

3/23/17

Science Fair CASE Number: PH007JR

Does the volume of a pressure vessel affect the height and hangtime of a bottle rocket?

# All I Need is Just Some Space!

## Abstract:

This researcher's project for CASF is on bottle rockets and the effects of volume on a pressure vessel on height and hangtime?". The question for this project states as follows, "Does the volume of a pressure vessel affect the height and hangtime of a bottle rocket?". Moreover, this scientist thinks if the volume of a pressure vessel of a bottle rocket is decreased by half, the same rocket is exactly 2x smaller in size than the other and, the weight of the 1L rocket is 2x smaller than the 2L bottle rocket then the height and hangtime will be the same. This project will demonstrate the processes of building and testing bottle rockets.

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rockets.

2 times smaller than the 2L bottle rocket then the height and hangtime will be the same of both volume of 1 in the ratio 1:2) is exactly 2 times smaller in size and, the weight of the 1L rocket is volume of one bottle rocket is 50% of the other rockets volume, and the same rocket (with the If there are 2 bottle rockets, and the ratio of the rockets volume is 1:2. In other words, the

#### **Hypothesis:**

this builder build this own rockets.  
result of the difficulty of creating a 2L bottle rocket. Hence, this experiment will impact the way rocket being exactly 2 times smaller than the 2L rocket. This idea occurred to this researcher as a rocket. The 2L rockets took up a lot of space and effort. As a result, the idea of making a 1L Olympiad. One of the problems that this scientist came across was when building a 2-liter bottle now. This scientist has won many medals at the state and regional level in this event in Science This builder has been building bottle rockets powered only by water and air for 3 years

#### **Background Information:**

Does the volume of a pressure vessel affect the height and hangtime of a bottle rocket?

#### **Questions:**

height of a 1 Liter and 2 Liter bottle rocket.

researcher hopes to achieve the same hangtime (the time that the rocket is in the air) and the reducing fuel, material, and most importantly cost. Furthermore, in this experiment, this launching a bottle rocket. In addition, this project could potentially help future space mission by the rockets and the fin design. In addition, the website stated how to take precaution when least, the Robert Younge website contributed to this analysis' success in making the design of this expert through the main building parts such as the nosecone of the bottle rocket. Last but not rockets worked and how they compared to the NASA rockets. The US Water Rockets site guided gain some basic knowledge on water bottle rockets. The article showed how and why the bottle notable and reliable source for questions. The NASA Water Rocketry website helped this student Younge Water Rocket site. The Science Olympiad event helped this researcher by creating a event, the NASA Water Rocketry website, the US Water Rockets website, and the Robert of both rockets". This scientist could make these predictions based on the Science Olympiad rocket is 2 times smaller than the 2L bottle rocket then the height and hangtime will be the same (with the volume of 1 in the ratio 1:2) is exactly 2 times smaller in size and, the weight of the 1L words, the volume of one bottle rocket is 50% of the other rockets volume, and the same rocket this hypothesis, "if there are 2 bottle rockets, and the ratio of the rockets volume is 1:2. In other hangtime of a bottle rocket. After researching online and in books, this researcher came up with rocket. This scientist wanted to know if the volume of a pressure vessel affects the height and This scientist started this project in order to achieve a more efficient way of designing a bottle

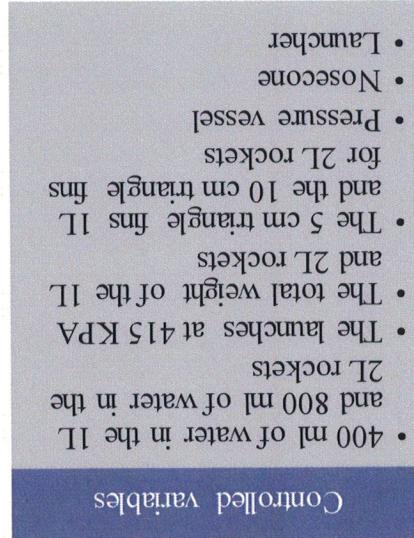
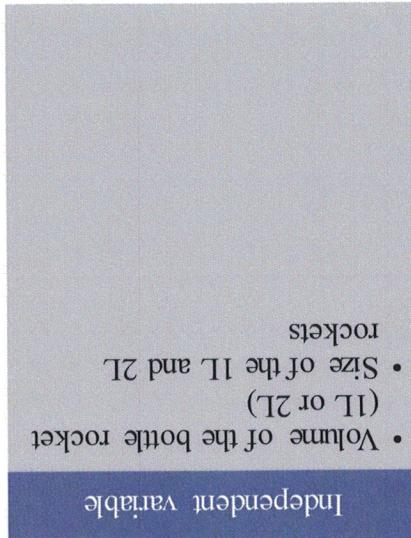
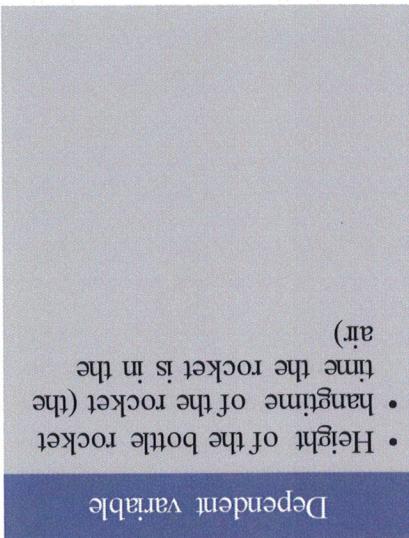
## Introduction:



This scientist's experimental controls are the 2 Liter bottle rockets. In this case, same altitude as the 2L bottle rocket. In addition, the 2L bottle rocket will have the same features and will be built from the same material. Thus, eliminating variables that would cause a failure in this experiment.



#### Experiment Control:



rocket. However, the 1L bottle rocket will be 2x smaller in size and in weight.

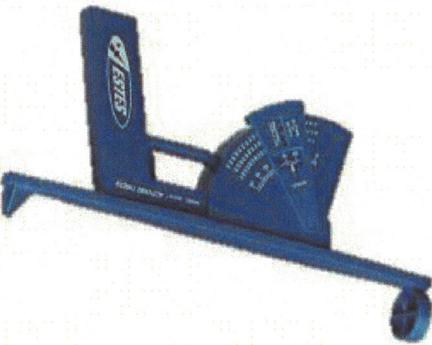
This scientist is testing the if the 1L bottle rocket will get the same results as the 2L bottle. This test group in this science experiment are the 1L bottle rockets. This is because

#### Test Group:

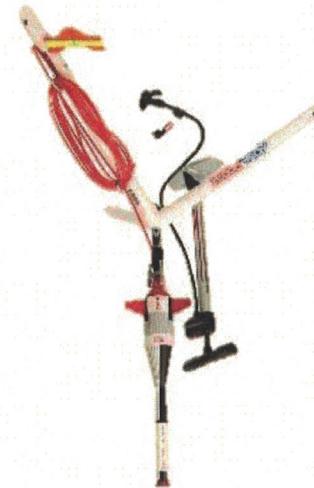
Materials	Quantity
Inhaling the fumes of CA glue	•
The launcher could tip over and fire towards a person	•
There is a chance of rockets exploding on the launchpad	•
Safety glasses	•
Risks, Safety & Cautions:	
1L bottles	4
2L bottles	4
Equilateral triangle fins with the side length of 10 cm made from cardboard	6
Equilateral triangle fins with the side length of 10 cm made from cardboard	6
cardboard	9
T8 fluorescent light covers (one should be cut in half)	3
Ping Pong balls	9
Plastic Easter eggs	6
Paper	5
CA or Super Glue 8 oz	1
Plastic Beaker 100 mL	1
Esites Alitack	1
10 cm pieces of Masking Tape	6
5 cm pieces of Masking Tape	6

### Materials:

- Inhaling the fumes of CA glue
- The launcher could tip over and fire towards a person
- There is a chance of rockets exploding on the launchpad
- Safety glasses



Estes Altirak



Aqua Port II Water Rocket Launcher

Ruler	1	
Bottle caps	6	
Safety Goggles	1 pair for each person	
Gloves	1 pair for each person	
Water	Around 3 gallons	
Clay	2000 grams	
Hot Glue Sticks	10	
Hot Glue Gun	1	
Scissors	1	
Aqua Port II Water Rocket Launcher	1	
Pen/Pencil and Sharpee	1	
Deluxe Port Pump II	1	
Measuring Tape (20 Meters)	1	

## Procedure:

### • Step 1

Let the glue gun heat while preparing your materials for building the bottle rocket.

### • Step 2

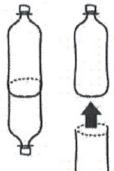
First, take 2 of both the 1L and 2L bottles and cut 10 cm from the nozzle. Do this for both sized bottles, in total there will be 4 bottles cut (2 2-liter nosecones and 2 1-liter nosecones). This will be the nosecone for the bottle rockets, below.

### • Step 3

Tape the nosecones to the top of the uncut 1L and 2L bottles and align the nosecone to the bottle to make a perfect cylinder. As shown below.

### • Step 4

Prepare your gluing surface, put the safety gear on and, get the T8 fluorescent light



You have very little time until the glue dries onto the nosecone tubes. Quickly take 1 bottle cap from the bottles and insert it into the one side of the nosecone tube. The cap should fit snug. Quickly, push the cap into the nosecone tube until the edges of both the cap and the nosecone tube are flush. Do this for all 4 nosecone tubes.

### • Step 5

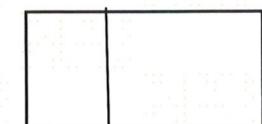
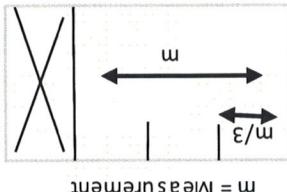
Set the nosecone aside to dry. Meanwhile, roll 1 sheet of paper around the 2L bottle and mark the meeting point of the edges of the paper. Do this for the 1L bottle too.

### • Step 6

After completing the marks on both papers. Measure the distance from the paper edge to the point marked. Then, divide the distance by 3. Now mark those 3 points. Also, label the paper used for the 2L rocket "2L" and, label the 1L rocket "1L".

### • Step 8

Roll the "2L" paper back onto the 2L bottle rocket and make the marks 7 cm from it again. Now connect the marks so the three lines are parallel to each other. Do this for only the nozzle of the bottle rocket. Then, slide the paper roll up about 10 cm and mark the nozzle of the 2L bottle rocket.



Set the nozzle aside to dry. Meanwhile, roll 1 sheet of paper around the 2L bottle and mark the meeting point of the edges of the paper. Do this for the 1L bottle too.

### • Step 7

After completing the marks on both papers. Measure the distance from the paper edge to the point marked. Then, divide the distance by 3. Now mark those 3 points. Also, label the paper used for the 2L rocket "2L" and, label the 1L rocket "1L".

Roll the "2L" paper back onto the 2L bottle rocket and make the marks 7 cm from the nozzle of the 2L bottle rocket. Then, slide the paper roll up about 10 cm and mark the nozzle of the 2L bottle rocket.

shown below.

After letting the bottle dry, screw the end of the nosecone tube to the nozzle. The long ones (4ft) should go on the 2L and the short ones that you cut in half should (2ft) go on the 1L rockets

#### • Step 16

Let all the bottles dry for 5 minutes on the cut bottle, previously referred as the nosecone.

#### • Step 15

tape. Do this for all fin marks only on the 2L bottles.

Afterward, take the 5 cm fins and hot glue 1 side of the fin to one of the fin lines on the

#### • Step 14

this for all fins marks ONLY on the 2L bottle rockets. Do

integrity will not be altered, in other words, it won't explode on the launcher. Do this gun to glue 1 side of the fin to one piece of tape (the tape that is covering the fin lines) on the 2L bottle rockets. This piece of tape will ensure that the fin gun to glue ready the hot glue gun for use, take the 10 cm fins and use the hot glue

Moreover, ready the hot glue gun for use, take the 10 cm fins and use the hot glue gun to glue (line marked on the bottles). As shown in the image to the right. Do this

#### • Step 13

only for the 1L bottles.

Furthermore, take the 5 cm pieces of masking tape and tape it in the center of the fin line (line marked on the bottles). As shown in the image to the right. Do this

#### • Step 12

rigid. Do this only for the 2L bottles.

the center of the fin line (line marked on the bottles). As shown in the image to the rockets with fin lines marked. Take the 10 cm pieces of masking tape and tape it in

Put the nosecone tube aside to dry. At this point, there should be a total of 4 bottle

#### • Step 11

seen below.

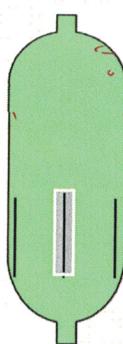
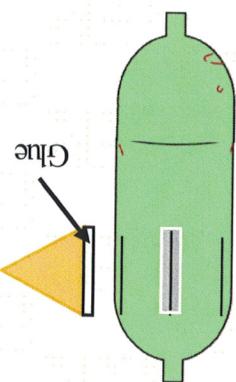
Now take one black end plug and CA it to the other side of the tube. Now CA the other side of the black plug and place the ping pong ball on top. In addition, CA the inner edge of the plastic egg. Then place it on top of the ping pong ball. As

slide the paper roll up about 5 cm and mark again. Now connect the marks so all the lines are parallel to each other. Do this for all the marks only the 1L bottle rockets.

Roll the "1L" paper back onto the 1L bottle rocket and make marks 7 cm from the nozzle. Then, slide the paper roll up about 5 cm and mark again. Now connect the marks so all the lines are parallel to each other. Do this for all the marks only the 1L bottle rockets.

#### • Step 9

After letting the bottle dry, screw the end of the nosecone tube to the nozzle. The long ones (4ft)





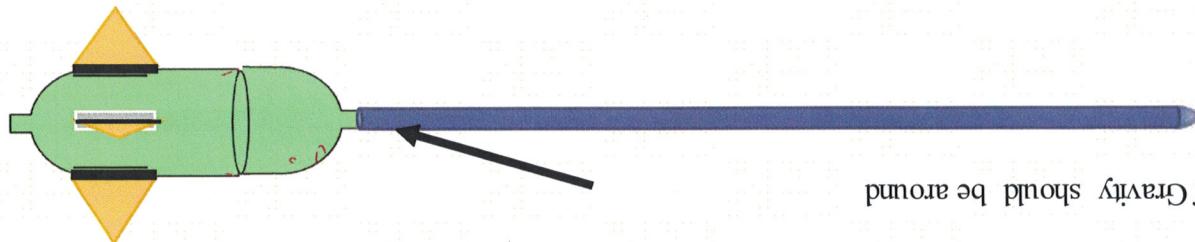
Add 800 mL of water only to 2L rockets and add 400 mL of water to only the 1L rockets.

#### • Step 2

Set the AquaPort II Water Rocket Launcher and the Deluxe Port Pump II up so it is ready to launch

#### • Step 1

Procedure (Launching):



Centre of Gravity should be around

- Centre of Gravity - The point on an object where both sides are equally balanced.

change as much.

- I added clay all around the rocket to make sure the Centre of Gravity would not

#### • Step 3

- If the 1L rocket is not half the weight of the 2L rocket, then you should add mass added clay to easily "fine-tune" the rockets.

- to make the 2L rocket twice as heavy as the 1L rocket. In my case, this researcher added clay all around the rocket to make sure the Centre of Gravity would not change as much.

#### • Step 2

- Now take all the rockets and weigh them on a scale. The 2L rockets should be half the weight of 1L rockets.

#### • Step 1

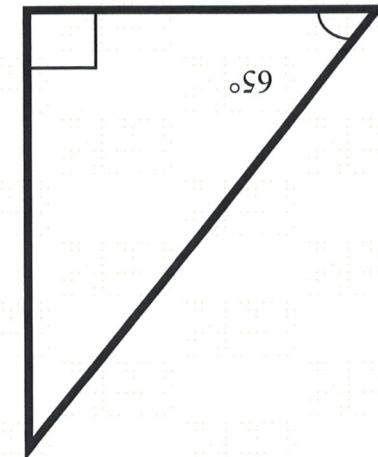
Procedure (Fine-tuning):

- Pump the Deluxe Port Pump II until the gauge reads 415 KPA. Then pull the trigger and time at the same time. Stop timing when it touches the ground.



20 Metres

65°



$$x \approx 10.7 \text{ Meters}$$

$$\tan(65^\circ) = \frac{20}{x}$$

Now use TAN to solve for the height. Say the angle was 65°.

- Step 5

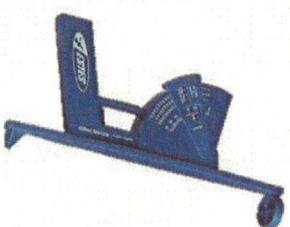
(20 m).

Then record the angle of on the Estes Altitrak and the distance you are away from the launcher

- Step 4

release the trigger.

To operate the Estes Altitrak hold the trigger when the rocket is launched and point the device at the rocket while in flight at its highest altitude. When the rocket reaches, the highest altitude



- Step 3

Have a person stand at the end of 20m with the Estes Altitrak.

- Step 2

After setting up the launcher, roll a measuring tape 20m away from the center of the launcher.

- Step 1

Procedure (Measuring Height):

## Results:

11

11.5

12

12.5

13

13.5

14

11

11.5

12

12.5

13

13.5

14

### Hanging time of Botttle Rocket

#### Data Table:

	Rocket #1 1L	Rocket #2 1L	Rocket #1 2L	Rocket #2 2L	Rockets
E 10 KMH - 11/30	13.14	12.93	13.48	13.46	
E 13 KMH - 11/30	12.63	12.28	13.2	12.43	
Calm - 11/29	12.64	12.39	12.37	12.48	
SSE 5.5 KMH - 11/29	12.16	12.44	12.05	12.89	
NW 13 KMH - 11/19	13.05	12.64	13.18	12.73	
N 5 KMH - 11/18	13.02	12.57	12.74	12.39	

#### Bar Graphs:

An analysis of this graph allows this scientist to say that the rocket's times are consistent among other rockets on the same day. Rocket #1 1L times were between 12.16 - 13.14 seconds.

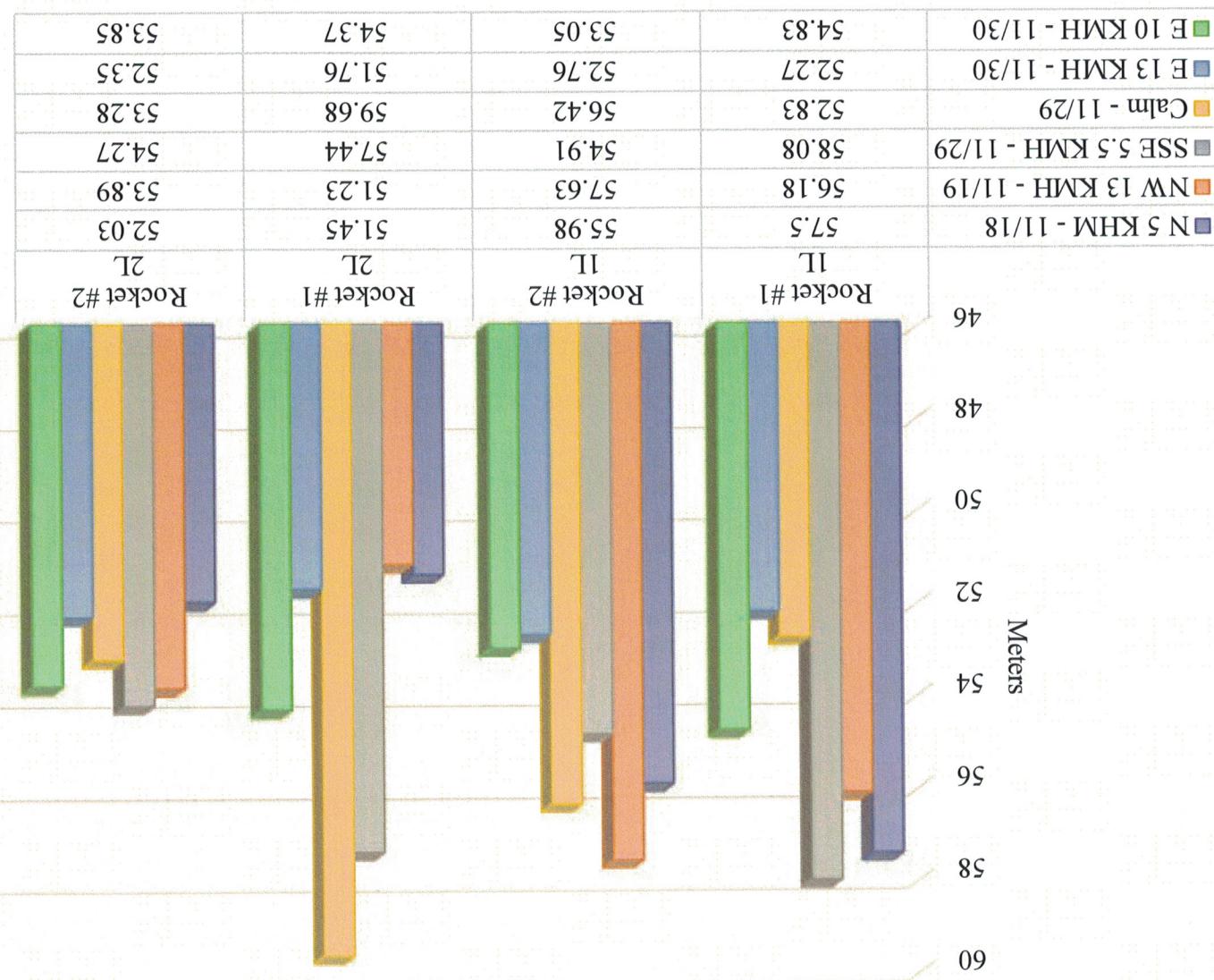
Rocket #2 1L times were 12.28 - 12.93 seconds. Rocket #1 2L times were 12.05 - 13.48 seconds.

metres. Rocket #2 1L height was 52.76 – 57.63 meters. Rocket #1 2L height was 51.23 – 59.68 meters. Rocket #2 1L height was 52.76 – 57.63 meters. Rocket #1 1L height was between 52.27 – 58.08 consistent among other rockets on the same day. Rocket #1 1L height was between 52.27 – 58.08

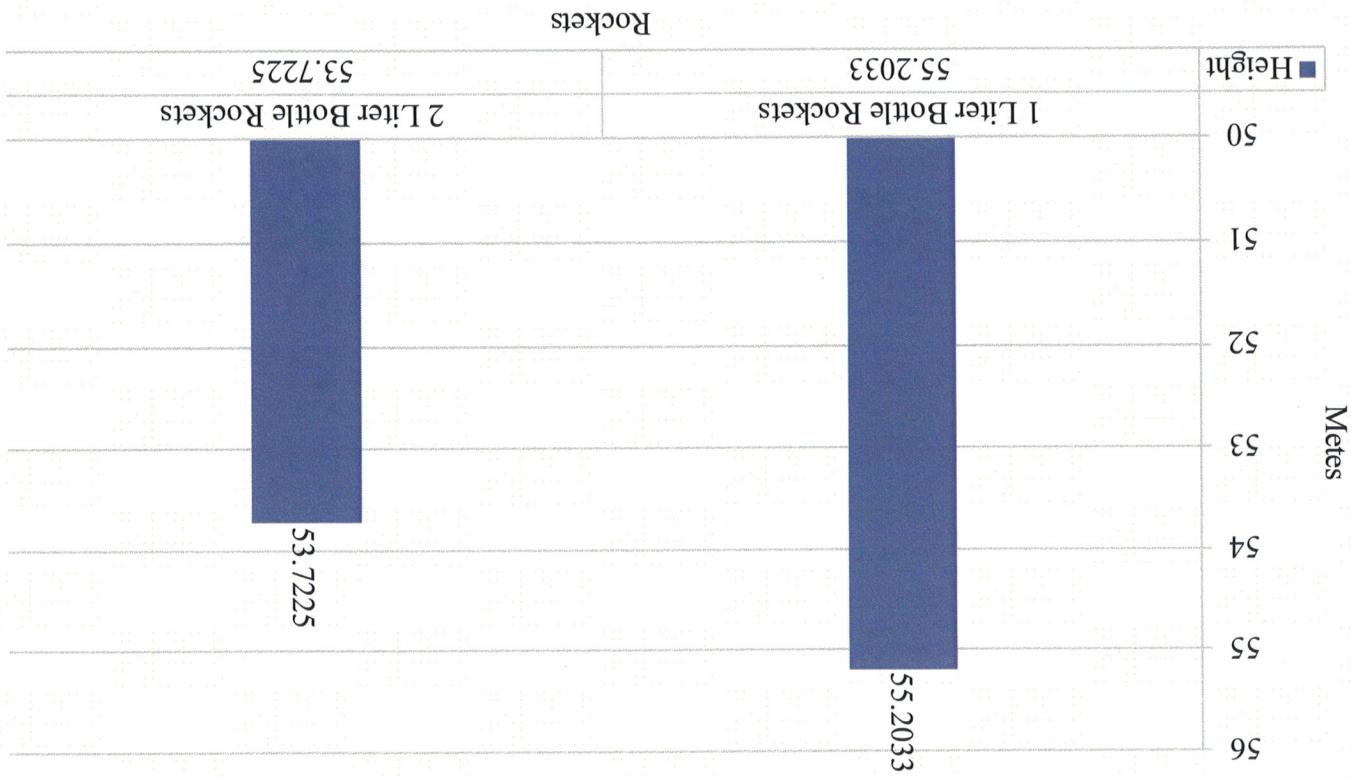
An analysis of this graph allows this scientist to say that the rocket's heights are

dramatically. Thus, supporting my hypotheses.

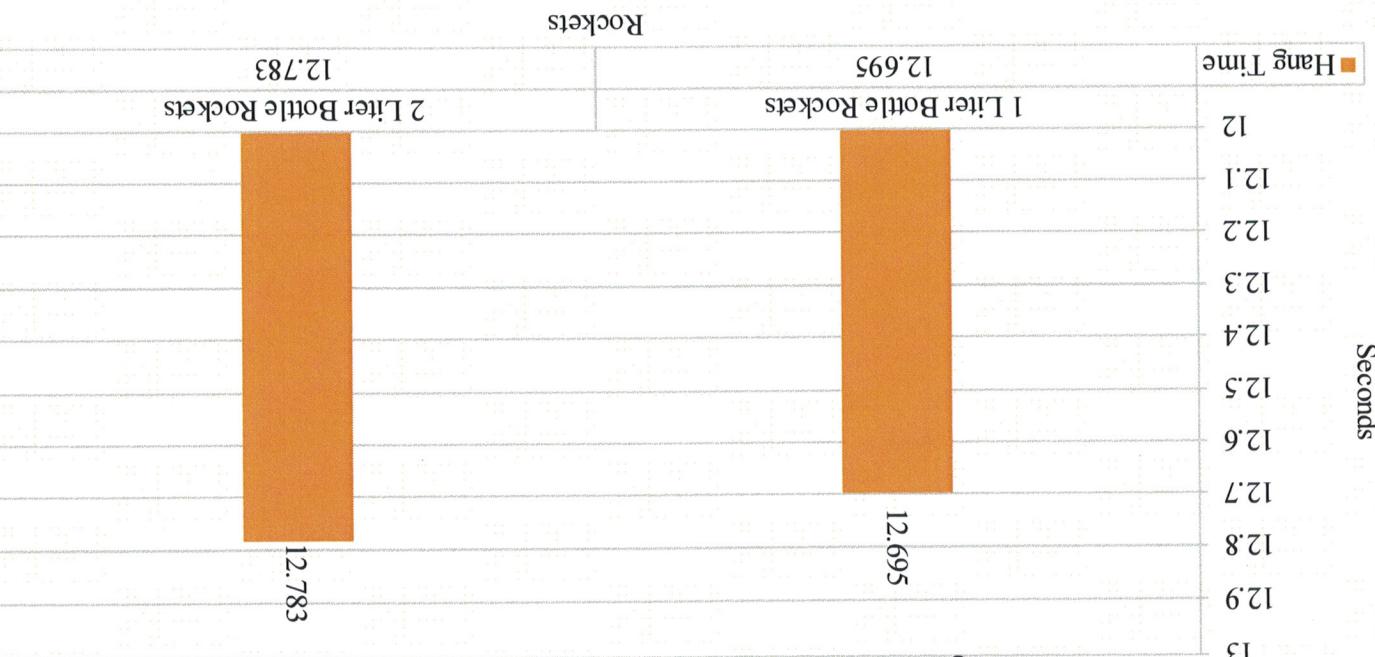
### Rockets



seconds. Rockets #2 2L times were 12.39 – 13.46 seconds. Hence, the times did not change



Averages of the 2 Liter and 1 Liter Bottle Rocket Height



Averages of the 2 Liter and 1 Liter Bottle Rocket Hangtime

$$\frac{dp_z}{dz} = \frac{d}{dt} \left( -g - \frac{M}{\beta} a_z |a_z| \right),$$

Empty rocket weight	$M_0$	Initial amount of water	$M_W$	Bottle Volume	$V_b$	Initial pressure	$p_0$	Drag Coefficient (~0.5 for smooth cylinder)	$C_d$	Gravitational Constant	$g$	Simulation time step	$\Delta t$	Bottle radius	$R_b$	Nozzle radius	$R_n$
---------------------	-------	-------------------------	-------	---------------	-------	------------------	-------	---	-------	------------------------	-----	----------------------	------------	---------------	-------	---------------	-------

If the rocket has emptied itself and weighs only  $M_0$  (there is no more water left in the bottle rocket), this scientist is left with a simple drag equation:

$$\frac{dM}{dt} = -\alpha,$$

$$\alpha = \frac{d}{dt} \frac{dp_z}{dz},$$

$$\frac{dp_z}{dt} = F_a - \frac{M}{\beta} a_z |a_z|,$$

equation for the evolution of the internal mass:

Given the thrust and the mass loss rate, this scientist can fit in the equations of motion and an

$$F_a \equiv -\frac{dp}{dm} V_e = 2\pi r_n^2 (p_{in} - p_{out}).$$

$$\alpha \equiv -\frac{dM}{dt} = \pi r_n^2 \rho_m \sqrt{\frac{2(p_{in} - p_{out})}{V_e}},$$

$$p_{in} = p_0 \left( \frac{V_0 + (M(0) - M(t)) / \rho_m}{V_0} \right)^{-1},$$

rate  $\alpha$  and the thrust  $F_a$  given the current mass of the rocket  $M(t)$ :

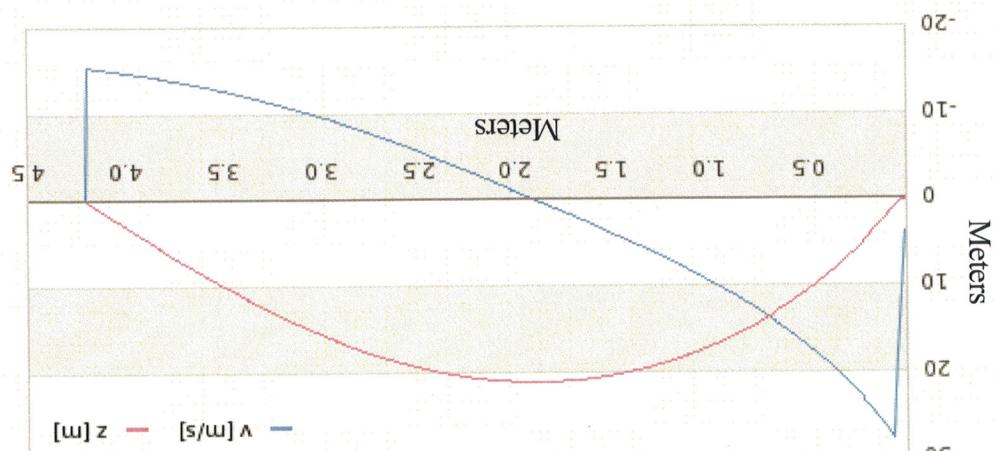
At every given moment, this scientist can calculate the internal pressure  $P_P$ , the mass loss

is mathematically true. This researcher can look at a rocket at a mathematical level:

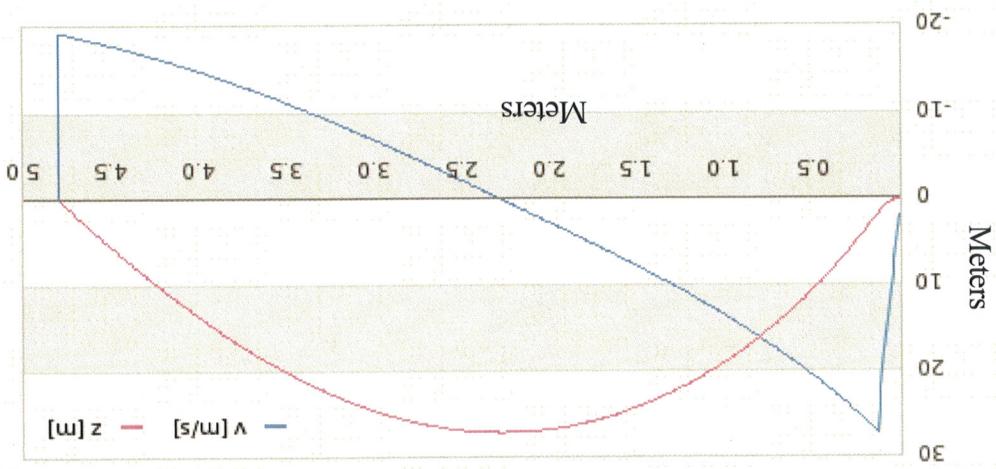
From the data collected above, this scientist can see the patterns in the data. As a result, the LL and ZL rockets had no or minimal variation in data. To prove that this experiment is also

## Discussion:

1L Bottle Rocket:  
Max Height: 21.1 meters



2L Bottle Rocket:  
Max Height: 27.2 meters



As you can see the bottle rockets height were in the range of 6 meters. However, when

compared to the real world the heights achieved are considered acceptable. Furthermore, this experiment could help NASA in an emergency space mission by ensuring that the altitude of the

rocket will be the same as a rocket twice as small.

In conclusion, this study was conducted in order to find out if there was a difference between a 1 Liter water bottle rocket and a 2 Liter water bottle rocket and does the height and hang time change? The hypothesis of the study stated, "If the volume of a pressure vessel of a bottle rocket is decreased by half, the same rocket is exactly 2x smaller in size than the other and, the weight of the 1L rocket is 2x smaller than the 2L bottle rocket then the height and hang time will be the same". This researcher found as long as the ratio of weight was 2:1, 2 being the weight of the 2 Liter rocket, and 1 being the weight of the 1 Liter rocket. Then the height and hang time of the rockets will be the same. Consequently, the data supported the hypothesis. This is shown through the data this scientist has collected, Rocket #1 1L times were between 12.16 - 13.48 seconds. Rockets #2 2L times were 12.39 - 13.46 seconds. Hence, the times did not change at all dramatically, this time range would be considered great despite the variables in this experiment. Furthermore, this scientist can say that the rocket's heights are consistent among other rockets on the same day. Rocket #1 1L height was between 52.27 - 58.08 meters. Rocket #2 2L height was 52.03 - 53.89 meters. Thus, from the data this scientist has collected, this scientist has accepted that his hypotheses is correct. Some errors that might have caused some variables in time and height may include the inconsistent speed of pumping and the inaccuracy of the pressure gauge. Moreover, the fins could have been placed too far up which may have caused an unstable flight leading to a decrease in hangtime.

If this scientist were to do his experiment again he would use a wind tunnel to check that the stability for all rockets would match and the CPP was the same for all. Moreover, this scientist would use 4 of the same bottle rocket launchers to launch his rocket, eliminating variables such as wind gust, rain, etc. Next year this expert could test if the spin of a bottle rocket affected the height, velocity, and hangtime of a bottle rocket.

**Conclusion:**

- Stiff fins are the best fins. Flexibility decreases the effectiveness of a fin.

#### **Recommendations:**

- Place the grain of the fin perpendicular to the bottle. This will make the fin stiffer and stronger.
- "Swing Testing" is a quick way to determine if a rocket has reasonable stability. This test is done by tying a string around the rocket at its Center of Gravity and swinging the rocket around.
- Fins cause very little drag and do not weigh very much. A non-stable rocket that is flying sideways is creating a lot of drag. Non-stable rockets have a lot of problems with deployment of their parachute.

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First, this scientist would like to thank the Science Olympiad forums community for helping this scientist gather information on a bottle rocket. Next, this researcher would like to thank the helpful, and always supportive science teacher. Last but not least this researcher would like to thank the Faggle View Science Olympiad team for helping collect the data needed.

## Acknowledgements:

## OFFICIAL ABSTRACT and CERTIFICATION

A Deep Learning Approach for Arrhythmia Detection

Pick one only —

mark an "X" in box

at right

Sciences

Biochemistry

Biomedical Engineering

Sciences

Earth & Environmental Sciences

Materials and Design

Energy: Sustainable

Embedded Systems

Mathematics

Microbiology

Physics & Astronomy

Plant Sciences

Robotics & Intelligent

Machine Systems

Microorganisms

Potentially hazardous biological agents

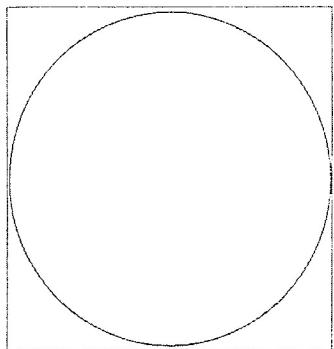
Human Participants

Vertebrate animals

Microbial

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check ALL that apply):
- human participants
  - vertebrate animals
  - microorganisms
  - DNA
  - RNA
  - tissue
  - plant sciences
  - robotics & intelligent machines
  - machine systems
  - potentially hazardous biological agents
  - microorganisms
  - microbial
  - vertebrate animals
  - worked or used equipment in a regulated research institution
  - Yes
  - No
2. I/we worked or used equipment in a regulated research setting (check ALL that apply):
- materials science
  - engineering mechanics
  - environmental engineering
  - energy
  - sustainable design
  - embedded systems
  - mathematics
  - microbiology
  - physics & astronomy
  - plant sciences
  - robotics & intelligent machines
  - machine systems
  - microorganisms
  - microbial
  - vertebrate animals
  - human participants
  - potentially hazardous biological agents
  - DNA
  - RNA
  - tissue
  - plant sciences
  - robotics & intelligent machines
  - machine systems
  - potentially hazardous biological agents
  - microorganisms
  - microbial
  - vertebrate animals
  - human participants
  - worked or used equipment in a regulated research institution
  - Yes
  - No
3. This project is a continuation of previous research.
- Yes
  - No
4. My display board includes non-published photographs/visuals
- Yes
  - No
5. This abstract describes only procedures performed by me/us.
- Yes
  - No
6. I/we hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.
- Yes
  - No

This stamp or embossed seal attests that this project is in compliance with all federal and state laws and regulations and that all appropriate reviews and approvals have been obtained including the final clearance by the Scientific Review Committee.



Aditya Kende

Cumberland Valley High School, Mechanicsburg PA, Adams County

A Deep Learning Approach for Arrhythmia Detection

Sciences

Biochemistry

Biomedical Engineering

Sciences

Earth & Environmental Sciences

Materials and Design

Energy: Sustainable

Embedded Systems

Mathematics

Microbiology

Physics & Astronomy

Plant Sciences

Robotics & Intelligent

Machine Systems

Microorganisms

Microbial

Vertebrate animals

Human Participants

Microbial

**Checklist for Adult Sponsor (1)**

This completed form is required for ALL projects.

Sponsor in collaboration with the student researcher(s):

To be completed by the Adult Sponsor in collaboration with the student resesarcher(s):

1. ■ I have reviewed the Intel ISEF Rules and Guidelines.

Project Title: A Deep Learning Approach for Arrhythmia Detection

I have reviewed the student's completed Student Checklist (1A) and Research Plan/Project Summary.

Uttarve worked with the students and we have discussed the possible risks involved in the project.

4.  The project involves one or more of the following and requires prior approval by an SRC, IRB, IACUC or IBC:  
 Humans       Potentially Hazardous Biological Agents  
 Vertebrate Animals       Microorganisms       rDNA       Tissues

5. Items to be completed for ALL PROJECTS

44. Adult Sponsorship/Project Summary  
45. Adult Sponsorship Checklist (1)

■ Student Checklist (1A) ■ Approval Form (1B)

- Regulated Research Institutional/Industrial Setting Form (1C) (when applicable; after completed experiment)
- Continuation/Research Progression Form (7) (when applicable)

Humans, including student designed inventions/prototypes. (Requires prior approval by an Institutional Review Board (IRB); see full text of the rules.)

- Human Participants Form (4) or appropriate Institutional IRB documentation
- Sample of informed Consent Form (when applicable and/or required by the IRB)
- Qualifed Scientist Form (2) (when applicable and/or required by the IRB)

**Vertebrate Animals** (Requires prior approval, see full text of the rules.)

- Veretbrate Animals (Requires prior approval, see full text of the rules.)
- Veretbrate Animal Form (5A) - for projects conducted in a school/home/field research site (SRC prior approval required.)
- Veretbrate Animal Form (5B) - for projects conducted at a school/home/field research site (SRC prior approval required.)
- Use Committee (IACUC) approval required prior experimentation.
- Qualifed Scientist Form (2) (Required for all veretbrate animal projects at a regulated research site or when applicable)

Potentially Hazardous Biological Agents (Requires prior approval by SRC, IACUC or IBC, see full text of the rules.)

- Human and Vertebrate Animal Tissue Form (6B) - to be completed in addition to Form 6A when project involves the use of fresh or frozen tissue, primary cell cultures, blood, blood products and body fluids.
- Qualified Scientist Form (2) (when applicable)
- The following are exempt from prior review but require a Risk Assessment Form 3: projects involving protists, archae and similar microorganisms, for projects using manure for composting, fuel production or other non-cultural experiments, projects using coliform water test kits, microbial fuel cells, and projects involving decomposing vertebrate organisms.
- Hazarous Chemicals, Activities and Devices (No SRC prior approval required, see full text of the rules.)
- Risk Assessment Form (3)
- Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)

- Risik Assessment Form (3)
- Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)

10/29/2019

Signature

CIVILIN@CVSCLOUDS.ORG

Date of Review (mm/dd/yy)

Adult Sponsors Printed Name

17-736-2227

17-736-2227  
civlin@cvsschools.org

## **Student Checklist (1A)**

This form is required for ALL projects.

- |  |  |                                 |                                |
|--|--|---------------------------------|--------------------------------|
| 1. a. Student/Team Leader:   | Aditya Kendar  | Grade:                          | 11                             |
| b. Team Member:  |  | c. Team Member:                 |                                |
| A Deep Learning Approach for Arrhythmia Detection  |  |                                 |                                |
| 2. Title of Project:   |  |                                 |                                |
| a. School:   | Cumberland Valley HS   | School Phone:                   | (717) 697-8261                 |
| b. School Address:   | 6746 Carlisle Pike<br>Mechanicsburg, PA 17050                                    |                                 |                                |
| 4. Adult Sponsor:  | Christopher Irvin<br>Phone/Email: cirlin@cvcschools.org                          |                                 |                                |
| 5. Does this project need SRC/IRB/IACUC or other pre-approval? <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Tentative start date: |  |                                 |                                |
| 6. Is this a continuation/progression from a previous year? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No                          |  |                                 |                                |
| a. Attach the previous years' Abstract and Research Plan/Project Summary   | b. Explain how this project is new and different from previous years on          |                                 |                                |
| c. Continue this laboratory experiment/data collection:  |  |                                 |                                |
| 7. This year's laboratory experiment/data collection:  |  |                                 |                                |
| 8. Where will you conduct your experimentation? (check all that apply)   | <input type="checkbox"/> Research Institution                                    | <input type="checkbox"/> School | <input type="checkbox"/> Field |
| <input checked="" type="checkbox"/> Home   | <input type="checkbox"/> Other:  |                                 |                                |
| 9. List name and address of all non-home and non-school work site(s):  |  |                                 |                                |
| 10. Complete a Research Plan/Project Summary following the Research Plan/Project Summary Instructions  | <p>Name: _____</p> <p>Address: _____</p> <p>Phone: _____</p> <p>Email: _____</p> |                                 |                                |
| 11. An abstract is required for all projects after experimentation.  | and attach to this form.   |                                 |                                |

ECG-Based Abnormal Heartbeat Classification: A Deep Learning Approach for Arrhythmia

Detection

Aditya Kendre

Cumberland Valley High School

## Rationale

Electrocardiograms (ECG) have created a profound impact in the field of cardiology, specifically in recognizing of heart arrhythmias. Non-invasive arrhythmia analysis is based on 10

arrhythmia occurs in the United States yearly (Mayo Clinic). Diagnosing this disease early is the key to one's well-being, yet 18% of cardiologists misinterpreted ECGs containing atrial fibrillation

(Akh et al, 2006). With the recent advancements in technology, Machine Learning algorithms such as Deep Neural Networks (DNNs), allow a computer to learn features and identify patterns

within a given dataset. On the basic level, DNNs receive input data, and through a series of weights and biases, outputs a confidence value in all possible labels of the dataset, similar to a

human's neural network. Furthermore in the accuracy of abnormal heartbeat classification will allow cardiologists to accurately, and efficiently recognizing arrhythmia before becoming prevalent in one's well-being.

## Research

Research Question: This research project will examine whether a classifier will be able to accurately identify abnormal heartbeat in ECGs.

Hypothesis: If an image classifier received a supervised dataset of heart arrhythmia of ECGs,

then the image classifier will allow an accurate identification of arrhythmia.

Expectation: The image classifier should reach an accuracy of above 82%.

Procedure:

1. Gather a dataset of annotated ECGs

2. Determine type of classifier used to learn dataset features

3. Analyze results using Gradient Descent and Mean Loss function

Risks and Safety:

This research project involves no risks or safety concerns.

## References

- Allaras, Miguel, Soriano, & Silvia. (2019, July 3). A Fast Machine Learning Model for ECG-Based Heartbeat Classification and Arrhythmia Detection. Retrieved October 30, 2019, from <https://www.frontiersin.org/articles/10.3389/fphy.2019.00103/full>.
- Mayo Clinic. (2019, April 2). Heart arrhythmia. Retrieved October 30, 2019, from [https://www.mayoclinic.org/diseases-conditions/heart-arrhythmia/symptoms-causes/syc-20350668?utm\\_source=Google&utm\\_medium=abstract&utm\\_content=Cardiac-arrhythmia&utm\\_campaign=Knowledge-panel](https://www.mayoclinic.org/diseases-conditions/heart-arrhythmia/symptoms-causes/syc-20350668?utm_source=Google&utm_medium=abstract&utm_content=Cardiac-arrhythmia&utm_campaign=Knowledge-panel).
- Srinivasan, N. T., & Schillings, R. J. (2018, June). Sudden Cardiac Death and Arrhythmias. Retrieved October 30, 2019, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6020177/>.

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair		Date of Approval (mm/dd/yy)	Signature	State/National SRC Chair's Printed Name	(Where applicable)
		Date of Approval (mm/dd/yy)	Signature	Regional SRC Chair's Printed Name	
<p>I certify that this project adheres to the approved Research Plan/Project Summary and complies with all Intel ISEF Rules.</p>					

### 3. Final Intel ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Chair's Printed Name		Date of Approval (mm/dd/yy)	Signature	Date of Approval (mm/dd/yy)	Signature
<p>Institutional approvals (e.g., IACUC, IRB). This project was conducted at a regulated research institution (not home or high school, etc.), was reviewed and approved by the proper institutional board before experimentation and complies with the Intel ISEF Rules. Attach (1C) and any required documents prior to experimentation.</p>					
<p>The SRC/IRB has carefully studied this project's Research Plan/Project Summary and all the required forms are included. My signature indicates approval of the Research Plan/Project Summary before the student begins experimentation.</p>					
<p><b>BEFORE experiments that need prior SRC/IRB approval</b> b. Required for research conducted at all Regulated Research institutions with no prior fair SRC/IRB approval. <b>OR</b> a. Required for projects that need prior SRC/IRB approval</p>					

(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

### 2. To be completed by the local or affiliated Fair SRC

Student's Printed Name		Date Acknowledged (mm/dd/yy)	Signature	Date Acknowledged (mm/dd/yy)	Signature
<p><b>b. Parent/Guardian Approval:</b> I have read and understand the risks and possible dangers involved in the Research Plan/Project Summary. I consent to my child participating in this research.</p>					
<p><b>a. Student Acknowledgment:</b> I have read and will abide by the following Ethics statement</p> <ul style="list-style-type: none"> <li>• I have read the Intel ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.</li> <li>• I understand the risks and possible dangers to me of the proposed research plan.</li> <li>• I understand that plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data, Fraudulent misconduct are not condoned at any level of research or competition. Such practices include but are not limited to misconduct researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and plagiarism will fail to qualify for competition in affiliated fairs and the Intel ISEF.</li> </ul>					

A completed form is required for each student, including all team members.

## Approval Form (1B)

**- PLEASE DO NOT FAX ENTRY PACKETS -**

TEACHERS: RETURN THIS FORM WITH ALL REQUIRED FORMS ATTACHED NO LATER THAN ESTABLISHED DEADLINE  
CASEF, Fair Director • Whittaker Center for Science and the Arts • 225 Market Street, 2nd Floor • Harrisburg, PA 17101

Directors: Home Phone 717-343-5155 E-mail MrsSchulz@msn.com Signature MrsSchulz  
Our school fair committee rates this exhibit as \_\_\_\_\_ of \_\_\_\_\_ to be entered from our school in the Capital Area Science and Engineering Fair with # best.

FAIRURE TO RANK AND SIGN EACH PROJECT COULD RESULT IN ELIMINATION OF ALL PROJECTS FROM YOUR SCHOOL.  
INCLUDED AT CASEF, IF ANY PROJECT NEEDS TO BE ELIMINATED, IT WILL BE DONE UPON YOUR RATING BELOW.  
Completed and signed a Checklist for Adult Sponsor Form and it is attached to this form. DUE TO SPACE, SOME PROJECTS MAY NOT BE  
To the best of my knowledge, the exhibit described on this form is the work of the student entering it and the information given is correct. I've  
8. SCHOOL FAIR DIRECTOR APPROVAL

Parent or Guardian's Signature Debby

the use of CASEF as well as the sponsoring organization. There is no expiration date on this release and I will not seek compensation for usage.  
CASEF to take photographs of my child, named above. I understand that these photographs will be taken for recipients of Special Awards solely for  
Science and Engineering Fair (CASEF) in accordance with its rules and regulations. Additionally, by my signature, I am giving permission for  
7. My son, daughter or ward, whose name appears above and who has signed the statement above, has my permission to participate in the Capital Area

Student Exhibitor's Signature Debby

a. The exhibit which I plan to enter in the Capital Area Science and Engineering Fair, is my own work and has been completed by me within the  
rules of the Capital Area Science and Engineering Fair which I am familiar.  
b. If the exhibitor is accepted, I hereby agree to abide by all rules of the Capital Area Science and Engineering Fair.  
c. I understand that my exhibit is entered at my own risk and that the Capital Area Science and Engineering Fair and Whittaker Center for Science

and the Arts are not responsible for loss or damage to my exhibit or any of its parts.  
If my project involves research with vertebrate animals, human subjects, recombinant DNA, tissue, pathogenic agents or controlled substances,  
all necessary, completed certification forms were approved by the proper Scientific Review Committee/Mstitutional Review Board in December  
and are attached to this form.  
Exhibit Information/Project Abstract Form and it is attached to this form.  
5. a. I have completed a Research Plan and Approval Form with all required signatures and it is attached to this form. I have also completed an

**THE CAPITAL AREA SCIENCE AND ENGINEERING FAIR THE FOLLOWING STATEMENTS MUST BE SIGNED.**

**IMPORTANT... TO HAVE YOUR ENTRY ACCEPTED FOR EXHIBITION IN**

**MEMBER must complete and submit this**

- NOT: For team projects, each team
- Plant Sciences
- Physics & Astronomy
- Microbiology
- Medicine & Health
- Mathematical Sciences
- Environmental
- Engineering
- Earth Science
- Computer Science
- Chemistry
- Cellular & Molecular Biology
- Biotechnology
- Behavioral & Soc. Sciences
- Animal Sciences
- 4. CATEGORY (check one)
- 3. EXHIBIT SIZE
- a. Junior Division (Grades 7, 8) - Maximum exhibit width is 36 inches.
- b. Senior Division (Grades 9, 10, 11, 12) - Maximum Exhibit width is 42 inches.
- c. All projects must be NO MORE than ...  
30 inches deep • 9 ft. high • 250 lbs. in weight.

**EXHIBIT TITLE A Deep Learning Approach for Activity based Detection**  
Is Electricity Needed for Display?  YES  NO

Capable Every Word in Title (maximum of 84 characters)

**STUDENT PROJECT INFORMATION**

Name of Parent/Guardian <u>Last</u> <u>Adriya</u> <u>M.</u> Grade <u>11</u> Age <u>16</u>	School <u>Cumbria Valley HS</u> School Phone <u>717-343-8261</u>
Home Address <u>12 Hanover CR</u> <u>Mechanicsburg</u> City <u>17050</u> Zip Code	E-mail Address <u>Skandivalya@gmail.com</u>
PRINT all information	

1. STUDENT EXHIBITOR INFORMATION

Please PRINT all information

**Capital Area Science and Engineering Fair**  
**Student Exhibitor Entry Form**

Project #



Please contact me by email, and we can schedule a conference on a date and at a time that fits your schedule.

Individual Conferences (November 5 – 22, 2019)

- Several days after school (dates posted each week)
- Daily at 7:30 AM during Resouce Period

#### Extra Help

- 3. Schedule a date & time to retake the assessment.
  - 2. Submit corrections for teacher review.
  - 1. Make corrections to the original test/quiz.
    - ◆ Within ONE WEEK of receiving the graded original assessment, students should...
      - ◆ Only one assessment may be retaken each marking period.
- ♦ Retake Policy: Students may retake an individual assessment under the following conditions.
- had a chance to review or ask questions about the material in class.
- understanding of assigned practice problems. These checks/quizzes will only be given after students have learned in class. Periodic (approximately weekly) homework checks and/or quizzes will monitor student selected to give students an opportunity to both reinforce and extend their understanding of concepts.
- Homework is assigned almost daily and is essential practice for concept mastery. Problems are carefully graded to give students an opportunity to both reinforce and extend their understanding of concepts.

#### Grading

- Individual Grades and Marking Period Averages
  - and any special assignments or projects
  - Calendar listing daily homework assignments, tests/quizzes,
  - Answer Keys
  - Class Notes
  - Schoolology Resources
- Major Units of Study: Collecting Data Descriptive Statistics Inferential Statistics Methods of Data Collection Summary Statistics Linear Regression Sampling Techniques Graphical Displays Hypothesis Testing Confidence Intervals

#### Schoolology Resources

Online course materials (including calendar) available through Schoolology.

Mrs. Anne Rogalski [arogalski@cvschools.org](mailto:arogalski@cvschools.org)

# The Science and Art of Data

## Statistics:

Complete this sheet and place it atop your completed forms before you scan and submit them.

## CV Approval Cover Sheet

Name: Aditya Kendre

Email: kendreaditya@gmail.com

Billing: CVHS Grade: 11

Sponsor initials:

AC

1: Adult Sponsor Checklist - Sponsor and Signer Signature

AC 1A: Student Checklist - Student and Project Details, plus the separate type-written Research plan (i.e. title, problem, hypotheses, materials, procedure, and analysis) with five-source Bibliography.

AC 1B: Approval form - Signatures of student and parent/guardian, as well as signatures of SRC or IRB if required.

### Potential forms: Determined with your sponsor by using the Form Wizard.

AC 2: Quantified Scientist form - may be needed for projects that have human participants, vertebrate animals, potentially hazardous biological agents (including microbes) and DE-A-controlled substances.

AC 3: Risk Assessment form - required by the CV IRB in order to determine if the project involves hazardous chemicals (not found in a typical high school chemistry laboratory setting), hazardous activities or devices (i.e. weapons), and microorganisms that are not exempt from pre-approval.

AC 4: Human Participants form - ALL projects that use human participants.

AC 5A: Vertebrate Animal - ALL non-exempt vertebrate projects conducted at home/school/field site

AC 5B: Vertebrate Animal - for vertebrate projects conducted in a Regulated Research Institution

AC 6A: Potentially Hazardous Biological Agents Risk Assessment - needed for microorganisms, DNA,

AC 6B: Human and Vertebrate Animal Tissue - for projects that use fresh/frozen tissues (including primary cell lines, human and other primate established cell lines and tissue cultures), blood, blood products and body fluids

AC 7: Contamination/Research Progression - Required for projects that are a continuation/progression in the same field of study as a previous project for this student. NOTE: The previous year's abstract and research plan must be included with the form.

<p><b>Risk Assessment Form (3)</b></p> <p>Must be completed before experimentation.</p>	
<p>Student's Name(s) <u>Aditya Kendre</u></p>	
<p>Title of Project <u>A Deep Learning Approach for Arrhythmia Detection</u></p>	
<p>To be completed by the Student Researcher(s) in collaboration with Designated Supervisor/Qualified Scientist</p>	
<p>1. List all hazardous chemicals, activities, or devices that will be used; identify microorganisms exempt from pre-approval (see Potentially Hazardous Biological Agent rules).</p>	
<p>2. Identify and assess the risks involved in this project.</p>	
<p>3. Describe the safety precautions and procedures that will be used to reduce the risks.</p>	
<p>4. Describe the disposal procedures that will be used (when applicable).</p>	
<p>5. List the source(s) of safety information.</p>	
<p>Not Applicable</p>	
<p>To be completed and signed by the Designated Supervisor (or Qualified Scientist, when applicable):</p>	
<p>I agree with the risk assessment and safety precautions described above. I certify that I have reviewed the Research Plan/Project Summary and will provide direct supervision.</p>	
<p>Date of Review (mm/dd/yy) <u>1-25-20</u></p>	
<p>Designated Supervisor's Printed Name <u>Nivuth Kendre</u></p>	
<p>Signature </p>	
<p>Position &amp; Institution <u>Software Engineer</u></p>	
<p>Phone or email contact information <u>nivukendre@gmail.com</u></p>	
<p>Experience/Training as relates to the student's area of research <u>Some. Scienctific Experience</u></p>	

Date 1/15/2020 Signature of Sponsor C. M.

Date 1/15/2020 Signature of Parent R. W.

Date 1/15/2020 Signature of Student R. W.

he/she receive a First Award at the Region 4 Competition.

we agree to make every attempt to have the student present at the Region 4 Competition and at the State Competition should we expect a judge's evaluation of this research as final. In addition, we agree to ensure a fair result. Using specifically designed rubrics along with orientation of judges, our judging committees do an exceptional job to evaluate the student's research as final. In addition, PJAIS tries to make the evaluations as objective as possible. Using specifically designed rubrics along with orientation of judges, our judging committees do an competition across the state will undoubtedly produce some results that are not expected. PJAIS tries to make the evaluations final submissions. Once the judging panel is released the score and award is final. The large number of participants and the awards are acceptable to the entire judging panel. If there is a disagreement before the rectified before the judges cannot be "rejudging" of any presentations. Judges are polled before submitting their final results to ensure that the scores apply. First, all presentations must take place on that site. Secondly, the results are deemed final. There the presenters, judges, and supporters converge on the specific venue on a specific date, certain restrictions must surrounding the competition site. The Regional and State competitions are held at a central location on a single day. In that science rules and with advice only from others. PJAIS at the regional and the state level utilizes judges from the area surrounding the competition site.

We certify that this research has been conducted by the student in accordance with the Pennsylvania Junior Academy of Science rules and with advice only from others. PJAIS at the regional and the state level utilizes judges from the area surrounding the competition site.

<input type="checkbox"/> Biochemistry (BC)	<input type="checkbox"/> Behavioral/Psychology (BEH)	<input checked="" type="checkbox"/> Biology general (BIO)	<input type="checkbox"/> Chemistry (CHM)	<input type="checkbox"/> Computer (CPS)	<input type="checkbox"/> Earth and Space (ES)	<input type="checkbox"/> Ecology (EC)	<input type="checkbox"/> Mathematics (MAT)	<input type="checkbox"/> Microbiology (MIC)	<input type="checkbox"/> Physics (PHY)	<input type="checkbox"/> Zoology (ZOO)
<u>Mechanism of Drowsiness</u>										
<u>Hammertown</u>										
PA 17050										
City _____ State _____ Zip _____										

Research Area: Check the research area. If the research could overlap areas please rank as 1, 2, 3.

School Name: Cumbergland Valley HS Sponsor: Chris Trivin

(Must be exactly the same for every student)

1 2 3 4 5 6

Number of years in PJAIS (if this is your first year please circle 1)

4 Home Phone: 717-620-8444 Email: [kendricadihyak@gmail.com](mailto:kendricadihyak@gmail.com)

First Name <u>Aldithya</u>	Last Name <u>Kendric</u>	Gender <u>F</u>
Grade <u>11</u>	Region <u>4</u>	

Please type or print very neatly:

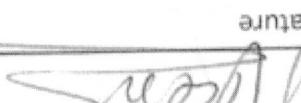
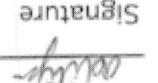
<p><b>Project Title:</b> A Deep Learning Approach for Arrhythmia Detection</p> <p><b>Student's Name(s):</b> Aditya Kende</p> <p><b>To be completed by the Adult Sponsor in collaboration with the student researcher(s):</b></p> <p>This completed form is required for All projects.</p> <p><b>Checklist for Adult Sponsor (1)</b></p>	
<p>I have reviewed the Intel ISEF Rules and Guidelines.</p> <p>I have reviewed the student's completed Student Checklist (1A) and Research Plan/Project Summary.</p> <p>I have worked with the student and we have discussed the possible risks involved in the project.</p> <p>The project involves one or more of the following and requires prior approval by an SRC, IRB, IACUC or IBC:</p> <ul style="list-style-type: none"> <li>■ Humans</li> <li>■ Potentially Hazardous Biological Agents</li> <li>■ Vertebrate Animals (see full text of the rules)</li> <li>■ Vertebrate Animal Form (5A) - for projects conducted in a school/home/field research site (SRC prior approval required)</li> <li>■ Vertebrate Animal Form (5B) - for projects conducted at a Regulated Research Institution. (Institutional Animal Care and Use Committee (IACUC) approval required prior experimentation)</li> <li>■ Qualifying Scientist Form (2) (when applicable)</li> <li>□ Human and Vertebrate Animal Tissue Form (6B) - to be completed in addition to Form 6A when project involves the use of fresh or frozen tissue, primary cell cultures, blood, blood products and body fluids.</li> <li>□ Potentially Hazardous Biological Agents Prior approval by SRC, IACUC or IBC; see full text of the rules.)</li> <li>□ Qualifying Scientist Form (2) (when applicable)</li> <li>□ The following are exempt from prior review but require a Risk Assessment Form 3: projects involving protocols, archive and similar microorganisms, for projects using manure for composting, fuel production or other non-cultural experiments, projects using color change colloidal water test kits, microbial fuel cells, and projects involving decomposing vertebrates, organisms.</li> <li>□ Hazardous Chemicals, Activities and Devices (No SRC prior approval required, see full text of the rules.)</li> <li>□ Risk Assessment Form (3)</li> <li>□ Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)</li> </ul>	
<p><b>Adult Sponsor's Printed Name</b> Christopher Irving</p> <p><b>Date of Review (mm/dd/yy)</b> 10/29/2019</p> <p><b>Signature</b> </p> <p><b>Email</b> civin@cvschools.org</p> <p><b>Phone</b> 717-736-2227</p>	<p><b>Phone</b> 717-736-2227</p>

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair		I certify that this project adheres to the approved Research Plan/Project Summary and complies with all Intel ISEF Rules.	
Date of Approval (mm/dd/yy)	Signature	Date of Approval (mm/dd/yy)	Signature
Regional SRC Chair's Printed Name		State/National SRC Chair's Printed Name (where applicable)	

### 3. Final Intel ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Chair's Printed Name		Date of Approval (mm/dd/yy)	Signature
Institutional approvals (e.g. IACUC, IRB). This project was conducted at a regulated research institution (not home or high school, etc.), was reviewed and approved by the proper institutional board before experimentation and complies with the Intel ISEF Rules. Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).		Date of Approval (mm/dd/yy)	Signature
The SRC/IRB has carefully studied this project's Research Plan/Project Summary and all the required forms are included. My signature indicates approval of the Research Plan/Project Summary before the student begins experimentation.		(Must be prior to experimentation.)	
OR		SRC/IRB Chair's Printed Name	
BEFORE experimentation (humans, vertebrates or potentially hazardous biological agents). b. Required for projects that need prior SRC/IRB approval		Date of Approval (mm/dd/yy)	Signature

### 2. To be completed by the local or affiliated Fair SRC

Students' Printed Name		Date Acknowledged (mm/dd/yy)	Signature
b. Parent/Guardian Approval: I have read and understand the risks and possible dangers involved in the Research Plan/Project Summary. I consent to my child participating in this research. (Must be prior to experimentation)		Nirvutti Kendre  10/24/2014 (Must be prior to experimentation)	
a. Student Acknowledgment: • I have read and will abide by the following Ethics statement • I understand the risks and possible dangers to me of the proposed research plan. • I have read the Intel ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research. • Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent misconduct are not condoned at any level of research or competition. Such practices include but are not limited to misconduct that fail to qualify for competition in affiliated fairs and the Intel ISEF.		Aditya Kendre  10/24/2014 (Must be prior to experimentation)	
Parent/Guardian's Printed Name		Date Acknowledged (mm/dd/yy)	Signature

A completed form is required for each student, including all team members.	
<b>Approval Form (1B)</b>	

## Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader:	Aditya Kende	Grade:	11
b. Team Member:			
c. Team Member:			
2. Title of Project:	A Deep learning Approach for Arrhythmia Detection		
3. School:	Cumberland Valley HS	School Phone:	+1 717 697 9261
School Address:	Mechanicsburg, PA 17050		
4. Adult Sponsor:	Christopher Trun	Phone/Email:	christ@cvschools.org
5. Does this project need SRC/IRB/IACUC or other pre-approval?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	Tentative start date: 12/1/2019
6. Is this a continuation/progression from a previous year?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	If Yes:
a. Attach the previous years <input type="checkbox"/> Abstract and <input type="checkbox"/> Research Plan/Project Summary	b. Explain how this project is new and different from previous years on <input type="checkbox"/> Continuation/Research Progression Form (7)		
7. This year's laboratory experiment/data collection:	<input type="checkbox"/> Actual Start Date: (mm/dd/yy) 12/21/2019 <i>Alternative dates available</i>		
8. Where will you conduct your experimentation? (check all that apply)	<input type="checkbox"/> Research Institution <input type="checkbox"/> School <input type="checkbox"/> Field <input checked="" type="checkbox"/> Home <input type="checkbox"/> Other:		
9. List name and address of all non-home and non-school work site(s):	<hr/> <hr/> <hr/> <hr/>		
10. Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions	<hr/> <hr/> <hr/> <hr/>		
11. An abstract is required for all projects after experimentation.	and attach to this form.		

Finalist Signature

Date

3/14/21

Finalist Signature

Date

3/14/21

use of my likeness or information as described in this release.

Society for Science, Regeneron and ISEF sponsors are not obligated to use nor provide compensation for any to the public posting of my abstract information and material, in the Society's sole discretion. I understand that name in connection therewith and agree that I will cooperate with publicity of the Regeneron ISEF. I also agree sponsors for the purposes of illustration, advertising or publication in any manner. I consent to the use of my or likenesses of me that may be used by Society for Science, Regeneron Pharmaceuticals, Inc., or other ISEF and any other written materials and social media postings submitted by me as well as any photographs, videos I agree that appropriate information about me may be used for publicity purposes. This includes my abstract media before, during and after the Regeneron ISEF.

request your availability and cooperation when contacted, interviewed, photographed and videotaped by the Finalist at Regeneron ISEF, the Society also reserves the right to publicly publish a Finalist's abstract. We photographs or information about you in written reports or online publications and listings. By participation as a the Regeneron ISEF may wish to publicize their involvement in the Regeneron ISEF, which may include using Society for Science, Regeneron Pharmaceuticals, Inc., and organizations and businesses sponsoring awards at

## Publicity

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not accept any liability related to my participation in the Regeneron ISEF.

I have read the above paragraph and understand and accept that the ISEF indemnified Entities cannot and will not accept any liability related to my participation in the Regeneron ISEF.

In consideration of Finalist's participation in the Regeneron ISEF, Finalist and Finalist's Parent/Legal Guardian agree to release, indemnify, and hold harmless Society for Science, Regeneron Pharmaceuticals, Inc., and any other sponsors, their employees, agents, contractors, affiliated entities (including public day organizations) collectively, the ISEF indemnified Entities) from and against any and all liability for any injuries, loss, harm, damage, cost, or expense of any kind, including, without limitation, property damage, personal injury, and/or death, arising in whole or in part, directly or indirectly, from Finalist's participation in the Regeneron ISEF or (collectively, the Regeneron ISEF) from and against any and all liability for any injuries, loss, harm, damage, cost, or expense of any kind, including, without limitation, property damage, personal injury, and/or death, arising in whole or in part, directly or indirectly, from Finalist's participation in the Regeneron ISEF or Finalist's acceptance, receipt, use, and/or misuse of any prize awarded to Finalist.

## Limitation of Liability

All finalists MUST return this form with their Regeneron ISEF paperwork to compete at the Regeneron ISEF 2021.

Please read the following carefully, sign and obtain the signature of a parent or legal guardian.

## Releases

Regeneron International Science and Engineering Fair 2021

Name of Finalist: *Aleliya Kenarue* Fair ID: USPA01

## Code of Conduct

### Regeneron International Science and Engineering Fair 2021

Name of Finalist: Adithya Kendale  
Fair ID: USPA01

Please read the following carefully, sign and obtain the signature of a parent or legal guardian.  
ALL finalists MUST return this form with their Regeneron ISEF paperwork to compete at the Regeneron ISEF 2021.

#### 1. As a finalist of Regeneron ISEF, I agree to:

- a. Be in compliance with the Society for Science-harassment policy. In this online format, I recognize that harassment includes cyberbullying, trolling, the use of bad language, personally explicit language or imagery, political attacks, racist language or imagery, personal attacks and posts that demean, insult, threaten or belittle others' work. I recognize my responsibility to report any such harassment by others in good faith of healthy dissource. Report any incident immediately.
  - b. Be responsible in listing, viewing or reading carefully before commenting. When posting I will be thoughtful and civil and will provide only constructive feedback.
  - c. Be respectful of differing viewpoints and experiences and to be collegial and respectful in any questions or comments I post.
  - d. Refrain from solicitation of any kind.
2. I further understand that a Finalist guilty of any of the following will fail to qualify or will forfeit all awards received and may be banned from all future participation in the Society programs:  
a. Presents another researcher's work as one's own and/or fabricates data.  
b. Submits a project or abstract that does not reflect independent student research from the current research period.  
c. Makes changes to their project after final clearance by the SRC and Display and Safety checks.
3. Appropriate attire is expected. Business attire is not required, but please plan to wear a shirt that does not include any graphics or logos.

4. All finalists will be given the date and a 3-hour period of time for judging between May 3-6, 2021 dependent on the schedule of their category. Preferences will be taken into account for one of 3 - 3 hour time periods to accommodate time zone differences. To compete and be eligible for awards, a finalist must be in attendance via video conference during their scheduled 3-hour period.
5. The activities of Regeneron ISEF 2021 will be held from May 16-21 and all finalists are encouraged to participate in all events.

I have read and understand the above rules and agree to adhere to them to the best of my ability. I understand that failure to meet these standards may result in being removed from the event and banned from future events.

Date: 3/14/21  
Signature:

Date: 3/14/21  
Finalist Signature:

Date: 3/14/21  
Parent/Legal Guardian Signature:

Project Title: Generative Adversarial Networks for PGG Arrhythmia Detection		Students Name(s): <b>Aditya Kendale</b>																																														
To be completed by the Adult Sponsor in collaboration with the student researcher(s):																																																
<p><b>Checklist for Adult Sponsor (1)</b></p> <p>This completed form is required for ALL projects.</p>																																																
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## Student Checklist (IA)

This form is required for ALL projects.

1. Student/Team Leader: <b>Aditya Kendre</b>	Grade: <b>12</b>	Email: <b>Kendreaditya@gmail.com</b>	Phone: <b>(717) 622-1281</b>	b. Team Member: _____ c. Team Member: _____
Generative Adversarial Networks for PCG Arrhythmia Detection				
2. Title of Project:				
3. School: <b>Cumberland Valley High School</b> School Phone: <b>(717) 506-3413</b> School Address: <b>6746 Carlisle Pike Mechanicsburg, PA 17050</b> Phone/E-mail: <b>miforeck@cvcschools.org</b>				
4. Adult Sponsor: <b>Mike Floreck</b> Phone/E-mail: <b>miforeck@cvcschools.org</b>				
5. Does this project need SRC/IRB/IACUC or other pre-approval? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Tentative start date: _____				
6. Is this a continuation/progression from a previous year? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No If yes: _____				
a. Attach the previous years' <input checked="" type="checkbox"/> Research and <input type="checkbox"/> Abstract and <input checked="" type="checkbox"/> Research Plan/Project Summary				
b. Explain how this project is new and different from previous years on <input checked="" type="checkbox"/> Continuation/Research Progression Form (7)				
7. This year's laboratory experiment/data collection: _____				
8. Source of Data: _____				
9. List name and address of all non-home and non-school work site(s):  <input type="checkbox"/> Collected self/mentor <input checked="" type="checkbox"/> Other Describe/url: <b>Physionet Database</b>				
10. Complete a Research Plan/Project Summary following the Research Plan/Project Summary Instructions  Name: _____ Address: _____ Phone: _____ Email: _____				
11. An abstract is required for all projects after experimentation.  and attach to this form.				



6. I/we hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.

yes  no  
myself:  yes  no

5. My display board includes non-published photographs/visual depictions of humans (other than

yes  no  
This project is a continuation of previous research.

4. We worked or used equipment in a regulated research institution or industrial setting.

yes  no

2. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only.

yes  no  
Human participants  vertebrate animals  microorganisms  DNA  tissue  
Potentially hazardous biological agents

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check all that apply):

<input type="checkbox"/>	Sciences
<input type="checkbox"/>	Translational Medical
<input type="checkbox"/>	Systems Software
<input type="checkbox"/>	Machines
<input type="checkbox"/>	Robotics & Intelligent
<input type="checkbox"/>	Plant Sciences
<input type="checkbox"/>	Physics and Astronomy
<input type="checkbox"/>	Microbiology
<input type="checkbox"/>	Mathematics
<input type="checkbox"/>	Materials Science
<input type="checkbox"/>	Environmental Engineering
<input type="checkbox"/>	Engineering Mechanics
<input type="checkbox"/>	Materials and Design
<input type="checkbox"/>	Energy: Sustainable
<input type="checkbox"/>	Embedded Systems
<input type="checkbox"/>	Electronics
<input type="checkbox"/>	Earth & Environmental
<input type="checkbox"/>	Bioinformatics
<input type="checkbox"/>	Computational Biology and
<input type="checkbox"/>	Chemistry
<input checked="" type="checkbox"/>	Cellular & Molecular Biology
<input type="checkbox"/>	Biomedical Engineering
<input type="checkbox"/>	Typically, Electrocardiograms are used to diagnose arrhythmias, requiring medical-grade equipment to detect arrhythmias in Phonocardiograms (PCGs).
<input type="checkbox"/>	Propose a novel approach to detect arrhythmias in Phonocardiograms (PCGs), with the rapid growth of computational power and complex algorithms, we
<input type="checkbox"/>	Aditya Kende
<input type="checkbox"/>	Cumberland Valley HS, Mechanicsburg, PA, USA
<input type="checkbox"/>	Category
<input type="checkbox"/>	Pick one only--
<input type="checkbox"/>	mark an "X"
<input type="checkbox"/>	in box at right
<input type="checkbox"/>	Animal Sciences
<input type="checkbox"/>	Biotechnology
<input type="checkbox"/>	Behavioral and Social Sciences
<input type="checkbox"/>	Biochemistry
<input type="checkbox"/>	Biomedical Health Sciences
<input type="checkbox"/>	Cellular & Molecular Biology
<input type="checkbox"/>	Chemical Engineering
<input type="checkbox"/>	Computer-Aided Cardiac Illnesses. PCGs provide ease of access to everyone who has a device capable of recording audio, allowing medical professionals to treat arrhythmias in the development stages. The new design compares two subsystems; one is based on the relationship between arrhythmias. The association between PCGs and PCGs is amended to translate from one space to another, where PCGs become dimensionally reduced, then reconstructed into a PCG signal. The second subsystem uses a Generative Adversarial Networks (GAN), in which both arbitrary PCG signals are generated, and preexisting ECG datasets are re-created into PCG signals (using subsyste
<input type="checkbox"/>	than ECG data; hence, more heart diagnostics can be made.
<input type="checkbox"/>	one). These signals are fed into a classifier that detects if an arrhythmia is present. This proposed system's advantage is that PCG data is more readily available than ECG data.
<input type="checkbox"/>	and preexisting ECG datasets are re-created into PCG signals (using subsyste
<input type="checkbox"/>	one). These signals are fed into a classifier that detects if an arrhythmia is present. This proposed system's advantage is that PCG data is more readily available than ECG data.
<input type="checkbox"/>	available than ECG data; hence, more heart diagnostics can be made.

arrhythmias in Phonocardiograms?

**Question.** Is it possible to create a model capable of surpassing the accuracy of Cardiologists in identifying heart

present within a patient.

**Problem Statement.** Every physical examination done with a stethoscope should aim to diagnose any arrhythmias

## 1 Introduction

is more readily available than ECG data; hence, more heart diagnostics can be made. Classifier that detects if an arrhythmia is present. This proposed system's advantage is that PCG data classifiers are re-created into PCG signals (using subsystem one). These signals are fed into a ECG datasets are re-created into arbitrary PCG signals (using subsystem one). The second subsystem uses a Generative Adversarial Networks (GAN), in which both arbitrary PCG signals are generated, and preexisting dimensionsally reduced, then reconstructed into a PCG signal. The second subsystem uses a Generative between ECGs and PCs is amended to translate from one space to another, where ECGs become Electrocardiograms (ECGs) and PCs, and the other between PCs and arrhythmias. The association stages. The new design comprises two subsystems; one is based on the relationship between capable of recording audio, allowing medical professionals to treat arrhythmias in the developmental stages. The new design comprises two subsystems; one is based on the relationship between (Rajpurkar et al., 2017). PCs, however, provide ease of access to everyone who has a device to detect arrhythmias in Phonocardiograms (PCGs). Typically, Electrocardiograms are used to diagnose arrhythmias; requiring medical grade equipment to accurately recognize cardiac illnesses With the rapid growth of computational power and complex algorithms, we propose a novel approach

## ABSTRACT

January 3, 2021

Mechanicsburg, PA 17050

Cumberland Valley High School

Aditya Kende

## ARRHYTHMIA DETECTION

## GENERATIVE ADVERSARIAL NETWORKS FOR PCG

The training phase involves 3 stages: AE training, AE+GAN training, and GAN fine-tuning. During training phases, all datasets will follow the following split: 70% - training, 15% - validation, 15% - testing; this cross-validation step validates that both models are not overfitting during the training phase. The first stage involves training the AE with a supervised dataset of ECG and PCG signals (Liu et al., 2016). The second stage involves training the AE and the

The model contains two sub-models, an Autoencoder (AE), and a Generative Adversarial Network (GAN). The AE is responsible for extracting relevant features from an ECG signal and constructing a PCG signal from the latent features. The GAN is responsible for extracting relevant features from an ECG signal and classifying the PCG signals.

2.1 Approach

2 Methodology

Current PCG arrhythmia diagnostics methods only recognize between Normal and Abnormal (binary classification), providing minimal information about what is present within the PCG signal (Aziz et al., 2020). This is because no PCG datasets exist that include more than 3 classes of arrhythmia. Therefore, it is necessary to transform pre-existing PCG datasets with multiple classes to PCG signals. This enables models to detect a larger range of arrhythmia without explicitly collecting new PCG recordings. Currently, no technology attempts to construct PCG signals from existing BCG data.

Electrocardiograms have created a profound impact in the field of cardiology, specifically in recognizing heart arrhythmias, a problem with the rhythm of one's heartbeat. Noninvasive arrhythmia analysis is based on multiple electrodes that reflect the electrical activity on ECGs. However, with the recent surge of heart-related medical cases, it is getting difficult to diagnose heart conditions at an early stage. As most treatments rely on detecting the disease in its infancy stages. Traditionally, arrhythmias are diagnosed by cardiologists by analyzing ECG recordings (Jordáens, 2018). Some clinics have adopted a new technique in which ECG and PCG signals are simultaneously recorded and then computationally analyzed. This, however, still requires an instrument capable of recording ECG data. Such instruments are only available during scheduled appointments, often which are recommended by physicians. If a physician fails to detect symptoms of arrhythmia, a patient may never receive a diagnosis. One study found 44% of cardiologists were not able to detect common cardiac events with stethoscopes (Mangirolle et al., 1993); in another study, delays in cardiac-related illnesses diagnosis and treatment impacted procedural success rates by as much as 24% (Bunck et al., 2013). We propose a method where it is now possible to accurately detect arrhythmias with only PCG recordings. This provides an opportunity for physicians to check for potential developments of cardiac arrhythmias at every physical

Materials List. Computer.

Network's, to identify heart arrhythmias in Phonocardiograms.

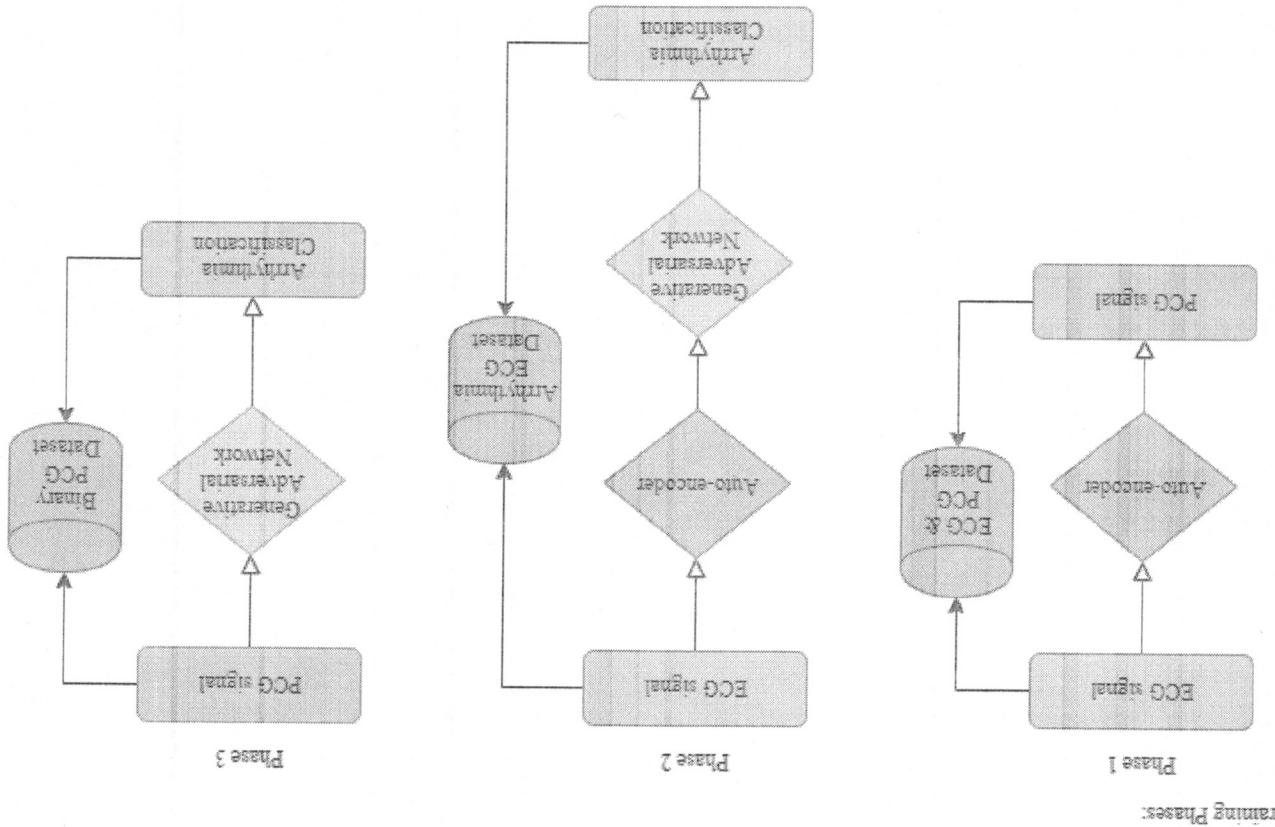
**Hypothesis:** It is possible to exceed the accuracy of Cardiologists when compared to that of a Generative Adversarial

**Overfitting:** One of the largest problems in Deep Learning overall, which possesses a threat to our model is overfitting. Overfitting typically happens when the model metrics of the training and validation set diverge. This suggests that the model is not generalizing, but rather memorizing the training dataset. To combat overfitting, researchers typically implement data augmentation techniques to reinforce important features in a dataset.

## 2.3 Potential Problems

While testing and training, the model will be validated against such metrics such as recall, precision, accuracy, loss, Fbeta, F1 score, and ROC/AUC score. These tests will ensure that the model is accurately predicting the classes, and identify important features within the datasets. Each step in the training phase will represent a milestone and an accuracy of 97% will mark the completion criteria.

## 2.2 Data Analysis



GAN with a supervised dataset of arrhythmias within ECGs (Goldberger et al., 2017). During the training process, the AE model will be frozen (the weights and biases of the AE model won't be trained) as this process is already done in the preceding stage. The last stage is fine-tuning the GAN on a binary supervised dataset of PCG signals (Normal vs Abnormal). This validates the model's metrics in the previous step.

- Domain Shift:** A domain shift occurs when a source dataset performs well but on a different dataset distribution, the performance drastically decreases. Typically, domain adaptation is often used to improve performance on target datasets. This is done by training the model itself on multiple datasets to improve the model's capacity to generalize.
- Training Time:** With large multi-model architectures, it becomes tough to train models on a single GPU. This can happen for a number of reasons, but the main reason is because the model takes up too much memory of the GPU. Generally, parallel processing is used to split tasks and assign them to different GPUs. For instance, the AE model will run on a single GPU, while the GAN will run on another GPU.
- [1] Jordaghe, L. (2018). A clinical approach to arrhythmias revisited in 2018. *Netherlands Heart Journal*, doi:10.1007/s12471-018-1089-1
- [2] Mangione, S. (1993). The Teaching and Practice of Cardiac Auscultation during Internal Medicine and Cardiology Training: A Nationwide Survey. *Annals of Internal Medicine*, 119(1), 47. doi:10.7326/0003-4819-119-1-19930701-
- [3] Bunch, T. J., May, H. T., Baer, T. L., Johnson, D. L., Weiss, J. P., Crandall, B. G., ... Day, J. D. (2013). Increasing time between first diagnosis of atrial fibrillation and catheter ablation adversely affects long-term outcomes. *Heart Rhythm*, 10(9), 1257-1262. doi:10.1016/j.hrtm.2013.05.013
- [4] Aziz, S., Khan, M. U., Alhaisoni, M., Akram, T., Alfat, M. (2020). Phonocardiogram Signal Processing for Automatic Diagnoses of Congenital Heart Disorders through Fusion of Temporal and Cepstral Features. *Sensors*, 20(13), 3790. doi:10.3390/s20133790
- [5] Felipe Alonso, "Detection of life threatening arrhythmias using feature selection and support vector machines", IEEE Transactions on Biomedical Engineering, Vol 61No.3,pp.832-840, March 2014.

## References

- A PREPRINT - JANUARY 3, 2021

<p><b>1. To Be Completed by Student and Parent</b></p> <p>a. Student Acknowledgment:</p> <ul style="list-style-type: none"> <li>• I have read and will abide by the science fair ethics statement.</li> <li>• I understand the risks and possible dangers to me of the proposed research plan.</li> <li>• I have read the ISFE Rules and Guidelines and will adhere to all International Rules when conducting this research.</li> <li>• Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and ISFE.</li> </ul> <p>Student's Printed Name <u>Aditya Kendre</u> Signature <u>aditya</u> Date Acknowledged (mm/dd/yy) <u>10/29/20</u></p> <p>b. Parent/Guardian Approval:</p> <ul style="list-style-type: none"> <li>• I have read and understand the risks and possible dangers involved in the Research Plan/Project Summary. I consent to my child participating in this research.</li> </ul> <p>Parent/Guardian's Printed Name <u>Nirvutti Kendre</u> Signature <u>Nirvutti</u> Date Acknowledged (mm/dd/yy) <u>10/29/20</u></p> <p>(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)</p> <p><b>2. To be completed by the local or affiliated Fair SRC</b></p> <p>a. Required for projects that need prior SRC/IRB approval</p> <p>b. Research conducted at all Regulated approval</p> <p>This project was conducted at a regulated research institution (not home or high school, etc.), was reviewed and approved by the proper institutional board before experiment and complies with the ISFE Rules. Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).</p> <p>The SRC/IRB has carefully studied this Project's Research Plan/Project Summary and all the required forms are included. My signature indicates approval of the Research Plan/Project Summary before the student begins experimentation.</p> <p>SRCC/IRB Chair's Printed Name _____ Signature _____ Date of Approval (mm/dd/yy) _____</p> <p><b>3. Final ISFE Affiliated Fair SRC Approval (Required for ALL Projects)</b></p> <p>a. Required for projects that need prior SRC/IRB approval</p> <p>b. Research conducted at all Regulated approval</p> <p>This project was conducted at a regulated research institution (not home or high school, etc.), was reviewed and approved by the proper institutional board before experiment and complies with the ISFE Rules. Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).</p> <p>The SRC/IRB has carefully studied this Project's Research Plan/Project Summary and all the required forms are included. My signature indicates approval of the Research Plan/Project Summary before the student begins experimentation.</p> <p>SRCC/IRB Chair's Printed Name _____ Signature _____ Date of Approval (mm/dd/yy) _____</p> <p><b>SRC Approval After Experimentation and Before Competition at Regional/State/National Fair</b></p> <p>I certify that this project adheres to the approved Research Plan/Project Summary and complies with all ISFE Rules.</p> <p>State/National SRC Chair's Printed Name _____ Signature _____ Date of Approval (mm/dd/yy) _____</p> <p>Regionals SRC Chair's Printed Name _____ Signature _____ Date of Approval (mm/dd/yy) _____</p> <p>Where applicable)</p>	
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A completed form is required for each student, including all team members.

## Approval Form (1B)

International Rules: Guidelines for Science and Engineering Fairs 2020-2021, [societyforscience.org/ISEF2021](http://societyforscience.org/ISEF2021)

Experiments/Training as relates to the student's area of research

<p><b>To be completed and signed by the Designated Supervisor (or Qualified Scientist, when applicable):</b></p> <p>I agree with the risk assessment and safety precautions and procedures described above. I certify that I have reviewed the Research Plan/Project Summary and the International Rules, including the science fair ethics statement and will provide direct supervision.</p>	
<p>Designated Supervisor's Printed Name</p>	<p>Date of Review (mm/dd/yy)</p>
<p>Signature</p>	<p>Phone or email contact information</p>
<p>Position &amp; Institution</p>	

N/A

5. List the source(s) of safety information.

N/A

4. Describe the disposal procedures that will be used (when applicable).

N/A

3. Describe the safety precautions and procedures that will be used to reduce the risks.

N/A

2. Identify and assess the risks and hazards involved in this project.

The only device used in this research project is a laptop.

1. List all hazardous chemicals, activities, or devices that will be used; identify microorganisms exempt from pre-approval (see Potentially Hazardous Biological Agent rules).

**Scientist:** (All questions must be answered; additional page(s) may be attached.)

To be completed by the Student Researcher(s) in Collaboration with Designated Supervisor/Qualified

Title of Project Generative Adversarial Networks for PCG Arrhythmia Detection

Student's Name(s) Aditya Kende

Must be completed before experimentation.

### Risk Assessment Form (3)

Components		Current Research Project Previous Research Project: Year: 19-20	Complementary Title ECG-Based Abnormal Heartbeat Classification: A Deep Learning Approach for Arrhythmia Detection PCG Arrhythmia Detection Genetic Adversarial Networks for ECG-Based Abnormal Heartbeat Classification: A Deep Learning Approach for Arrhythmia Detection To create a model capable of surpassing the accuracy of Cardiologists in identifying heart arrhythmias in Phonocardiograms using a Generative Adversarial Network A Generative Adversarial Network comprises a classifier model (which contains a convolutional Neural Network). The generator creates artificial PCG data to deceive the classifier into predicting the data from a dataset. Data augmentation. Manipulated variables include: Number of layers, Hidden Units, and the level of Data Augmentation. Hidden Units, Activation Functions, and level of Data Augmentation. ROC and AUC. Responding variables include: Loss, Accuracy, Recall, Precision, F-Beta Score, F1 Score, and Accuracy.	3. Changes in methodology A Convolutional Neural Network extracts latent features from an ECG signal. It follows a fully-connected Linear layer that predicts whether an arrhythmia is present within the electrocardiogram, based upon the features extracted by the CNN. Manipulated variables include: Number of layers, Hidden Units, and the level of Data Augmentation. Hidden Units, Activation Functions, and level of Data Augmentation. ROC and AUC.	4. Variable studied Manipulated variables include: Learning Rate, Batch size, Number of Epochs, Hidden Layers, and Accuracy. Responding variables include: Loss and Accuracy.	5. Additional changes ECG signal with a one-dimensional CNN. Converts between ECG and PCG signals using an Autoencoder.	Students Printed Name(s) Aditya Kendre Signature 10/30/20	Date of Signature (mm/dd/yy) 19-20
<p>I hereby certify that the above information is correct and that the current year Abstract &amp; Certification and project display board properly reflect work done only in the current year.</p> <p><input checked="" type="checkbox"/> Attached are: Abstract and Research Plan/Project Summary, Year: 19-20</p>								

To be completed by Student Researcher: List all components of the current project that make it new and different from previous research. The information must be on the form; use an additional form for previous year and earlier projects.

Students Name(s) Aditya Kendre

This form must be accompanied by the previous year's abstract and Research Plan/Project Summary.  
Required for projects that are a continuation/progression in the same field of study as a previous project.

## Continuation/Research Progression Projects Form (7)

<b>Required forms: These forms must be completed for All projects.</b>		
<b>Name:</b>	Aditya Kendre	
<b>Email:</b>	kendreaditya@gmail.com	
<b>Buidling:</b>	CVHS	Grade: 12
<b>Sponsor:</b>	Michael Floreck Email: mffloreck@cvschools.org	
<b>1: Adult Sponsor Checklist - Sponsor Initials</b>		
1A: Student Checklist – Student and Project Details, plus the separate type-written Research Plan (i.e. title, problem, hypothesis, materials, procedure, and analysis) with five-source Bibliography.		
1B: Approval form – Signatures of student and parent/guardian, as well as signatures of SRC or IRB if required.		
3: Risk Assessment form – required by the CV IRB in order to determine if the project involves hazardous chemicals (not found in a typical high school chemistry laboratory setting), hazardous activities or devices (i.e. weapons), and microorganism that are not exempt from pre-approval.		
2: Qualified Scientist form – may be needed for projects that have human participants, vertebrate animals, potentially hazardous biological agents (including microbes) and DEA-controlled substances.		
4: Human Participants form – ALL projects that use human participants.		
5A: Vertebrate Animal – ALL non-exempt vertebrate projects conducted at home/school/field site		
5B: Vertebrate Animal – for vertebrate projects conducted in a Regulated Research institution		
6A: Potentially Hazardous Biological Agents Risk Assessment – needed for microorganisms, RNA, cell lines, human and other primate established cell lines and tissue cultures (including primary tissue cultures, blood, bone, blood products and body fluids).		
6B: Human and Vertebrate Animal Tissue – for projects that use fresh/frozen tissues (including primary cell lines, human and other primate established cell lines and tissue cultures, blood, bone, blood products and body fluids).		
7: Continuation/Research Progression – Required for projects that are a continuation/progression in the same field of study as a previous project for this student. NOTE: The previous year's abstract and research plan must be included with the form.		

## **CV Approval Cover Sheet**

Complete this sheet and place it atop your completed forms before you scan and submit them.

Signature of Student	Date	1/4/2021	Signature of Parent	Date	1/4/2021	Signature of Sponsor
----------------------	------	----------	---------------------	------	----------	----------------------

We certify that this research has been conducted by the student in accordance with the Pennsylvania Junior Academy of Science rules and with advice only from others. PJA'S at the regional and state level utilizes judges from the area surrounding the competition site. The Regional and State competitions are held at a central location on a single day. In that presentation, judges, and support personnel converge on the specific venues on a specific date, certain restrictions must apply. First, all presentations must take place on that day and on that site. Secondly, the results are deemed final. There cannot be "rejudging" of any presentations after the competition has ended. Using specifically designed rubrics along with orientation of judges, our judging committee does an exceptional job to ensure a fair result. We further agree to accept the judge's evaluation of this research as final. In addition, we agree to make every attempt to have the student present at the Region 4 Competition and at the State Competition should he/she receive a First Award at the Region 4 Competition.

Biochemistry (BC)	2	Behavioral/Psychology (BEH)	2	Botany (BOT)	1	Chemistry (CHM)	1	Ecology (EC)	3	Earth and Space (ES)	3	Mathematics (MAT)	2	Zoology (ZOO)	

Research Area: If research could overlap areas, please rank as 1, 2, 3.

School Name: Cumberland Valley HS  
 Research Title (limit to 60 characters): Generative Adversarial Networks for PPG Arrhythmia Detection  
 Sponsor: Michael Floreck

Number of years participated in PJA'S (include this year)    1    2    3    4    **5**    6

Aditiya	First Name	Kendrie	Last Name	Male	Gender	12	Grade	Email	Home Phone	4	Region	PA	City	Mechanicsburg	Student Address	17050	Zip Code
717-620-8494																	

Please type or print very neatly:

## 2021 PJA'S Region 4 Presenter Registration Form



STUDENT'S SIGNATURE: *Dawn*

Date: *1/29/04*

(3) Carnegie Mellon University

(1) Penn State

(2)

Lehigh University

List the three Colleges/Universities to which you would like recommendations sent (list only those to which you have applied or will apply): Students may provide the PSAT Director the full names of the colleges/universities up until November 30 of their senior year. Give the full name of the school.

How many years, including this year, have you entered projects in PJAS regional meetings?

Category: Computer Science

Project Title: Generative Adversarial Networks for PCG Arrhythmia Detection

College Board Scores (SAT, PSAT, or ACT): Math 710 Verbal N/A Writing 650

High School Address: 6746 Carlisle Pike, Mechanicsburg, PA 17050

Name of High School: Cumberland Valley HS Sponsor's Name: Mike Florek

Student's e-mail address: kendiraditya@gmail.com

Home Address: 12 Hamlet Circle City: Mechanicsburg Zip: 17050

Student's Name: Aditya Kendre Grade: 12 PJAS Region: 4

PLEASE PRINT

JUNIORS and SENIORS: A letter of recommendation from your science teacher or guidance counselor AND a copy of your high school transcript including first quarter grades for the current school year must be submitted with this form. Please include a copy of your official SAT, PSAT, or ACT scores if these are not listed on your transcript. You may wish to "white-out" your social security number if it appears on your transcript, and this is recommended.

STUDENTS: PLEASE READ THE FOLLOWING INFORMATION CAREFULLY BEFORE YOU FILL OUT THIS FORM.

INTERVIEW FORM

Pennsylvania Science Talent Search



Signature of Regional Director or Chairman of Judging Committee

Judges' Signatures

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In a few words, describe your impression of the student. Indicate your reasons for recommending him/her in terms that may be relayed to admissions officers.

**JUDGE'S COMMENTS:**

This student should not be \_\_\_\_\_ recommended for academic scholarship consideration.  
This student should be \_\_\_\_\_ recommended for academic scholarship consideration.

**FOR SENIORS:**

This student should not be \_\_\_\_\_ recommended for admission to the colleges listed.  
This student should be \_\_\_\_\_ recommended for admission to the colleges listed.

**FOR JUNIORS:**

**RECOMMENDATION:**

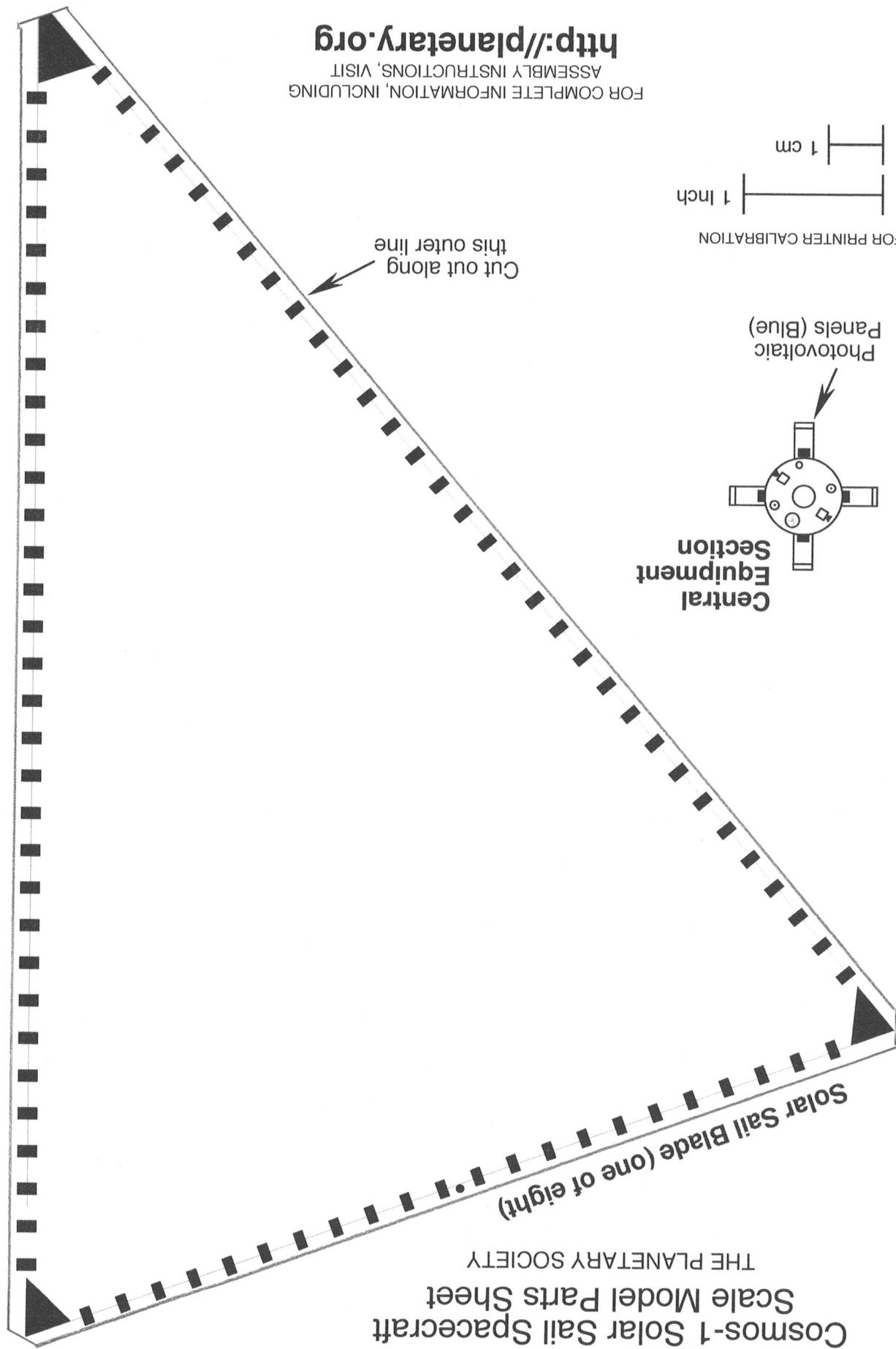
NO AWARD

FIRST AWARD

(Please check the appropriate circle.)

**PERFORMANCE IN REGIONAL PTA PRESENTATION:**

**TO BE COMPLETED BY THE JUDGES**



Early detection of cardiac arrhythmias has the potential to prevent the millions of mortalities that the disease causes globally. However, there are few automated systems to identify arrhythmias, but with the recent advancements in machine learning algorithms such as allow a model to learn features and identify patterns within a given technology. Hence, making it possible to automatically recognize diseases in ECGs, capable of identifying arrhythmias datasets. Machine learning algorithms such as allow a model to learn features and identify patterns within a given technology. Hence, making it possible to automatically recognize diseases in ECGs, capable of identifying arrhythmias datasets. Hence, making it possible to automatically recognize diseases in ECGs, capable of identifying arrhythmias datasets. However, despite this difficulty, processes like data augmentation allow for an increased amount and diversity of data. Here, the electrocardiogram (ECG) datasets were obtained from the PhysioNet database. The dataset was used to train a Convolutional Neural Network (CNN) on classifying cardiac arrhythmias. Experimental results illustrate advantages such as better responsiveness and higher accuracy of deep learning-based models when compared to the traditional analysis on ECGs.

**Summary:** Less than 250 word narrative paragraph and answer the following: What did you investigate? (Problem statement) How did you do it? (Experiment with control, independent and dependent variables, survey, behavioral observation, etc.) What did you expect? (hypotheses) Please type or attach typed copy:  
**What did you find out? (Conclusion statement)**

SET UP WITHOUT THIS FORM IN HARD COPY!! It must be checked and signed by a CASEF certifier. It must be displayed with the project at all times. To avoid disqualification, exhibits must meet certification requirements as stated in the ISEF rules.

IMPORTANT: This form MUST be completed and brought to set up. NO PROJECT WILL BE PERMITTED TO COMPETE UNLESS IT IS PRESENTED WITH THE CORRECT FORM.

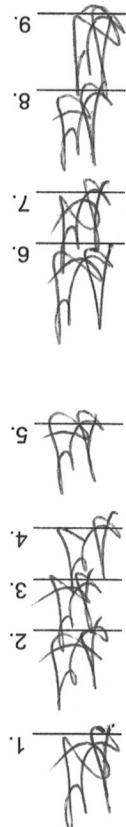
## Must Accompany Certification Checklist

PROJECT NUMBER SR-TEEM3-021

PROJECT TITLE A Deep Learning Approach for Arrhythmia Detection (84 character limit)

EXHIBIT IDENTIFICATION/PROJECT SUMMARY  
Capital Area Science and Engineering Fair



- 9.
  - 8.
  - 7.
  - 6.
  - 5.
  - 4.
  - 3.
  - 2.
  - 1.
- 

## Must Accompany Summary

### CASEF PROJECT CERTIFICATION

(To be completed by CASEF Certifier during set up of projects)

Project display is no more than **36 inches** in width  
Projects cannot exceed **30 inches** in depth or be more than **6 feet tall**.  
Projects cannot weigh more than **150 pounds**.

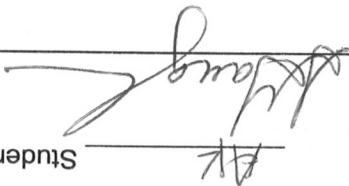
If electricity is needed, a grounded extension cord must be provided by student exhibitor.  
No living organisms (including plants, animals, or microbes); preserved vertebrate or invertebrate  
animals (including embryos); dried plant materials; taxidermy specimens or parts; human or animal parts; and human  
or animal food or wrappers/containers can be exhibited.

No soil or waste samples, chemicals, powders, or liquids (including water); food, poisons, drugs, controlled  
substances; dry ice or other sublimating substances; flammable or combustible materials; liquids of gases; and sharp  
hazardous, or dangerous items are displayed. No aggregate (concrete et al) substances can be displayed. No  
general laboratory equipment may display unless it is critical or unique to the final result or product (no scales,  
safety glasses, lab equipment, measuring devices, etc.). Any electronic devices needed to demonstrate project must

have prior approval to be carried in on judging day.  
Student name and school is **NOT** visible on display. Student number **SHOULD** be on display.

Neither early nor late entries will not be accepted. Understand that my project must stay on exhibit until after the  
award ceremony and failure to remove the display board will be removed after judging interviews.  
Project journal and research report are displayed on table in front of project. Electronic journals must be printed.  
Number. I understand the journal is 15% of the total score. Electronic journals must be printed.

Summary form and research journal displayed in front of project board.

  
Student(s) Initials

Signtature of CASEF Certifier

```
def pre_processing_data(data):
    for records in data:
        with open(records) as record:
            with open("ecg_file.in") as f:
                path = self.DATATECG_FILE[:: -1]
                metadata = open(path + ".head", "r").read().split("\n")
                ECGS = list(loadmat(path)[val[0]])
                for i in range(int(self.ECG_LENGTH+1)):
                    ECGS.insert(i, 0)
                ECGS.append(0)
                peaks = detect_beats(ECGS, float(metadata[2]))
                for peak in range(0, len(peaks),
                                  self.ECG_PER_SAMPLE):
                    ECG = ECGs[peaks[peak] - int(self.ECG_LENGTH/2):
                                peaks[peak] + int(self.ECG_LENGTH/2)]
                    ECG = (ECG + abs(np.min(ECG))) / np.max(ECG)
                    ECG = self.zero_padding(self.rnd_zero(ECG))
                    aug_ECG = (aug_ECG + abs(np.min(aug_ECG))) / np.max(aug_ECG)
                    aug_ECG = self.zero_padding(self.rnd_zero(aug_ECG))
                    aug_ECG = aug_ECG / np.array(aug_ECG)
                    self.data.append([np.array(aug_ECG)])
                self.records.append([self, LABELS[records]])
```

```
def pre_processing_labels():
    for records in data:
        with open(records) as record:
            with open("ecg_file.in") as f:
                path = self.DATATECG_FILE[:: -1]
                metadata = open(path + ".head", "r").read().split("\n")
                ECGS = list(loadmat(path)[val[0]])
                for i in range(int(self.ECG_LENGTH+1)):
                    ECGS.insert(i, 0)
                ECGS.append(0)
                peaks = detect_beats(ECGS, float(metadata[2]))
                for peak in range(0, len(peaks),
                                  self.ECG_PER_SAMPLE):
                    ECG = ECGs[peaks[peak] - int(self.ECG_LENGTH/2):
                                peaks[peak] + int(self.ECG_LENGTH/2)]
                    ECG = (ECG + abs(np.min(ECG))) / np.max(ECG)
                    ECG = self.zero_padding(self.rnd_zero(ECG))
                    aug_ECG = (aug_ECG + abs(np.min(aug_ECG))) / np.max(aug_ECG)
                    aug_ECG = self.zero_padding(self.rnd_zero(aug_ECG))
                    aug_ECG = aug_ECG / np.array(aug_ECG)
                    self.data.append([np.array(aug_ECG)])
                self.records.append([self, LABELS[records]])
```

```

Data Augmentation
Python Implementations

def zero_padding(self, ECG):
    if len(ECG) > self.ECG_LENGTH:
        return ECG[:self.ECG_LENGTH]
    else:
        for i in range(len(ECG)-len(ECG)):
            ECG.append(0)
    return ECG

def add_bursts(self, ECG):
    for pos in range(len(ECG)-11):
        if abs(np.random.randint(11)) < len(ECG):
            for _ in range(abs(np.random.randint(11))):
                ECG[pos:pos+abs(np.random.randint(11))] = [0]*abs(np.random.randint(11))
    return ECG

def resampling(self, ECG):
    margin = 60
    pos = abs(np.random.randint(len(ECG)-11))
    diast = abs(np.random.randint(7))
    for _ in range(np.random.randint(7)):
        ECG[pos:pos+diast] = [0]*diast
    return ECG

def resampling(self, ECG):
    margin = 60
    sig = np.random.randint(margin)
    abs(np.random.randint(margin)) + (self.ECG_LENGTH-MARGIN)))
    return signal.resample(ECG, abs(np.random.randint(MARGIN)))

```



Neural Networks require a constant input vector length. Hence, the raw ECG data was split into sequences, each with a length of 600 samples. These slices were based on each peak in an ECG. The peak is considered the middle of the sequence, and a margin of 300 samples on each side of the peak creates a full sequence. Each ECG sequence was normalized to values between -1 and 1.

**Fig. 3.** Example of raw ECG recording for each class, extracted from the Physinet dataset

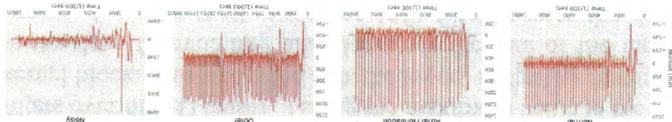
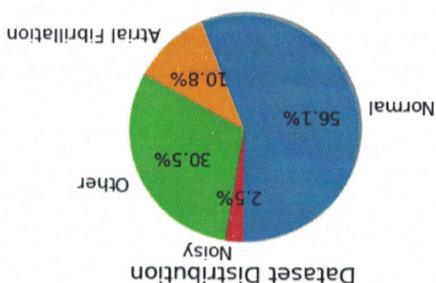


Fig. 2. Physisorbed data set distribution of classes (Normal, Attrial Fibrillation, Noisy, and Other).



The PhysioNet database contains 8,522 ECG recordings, divided into 4 classes: Normal, Atrial Fibrillation, Other, and Noisy. The raw data is provided in EDF- compliant MATLAB files, which include a mat file containing the ECG recording and ahea file containing the metadata for the V4 leads.

### III. METHODS

# A Deep Learning Approach for Arrhythmia Detection

Deep Learning is a subclass of Machine Learning, which is inspired by a neuron's structure, and function in the brain, groups of neurons are called Neural Networks. The first layer of a Neural Network is called the input layer and is composed of neurons that represent the input data. A neuron holds a number (often between 0-1), the number corresponds to the activation of each neuron. The layers in the middle are hidden layers. These layers contain neurons that are responsible for identifying features within the dataset. The activations in the last layer of a Neural Network is called the output layer. Each neuron's activation signifies the model's certainty for that class. Hence, the largest activation in the output layer represents the model's most confident output.

## II. DEEP LEARNING

Electrocardiograms (ECG) have created a profound impact in the field of cardiology, specifically in recognizing heart arrhythmias, a problem with the rhythm of one's heartbeat. Non-invasive arrhythmia analysis is based on multiple electrodes that reflect the electrical activity on ECGs. An estimated three million cases of arrhythmia occur in the United States yearly (Mayo Clinic). Diagnosing this disease early is the key to one's well-being, yet 18% of ECGs containing Atrial Fibrillation are misinterpreted by cardiologists (Auh et al, 2006). With the recent advancements in technology, Machine Learning algorithms such as Deep Neural Networks (DNNs) and Convolutional Neural Networks (CNNs), allow a mathematical model to learn features and identify patterns within a given dataset. Hence, making it possible to automatically recognize diseases in ECGs, capable of identifying arrhythmias to the accuracy of cardiologists.

## 1. INTRODUCTION

**Absaract**—Early detection of cardiac arrhythmia has the potential to prevent the millions of morbidities that the disease causes globally. However, there are few automated systems to identify arrhythmia. A significant impediment in achieving successfull methods include the lack of a large training dataset. Despite this difficulty, processes like data augmentation allow for an increased amount and diversity of data. Here, the electrocardiogram (ECG) datasets were obtained from the PhysioNet database. The dataset used to train a Convolutional Neural Network (CNN) on classifying cardiac arrhythmia. Experimental results illustrate advantages such as better responsiveness and higher accuracy of deep learning-based models when compared to the traditional analogs on ECGs.

Heart arrhythmias are irregular rhythms in heartbeats that affect 3 million people worldwide every year. Due to the increasing rate of ECGs recording for diagnosis, it is now possible to develop a Convolutional Neural Network to identify arrhythmias in ECGs. A CNN was developed and trained-

## V. CONCLUSIONS

the other class consists of many arrhythmias which generally are not structurally alike. Thus, it makes it difficult for the CNN to account for all features of arrhythmias. However, this issue can be solved by replacing the other class with specific arrhythmia classes.

Fig. 9. Confusion matrix on model predictions for each class in the training data

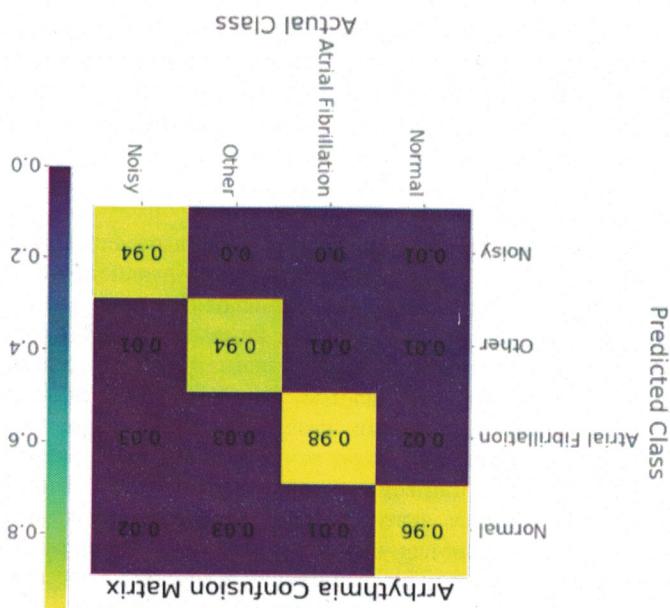
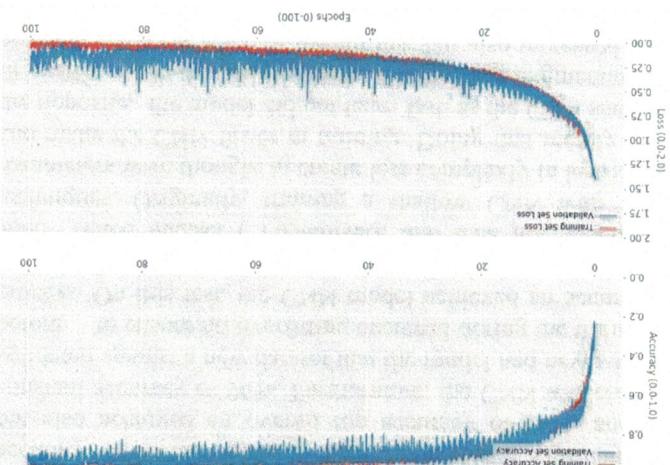


Fig. 8. Graph of the CNN metrics with data augmentation



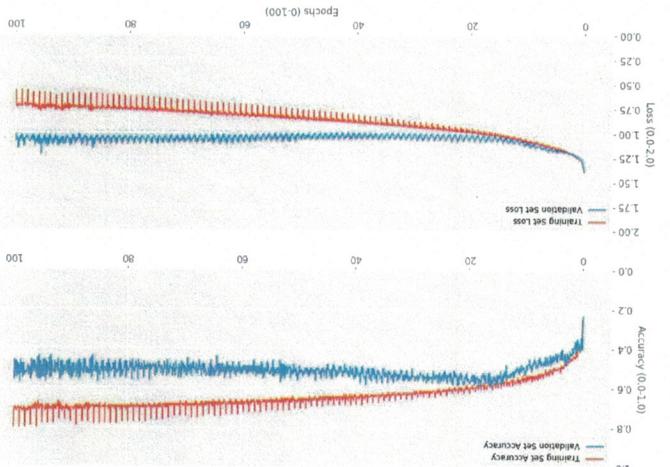
The confusion matrix conveys the mistakes the model makes for each class. The most common misunderstanding occurs in the class of other arrhythmias, confusing it with Atrial fibrillation or a normal ECG, 3% of the time. Atrial fibrillation

## Confusion Matrix

This model was trained on data that was augmented to a factor of 8 and had a total of 653 hyperparameters. The graph above illustrates that the CNN's training and validation set accuracy correlated to each other, implying the CNN is learning, rather than memorizing the training data. Furthermore, both accuracy curves approach 99%. Although the validation loss curve is more sporadic, both loss curves trend similarly, and approach a loss of 0.1.

The graph shows the CNN metrics for a model with 319 hyperparameters, and training without data augmentation. From graph, the CNN's accuracy resembles a logarithmic curve. As the validation set's accuracy approaches a horizontal asymptote at 60% and a point of inflection, the accuracy decreases. Likewise, the loss curve mimics an exponential curve, approaching a minimum loss of 1.0.

Fig. 7. Graph of the CNN metrics without data augmentation



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While training a CNN, it is important to constantly test the model after each epoch to examine if the model is overfitting (memorizing rather than learning) the training data. This is vital to a neural network's success in the real world, as the model will have to identify ECGs that it has never viewed before. To prevent overfitting, techniques like data augmentation can be used at the basic level. However, to be confident the CNN is not overfitting, a validation set can be made to assess the accuracy of the model while training. The validation set was created by partitioning 10% of the preprocessed data.

## Training Set and Validation Set

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