to help write the merit badge book, including documents, graphs, charts, tables, images, videos, and ideas from Optec, SPIE, OSA, Edmund Optics, Professor Stephen F. Jacobs, and Professor Rick Trebino of Georgia Institute of Technology, among many others. In addition, I want to mention SPIE has made a booklet titled "Photonics Technical applications of light Infographics", which contains many graphics that could be pasted directly into the merit badge book. An Optics/Photonics merit badge could possible multiply the exposure of the work and resources noted above by orders of magnitude. Lastly, SPIE recently awarded me an Educational Outreach grant, which is greatly helping me in my current and future merit badge and outreach efforts.

I will continue to work with my local scout troop to test activities and ideas for the proposed merit badge. There are many ideas to be tested, and many fail (or need adjustments/modifications), and many times each test results in additional ideas! For instance, the "Simulated Satellite Device" (refer to Figure 15) measured a single "row" of topographic data. If the device measured topography (e.g., blocks of wood) in a matrix pattern, after manually inputting the data into Excel, Excel can display the raw data in a 3D graph, which brings the data to visual life. A possible next step could be to use blocks painted different colors, add rough texture to the blocks (fabric), include a dish of water, (a surface that might not work!), and create a contour plot from the data (see Figure 29).

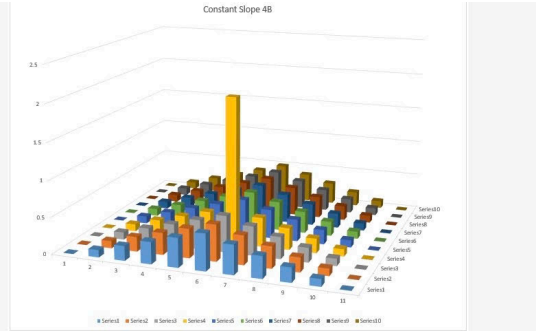


Figure 29. Excel 3D Chart of Simulated "Hill with a Tower" Topography Data.

In addition, the proposed merit badge book can include "hard copy" printed graphics, links to graphics (or videos), or both. The merit badge book is traditionally only hard copy; however, there are now on-line video links for four merit badges (Animation, Cooking, First Aid, and Robotics). So it has been done, and this merit badge can take this to the next level. This merit badge should take advantage of the widespread availability of computers with the preponderance of recent on-line public school instruction.

During the summer of 2021, I hope to present the "Proposed Optics/Photonics" merit badge at a scout summer camp, and staff an Optics/Photonics merit badge booth at the 2021 BSA National Jamboree at the Jamboree's Merit Badge Midway. The Scout National Jamboree is 10 days long, occurs once every four years, and 40,000 scouts and adult scout leaders usually attend. However, as of July 14, 2020, the National Jamboree has been postponed with no announced rescheduled date. Regardless, when the Jamboree does occur, I want the Optics/Photonics merit badge to be there, as a proposed merit badge or the Scouts BSA newest merit badge.

The requirements for this proposed merit badge could be determined by a committee of optics and photonics educators, scientists, engineers, technicians, and organizations such as SPIE, OSA, Optec, and others.

To better understand the merit badge process, I used the current merit badge requirements for the Astronomy merit badge as a template for the proposed Optics/Photonics merit badge requirements. The list is incomplete (by design).

It should be noted this has been my personal effort to date, but I would welcome making this effort official.

Proposed Optics/Photonics Merit Badge Requirements

1. Do the following:

> (a) Explain to your counselor the most likely hazards you may encounter while participating in optics and photonics activities, and what you should do to anticipate, help prevent, mitigate, and respond to these hazards.

(b) Explain first aid for injuries or illnesses such as burns and damage to your eyes that could occur during observation.

(c) Describe the proper eyewear, clothing, and other precautions for safely conducting optic and photonic activities.

2. Explain how a laser works.

3. Do each of the following:

(a) Describe a medical application of a laser.

(b) Describe a manufacturing application of a laser.

(c) Describe a measurement (metrology) application of a laser.

(d) Describe an application of a laser in communications.

4. Do the following:

(a) Make a sketch of a convex lens. Show the light rays entering and exiting the lens.

(b) Make a sketch of a concave lens. Show the light rays entering and exiting the lens..

(c) Describe at two materials used to make lens. What are their advantages and disadvantages when compared?

5. Do the following:

(a) While wearing diffraction glasses, describe what you see (Do not look at the sun!)

(b) Watch an educational optics or photonics video on the website of a scientific organization. Describe what you watched.

(c) Demonstrate reflection using a flashlight and a mirror.

(d) Make a pinhole camera, and take a picture of the image.

6. TBD …:

(a) Scratch and dig.

(b) Describe why optical components must be handled with care

(c) TBD

(d) TBD

7. Define…:

(a) The International Year of Light.

(b) TBD

(c) TBD

8. With your counselor's approval and guidance, do ONE of the following:

(a) Virtually attend a (previous) scientific conference and watch a presentation (this needs to be done with the approval and cooperation of the conference host, such as SPIE, OSA, or another similar organization). Note: either utilize existing interviews, pictures, and videos of previous conferences, or create one from scratch targeting young people. For instance, I took pictures and videos of the March 2020 OFC conference "Celebrating 50 Years of Light-speed Connections" display. This is a chance to exponentially increase the display's exposure.

(1) Describe the activities occurring there

(2) Describe the exhibits and displays you saw

(3) Describe the equipment and other instruments you saw on the Exhibition Floor

(4) Describe what you liked best

(b) Build

(c) TBD (can include a video link).

(d) TBD

9. Find out about three career opportunities in optics and photonics. Pick one and find out the education, training, and experience required for this profession. Discuss this with your counselor, and explain why this profession might interest you

REFERENCES

[1] https://boyslife.org/merit-badges/
[2] https://blog.scoutingmagazine.org/2019/02/11/2018-merit-badge-rankings-a-deep-dive-into-the-official-numbers-from-1-to-137/
[3] Donnelly, J. and Massa, N., "Light Introduction to Optics and Photonics", Laurin :Publishing Co. Inc. (2018)
[4] https://www.youtube.com/watch?v=saVE7pMhaxk
[5] Hecht, J., "City of Light the Story of Fiber Optics", Oxford University Press, New York & Oxford, 136-137 (1999)