Part 1: Registration

Created: 03/27/2018 • Last updated: 05/26/2018

Please complete this form to register as an official nominee of the 2018 Broadcom MASTERS competition. The content in Part 1 is not used in evaluation. Please note that this section contains a second page.

Student/Parent Information

STUDENT INFORMATION

* Required Field

Student First Name*	Su
Student Middle Name	(No response)
Student Last Name*	Kara
Student Preferred Name/Nickname	(No response)
Student Email Address*	su.kara@gmail.com
Student Phone Number (xxx-xxx-xxxx)	949-395-7845
Date of Birth (mm/dd/yyyy)*	11/26/2003
Sex	Female
Ethnicity	Not Hispanic or Latino
Race	White
T-shirt Size (adult sizes)*	Small
If you are selected as one of the Top 300 MASTERS or 30 finalists, do we have permission to share your contact information with your members of Congress?*	Yes

Mailing Address

Street Address 1*	25541 Aria Dr
Street Address 2	(No response)
City*	Mission Viejo
State*	CA
Zip Code*	92692

PARENT/GUARDIAN INFORMATION

This information will be used after the application has closed. You may enter the same adult listed in the Designated Adult section, or you may choose a different parent or guardian.

Parent/Guardian First Name*	Yilmaz
Parent/Guardian Last Name*	Kara
Parent/Guardian Relationship to Entrant	Father
Parent/Guardian cell phone number (xxx-xxx-xxxx)*	949-395-3053
Parent/Guardian home phone number (xxx-xxx-xxxx)	949-829-8081
Parent/Guardian Email Address*	ykara@hotmail.com
*If you are applying from one of our DOD fairs, please enter a US phone number above and your international phone number here	(No response)

Teacher/Science Fair Information

SCHOOL INFORMATION

Name of Current School (2017/2018 academic year)*

*If your school is not listed, please email **masters@societyforscience.org** with the name and address of your school and we will add it to the list. You can search for your school by typing in the name or the zip code. Home schooled students should select "Home School."

Newhart Middle School, Mission Viejo, CA, 92692

Type of School* Public

School Address

Street Address 1*	25001 Veterans Way
Street Address 2	(No response)
City*	Mission Viejo
State*	CA
Zip Code*	92692

Identify the teacher who has most supported your science or engineering project. This teacher MUST be a middle school teacher, a middle school informal science program educator, or a middle school homeschooling instructor. Your teacher receives application reminders and notifications from The Society, and receives notification if you are selected as one of the 30 finalists or Top 300 MASTERS. This teacher will receive awards if you advance to the Top 300 MASTERS or finalist level. You will not be permitted to change the teacher listed here after the application deadline.

Teacher Information

Teacher Prefix	Mr
Teacher First Name*	James
Teacher Last Name*	Wenk
Teacher Email Address*	jgwenk@capousd.org

Principal Information

Title	Principal
Principal First Name*	Jeff
Principal Last Name*	Jones
Principal Email Address*	jjjones@capousd.org

SCIENCE FAIR INFORMATION

You were nominated for the Broadcom MASTERS by USCA01. Did you receive a second nomination from another science fair?*

No

Is this a team project?*

No

Just a friendly reminder: each member of a team project needs to submit his/her own independent application in his/her own words.

If you worked on a team, please list the name(s) of your team member(s). If you did not work on a team, please leave this question blank.

	First Name	Last Name
Team Member #1		

	First Name	Last Name
Team Member #2		

Are you an alumnus of the Broadcom MASTERS program?*

This is my first year receiving a nomination! (Awesome!)

Part 2: Project Information

Created: 03/27/2018 • Last updated: 05/26/2018

This is your chance to tell us about your awesome science or engineering project in your own words. If you are feeling stumped, take a look at your science fair board for inspiration. This section is designed to feel like a judging interview at your science fair.

Project Title/Team info

Select a category that best describes your project*:

These categories might differ from the categories at your local science fair. Here's a helpful hint to help you choose: think about what type of scientist or educator would best understand your project.

Mathematics

Project Title* This is how your project title will appear in our materials if you are select to the top 300 or top 30.	Proof of Pappus Theorem with Circle Inversion by Developing an Open Source Software Application
What is your current grade (2017/2018 academic year)*?	8th
Remind us, is this a team project*? Just a reminder that each member of a team must submit his/her own application in his/her own words.	No

What was the inspiration for your science or engineering project? Please describe if there was a personal experience, challenge or individual(s) that inspired your choice of this project.* (max. 100 words)

I love math and computer science, so I looked for a challenging project that would let me learn a lot in both areas. Since I would be taking geometry in 8th grade, I focused on subjects in that field of mathematics. I came across a geometry problem that could be proved with the use of circle inversion. While studying circle inversion, I learned that it could be used to prove Pappus' theorem as well. I decided to develop an open-source software application to simulate circle inversion and prove Pappus' theorem.

Project Reflections

TELL US ABOUT YOUR SCIENCE FAIR PROJECT

What was your research question? For engineering projects: what was the human need or problem you wanted to solve?* (max. 50 words)

Pappus' theorem states that the height from the center of the nth inscribed circle in the Pappus chain is equal to n times the diameter of that circle. How can I use circle inversion to prove such a complex theorem by visually showing similarity (homothety) between circles and their inversions?

What was your scientific hypothesis or engineering design criteria?* (max. 125 words)

If I develop a software application to invert circles, I can use it to invert the circles in the Pappus chain. If I can also show similarity between the original circles and their inversions, I can visually prove Pappus' theorem. Therefore, it needs to have graphics features to draw points, lines, circles, and semicircles. Since I want to share this tool with everyone, it should be a web application that runs in a browser on any device.

Explain your methodology and procedures for carrying out your project in detail, addressing the questions below. *

For engineering projects, explain your methods and procedures for building your design, addressing the questions below (max. 400 words).

1) How did you collect your data? For engineering projects, how did you build your design?
2) What were your testing procedures? For engineering projects, how did you test your design?
3) Discuss your control group and variables tested. For engineering projects, discuss the controls and variables tested in your design.

1) I used a MacBook Pro to develop a web page in HTML5 and JavaScript. I wrote the source code in Brackets, an open-source text editor. This web page serves as a generic tool to simulate circle inversion and to draw a Pappus chain. The application can be used to invert a point or a circle with respect to an inversion circle. It can also be used to create a Pappus chain, invert the circles and semicircles, and show homothety between the circles in the Pappus chain, and their inversions.

2) I tested and debugged the software in the Safari browser on a MacBook Pro. I also used an iPad and an iPhone to verify that it worked on other devices properly. I created several test cases for different circle inversion scenarios. For inversion of a point, the point could be inside or outside the circle, on the circle, or at the center. For inversion of a circle, the circle could be passing through the center or not, concentric, or orthogonal. For a Pappus chain, the chain of circles could be on the left side, right side, or both sides. I created templates for each test case so that the user can easily load it with the click of a button. The user can either load a predefined template, or enter custom values to run their own inversions.

3) I used the following variables in my design and tests:
Controlled Variable: Inversion Circle (blue color)
Independent Variable: Original Point/Circle to be Inverted (green color)
Dependent Variable: Inverted Circle/Line (red color)
The inversion circle is the controlled variable because its parameters are kept fixed in the provided templates.
The original point/circle is the independent variable because its parameters change in each of the provided templates.
The inverted circle/line is the dependent variable because it is the outcome of each inversion.

How did you analyze and interpret your data?* (max. 300 words)

Use this section to write about the process of analyzing and interpreting your data. You will have an opportunity to share charts, tables, graphs, photos, etc. containing your data in a ONE (1) page PDF document later in this application. For engineering projects, this question still applies. Tell us HOW you formed your conclusions through observation and any special analysis used.

Each original circle in the Pappus chain and its inverted circle between the lines are homothetic with the center of homothety being the center of the inversion circle. Connecting the center of homothety to the center of original and inverted circles will create similar triangles.

Let d be the diameter and h be the height from the center of the original circle n in the Pappus chain. Similarly, let d' be the diameter and h' be the height from the center of its inverted circle between the lines. Since the circles between the lines are identical, we can easily observe that:

$h'/d' = n$

From similarity:

$h/d = h'/d'$

Therefore:

$h/d = n$

or

$h = n.d$

This simply proves Pappus' theorem, which states that the height from the center of the nth inscribed circle in the Pappus chain is equal to n times the diameter of that circle.

What conclusions did you reach? Why? How does your data support this conclusion?* (max. 250 words)

Circle inversion can be used to solve difficult problems such as proving Pappus' theorem by visually showing similarity between circles and their inverted images. However, it may not be trivial to see the inversion without proper drawings and calculations.

Since it wasn't practical to draw circles with various sizes and calculate their inversions on paper, I decided to develop a computer program with graphics features to draw basic shapes such as points, lines, and circles. This program let me simulate circle inversion and Pappus chain visually, while also showing the calculations.

I developed a web page in HTML and JavaScript with client-side coding. It runs in the latest browsers on all computers and mobile devices. I share this software application as an open-source tool with anyone interested in math, and specifically in circle inversion and Pappus chain. Please feel free to use the application and get the source code from my web page at http://sukarablog.weebly.com.

TELL US WHAT YOU LEARNED FROM YOUR PROJECT

Did questions or problems arise that you were not expecting? How would you adjust your experimental design or your engineering design process to address these problems?* (max. 150 words)

On a standard coordinate system in math, (0,0) is the bottom-left corner, and the y-coordinate increases as you move up. I quickly realized that a computer screen designates the top-left corner as (0,0), and the y-coordinate increases as you move down. Therefore, I converted the y-coordinate in my program by subtracting its value from the canvas height right before drawing a shape. This conversion made the canvas look more consistent with a math coordinate system.

I was planning to develop a server-side application in Java. However, I experienced three problems with it:

1) It was hard to host server-side Java code for free
2) I had to share my open-source Java code on a different website
3) Running the Java code in an applet caused security issues in the browser

Therefore, I developed a web page in HTML and JavaScript to solve all three problems at once.

Where did you conduct your experimentation?*

Please select all that apply.

A science or engineering project is never a solitary activity. Tell us who contributed to your research and what resources did they bring to your project:* (max. 250 words)

- Where and how did you conduct your research? What special equipment did you use?
- Who supervised and/or collaborated with you on your research (i.e. parents, teachers, mentors, peers?) What were their contributions?
- Were there others who helped you perform your research who you wish to tell the evaluators about?

I conducted almost all of my research at home. I used a MacBook Pro to do extensive online research about circle inversion, the Pappus chain, and web programming in HTML and JavaScript.

Mr. James Wenk, my geometry teacher, helped with circle inversion and homothety. He showed me the related concepts on dilation and similarity in our common core geometry book.

Last summer, I took online computer programming classes from Stanford University. I learned Java programming through those classes, but I didn't know how to share such a program with other people. I got the idea of developing a website as it would be easier to share my tools with the online community and even offer the application as an open-source software. Since I didn't know anything about web programming, I did a lot of online research to learn about website development. The W3Schools website helped me learn HTML and JavaScript with their sample code and test pages. I also learned how to debug my JavaScript code by using the Safari browser's developer tools. In summary, I designed, developed, and tested the software myself.

What did you learn from conducting and presenting your science fair project?* (200 word maximum)

Please consider addressing the following points in your answer:

- What lessons did you learn from doing your project?
- What lessons did you learn from presenting your project?
- What question would you ask next or engineering project would you pursue if you chose to continue exploring this topic?

When I started the project, I had no idea about circle inversion or the Pappus chain. First I had to learn these math concepts in detail. Although I learned Java programming through online classes last summer, I didn't know anything about web programming. So, I had to learn HTML and JavaScript to build my web page. It took me six months to finish this project, but it was worth every minute of it.

Presenting my project was more fun that I thought. I loved sharing my experience with other people. Squeezing everything into eight minutes was a challenge, but the judges were very kind and supportive throughout the interview.

This project builds the basis for inverting a point or a circle with respect to an inversion circle. However, it can be extended to the inversion of other shapes to analyze the effects of circle inversion. It can also be improved to invert shapes and objects with respect to a sphere in 3-D since most of the equations will be very similar to 2-D.

If you were a member of a team project, please explain your role in researching, developing and presenting your project. Describe how work was divided among your team. (max. 150 words)

(No response)

Part 3: Essay Questions

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This section provides you with an opportunity to tell us more about you and your thoughts about science, technology, engineering and math (STEM) as they relate to your project and in general.

Select one (1) question in each of the three sections: About My Project, About Me, and Solve a Problem, then compose your answers in the resulting text boxes.

About My Project (please select ONE question, then answer in the text box below): Submit an abstract for your project (250 words or less).

About My Project:

Arbelos is the region bounded by three semicircles where two of them are inside the third one. The semicircles share the same diameter line, and they’re all tangent to each other. Arbelos was named for its similarity to a knife used by shoemakers in ancient times.

Pappus chain is the chain of circles inscribed in the arbelos. Pappus of Alexandria proved a theorem in the 4th century A.D., which states that the height from the center of the nth inscribed circle is equal to n times the diameter of that circle. Pappus used Euclidean geometry to prove his theorem. Jakob Steiner invented circle inversion in the 19th century, which made life easier to prove complex theorems.

I created a web page with graphics features to simulate circle inversion. It displays three tabs to invert a point, to invert a circle, and to create a Pappus chain, invert its parts, and show homothety. The user can either load a predefined template, or enter custom values to run their own inversions.

I proved Pappus' theorem by visually showing similarity between circles in the Pappus chain and their inversions. It runs in the latest browsers on all computers and mobile devices. I share this tool as an open-source software application with anyone interested in math, and specifically in circle inversion and Pappus chain. Please feel free to use the application and get the source code from my web page at http://sukarablog.weebly.com.

About Me (please select ONE question, then answer in the text box below): If you could enhance one of your senses, which would you choose to enhance and why? (max. 250 words)

About Me:

If I could enhance one of my senses, I would choose eyesight. In my opinion, sight is the most important sense of all, and it could be improved by using special lenses. These lenses could have several features such as zooming in and out to see tiny details or distant objects. One day they could serve as a personal microscope or telescope.

These special lenses can play a movie by projecting it onto another device or creating a hologram. They may also pass the image directly to the brain without using an external device.

These lenses can record and replay anything that I have seen. They can be controlled with some special movement of the eyes or a remote control device such as a phone. Since they will record everything, I can easily scroll through my visual history. They can even serve as a witness tool in court cases. Although this may cause privacy concerns, the benefits will outweigh the disadvantages.

Solve a Problem (please select ONE question, then answer in the text box below):

Today the majority of Americans are outfitted with a variety of sensors- from pedometers on our wrists to accelerometers and gyroscopes in our phones. How might you use sensor data to estimate the total mileage traveled on foot by the population of the United States per year? Where might errors arise in this method of analysis? (max. 300 words)

Solve a Problem:

I would attach several sensors into the insole of a shoe. These sensors will:

1) Count the number of steps with a pedometer
2) Identify a swinging foot with a pressure sensor
3) Identify running, jumping, or climbing with a gyroscope
4) Measure the speed with an accelerometer
5) Calculate the total distance traveled on foot

However, it wouldn't be practical to use this insole in every shoe of all Americans. Therefore, I need to try it on a test group that would represent the whole population of the United States.

I have to calculate the total mileage traveled on foot by the test group for one month. I will take the average of the whole group and multiply by 12 to get the total mileage per year.

There may be technical issues with the insole in identifying different styles of walking. Some people walk on their toes, while other drag their feet. Dancing may not be easy to calculate either.

Major errors may arise from the selection of the test group as it may not be a good representation of the whole population. The test group must be made up of a large number of participants from different states, age groups, education levels, income levels, genders, urban, suburban, and rural communities.

Part 4: Personal Interests

Created: 03/27/2018 • Last updated: 05/27/2018

Tell us a about yourself as an individual, apart from your science fair project and your thoughts on science or engineering. Share information that will help us get to know you better.

Check activities in which you are currently or have been involved: Check all that apply	Art Club
	Athletics
	Music (instrument or choir)
	Community Service (where?): Math for Service, Mission Viejo International Wheelchair Tennis Tournament
	Science/Math Olympiad
Which instrument? (select all that apply)	Other, please specify...: Singing
Which sport? (select all that apply)	Tennis

What hobbies or extra-curricular activities do you most enjoy and why? (max. 100 words)

I have been playing tennis for eight years and participate in the USTA Open level tournaments. I prepared for Math Olympiad and AMC exams at Ardent Academy for five years. I attended Renaissance Art Academy for four years to complete all levels from drawing to oil painting. I love singing, and made over sixty cover songs in my YouTube channel. I completed the Youth Leadership Program provided by the Math for Service organization. I volunteered at the All Girls Math Tournament and I will keep working with them to expand their activities worldwide.

Tell us about a time you worked in a team. In your opinion, what is the most important trait of a successful team? (max. 150 words)

I attended the Youth Leadership Program of the Math for Service organization. We worked together for eight weeks to organize an Open House event. The goal of this event was to introduce the Math for Service organization to the community and to have an award ceremony for the volunteers based on their service hours. We also had a senior send-off and a college panel to share their special experiences with Math for Service and how it helped them with their college applications. I quickly realized that the most important trait of a successful team was strong leadership. Luckily the program was led by powerful leaders who gave clear directions throughout the whole process. We had several brainstorming sessions where we shared our ideas and came up with solutions that none of us could do on our own.

Is there additional information that you wish to share with the judges to help them better know you as an individual and what is personally important to you? Future goals, favorite topics, accomplishment of which you are most proud, etc.-- this is your chance to share anything (max. 100 words)

I would like to share with the judges an important lesson that I learned in a book called Mindset by Carol S. Dweck. It taught me how to develop a growth mindset as opposed to a fixed one. With a growth mindset, success is about going out of your comfort zone to learn something new. On the contrary, success is about proving you are smart for a fixed mindset. Effort makes you talented in a growth mindset, while it means you are not talented in a fixed mindset. Therefore, I decided to develop a growth mindset and keep improving myself.

Which one of the following STEM careers are you most interested in pursuing?

Please note-- careers will display below in random order. To find a specific career, click inside the box and type the name. If it's included in the list, the career will appear in blue.

Computer Scientist

Why does this career interest you? (max. 100 words)

I have always loved math and studied advanced subjects to prepare for Math Olympiad and AMC exams. Last summer, I learned programming methodologies in Java from online Stanford classes. I really enjoyed programming and decided to work on a science fair project related to both math and computer science. When I am programming, it feels like solving a math problem. I spend countless hours without noticing how time passes. Therefore, computer science seems to be the best fit as a career for me.

Science Fair Paperwork Wizard

Created: 03/27/2018 • Last updated: 05/27/2018

Where did you conduct your lab work? (check all that apply)	Home
Check all aspects among the following that were used in your research (must select at least one):	None of the above

If you have checked any of the aspects above, EXCEPT the last option "None of the above," your project may have required pre-approval by a Scientific Review Committee (SRC) or Institutional Review Board (IRB). Please upload copies of any forms your science fair or school required to approve your research, and answer the questions below.

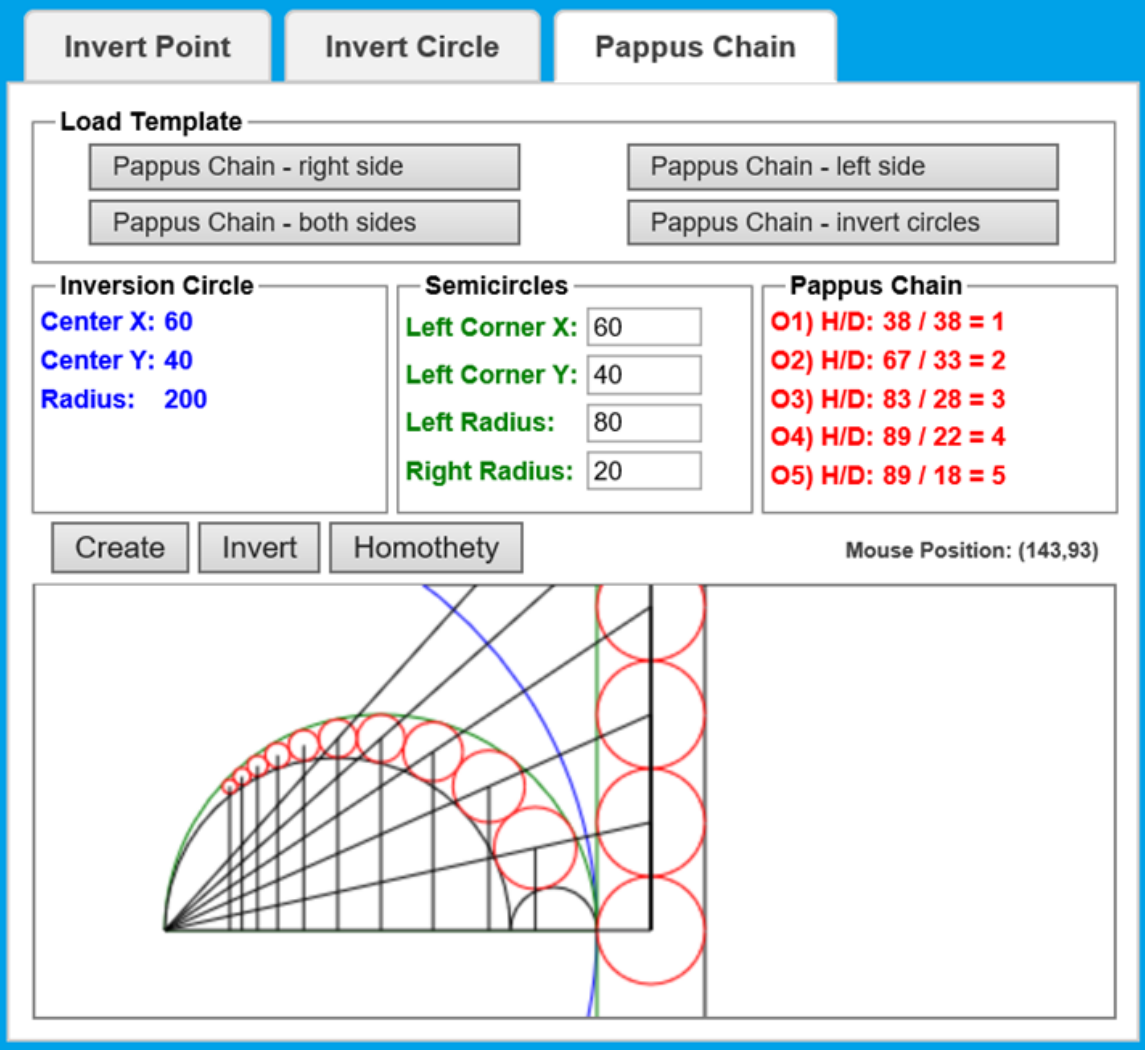
Many fairs use the Intel ISEF approval forms (Form 1A, 1B and other supplemental forms); however some fairs have their own local equivalent. Please see the Intel ISEF Rules for clarification: https://student.societyforscience.org/international-rules-pre-college-science-research

If you checked "None of the above," you do not need to submit any forms.

Please do not upload supplemental essays, abstracts, links, or documents about your project, as only the written information in your application will be reviewed

Thank you! You do not need to submit any paperwork to Broadcom MASTERS for additional review. We recommend that you save copies of any paperwork you may have completed for your personal records.

Proof of Pappus' Theorem with Circle Inversion by Developing an Open Source Software Application



Broadcom MASTERS®

Signature Page and Parent Permission Form

Student Last Name: KARA
Student First Name: SU
Fair Password: USCA01
(If Fair Password unknown, please list fair name, city and state)

Student Certification

I certify that all of the information given in the entry form is correct and has been completed by me. The project I have submitted is my own work, and has not been plagiarized, forged or fabricated from another researcher or source. I understand that fraudulent projects will fail to qualify for the Broadcom MASTERS competition.

I understand that the answers I am submitting may be used in any way by Society for Science & the Public and will not be returned to me. I certify that I have read and fully understand the eligibility requirements as outlined in this packet and that I satisfy all of them.

Su Kara — Signature of Student
3/27/18 — Date

Parent/Guardian Certification and Release

I consent to my child participating in the Broadcom MASTERS program. If my child is chosen as a finalist, I consent to his/her participation in an all-expense-paid trip to Washington, DC, from October 18 to 24, 2018 to be accompanied by one parent or guardian. I have read the eligibility requirements as outlined in this packet and I certify that my child has satisfied all of them and has worked independently on his/her submission.

I also hereby grant to Society for Science & the Public and their subsidiaries, affiliates and advertising, promotion and production agencies, and their respective assigns, permission to use my child's name, image and biographical information in advertising and promotional materials for purposes of advertising or promoting the Broadcom MASTERS program. I acknowledge and agree that I will have no right of approval, no claim to any compensation, and no claim arising out of the use of my child's submission, name, image or biographical information in connection with the exercise of the rights granted to Society for Science & the Public under this certification.

K. Kara — Signature of Parent/Guardian
3/27/18 — Date

This signature page **MUST** be included in the online Broadcom MASTERS Student Application in the upload section. To access the application, go to broadcommasters.fluidreview.com.

Questions? Contact MASTERS@SOCIETYFORSCIENCE.ORG