S3I Paper Wad
Interceptor Challenge 2024

Preface

Software, Simulation, Systems Engineering and Integration (S3I) Directorate, is excited for the opportunity to work closely with Tennessee Technological University students to conduct a competition designed for real world application. Students will expand his or her engineering experience navigating multiple competition challenges including electrical, computer, mechanical, and aerospace engineering concepts. The team at S3I is excited for this opportunity and looks forward to interacting with each student.

Introduction

The Department of Defense (DoD) is constantly evolving as new threats and technologies emerge. The newest threat is the paper wad. S3I is wanting to use this new threat as a chance to outreach to students across the United States. For this reason, S3I is searching for the best design to take into classrooms to gain the interest of new and emerging STEM students into the DoD.

Arena Specifications

The arena will be a 64”x78” rectangle outlined in black tape. The arena will then be split into 30- 1x1 foot squares as seen below in **Figure 1** with incomplete rectangles going to the outside boundaries of the arena. The three colored squares are all possible positions to which the launcher can be placed. The squares will be outlined in blue tape.

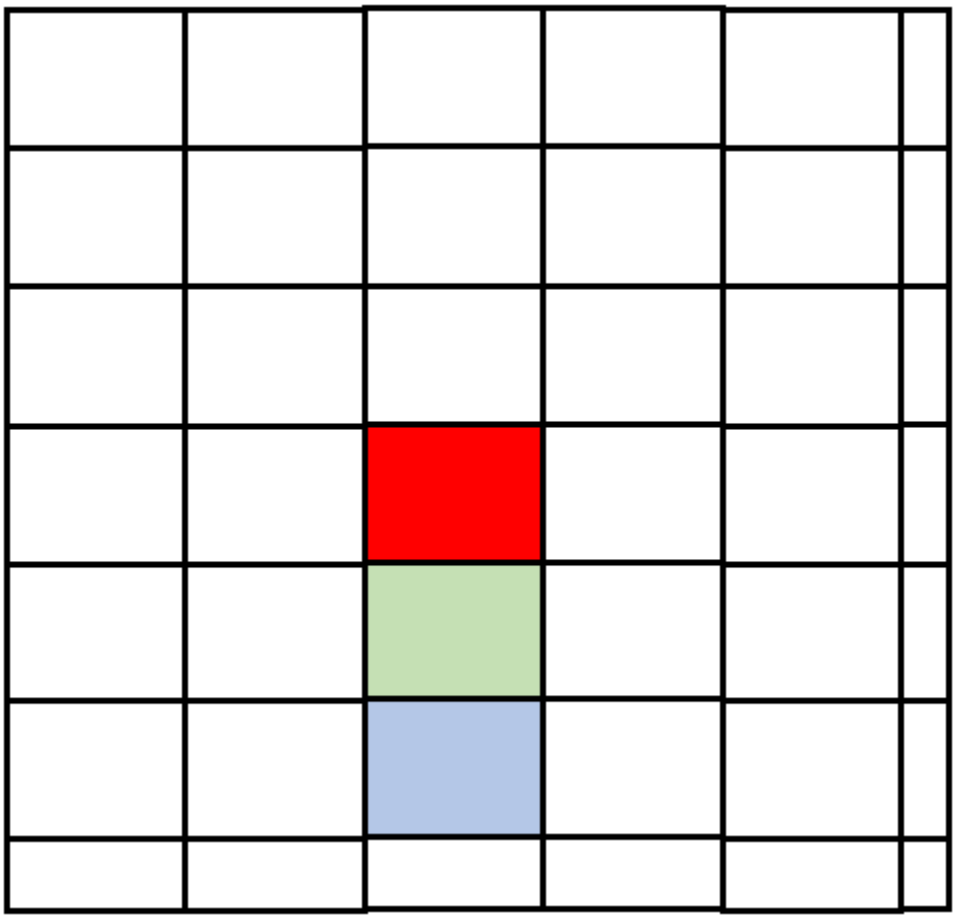

Figure 1: Aerial view of Arena Tape

The arena will then be accompanied by an A-frame structure with two subsequent anchor points and six sensor posts. **Figure 2** shows a side view of the arena and arena structures. The reader can see the distinction between Variable Height 1 (~43”) and Variable Height 2 (~50”). The reader can also see the three different anchor points. It is important to note that Anchor 2 is not a true anchor but a tensioner for the fishing line. Projectiles will start at Anchor 2 and traverse down to Anchor 3. The fishing line is depicted by the red line. The fishing line will be tied to Anchor 1 using a Fisherman’s knot. The fishing line will then traverse up to the 2x4x64 that is used as a cross beam for the variable height. An aerial view of the 2x4x64 is seen in **Figure 3**. Due to the unpredictability of the trajectory of a paper wad, the competition will use

practice golf balls on fishing to model the paper wad in the competition. It is important to note that each golf ball is separated by 4 inches. After the fishing line is through the 2x4x64, it will go through the eye bolt tensioner and is then tied off using a Fisherman knot to Anchor 3. It is also important to note that six sensor post will be available for the students to use along the gameboard.

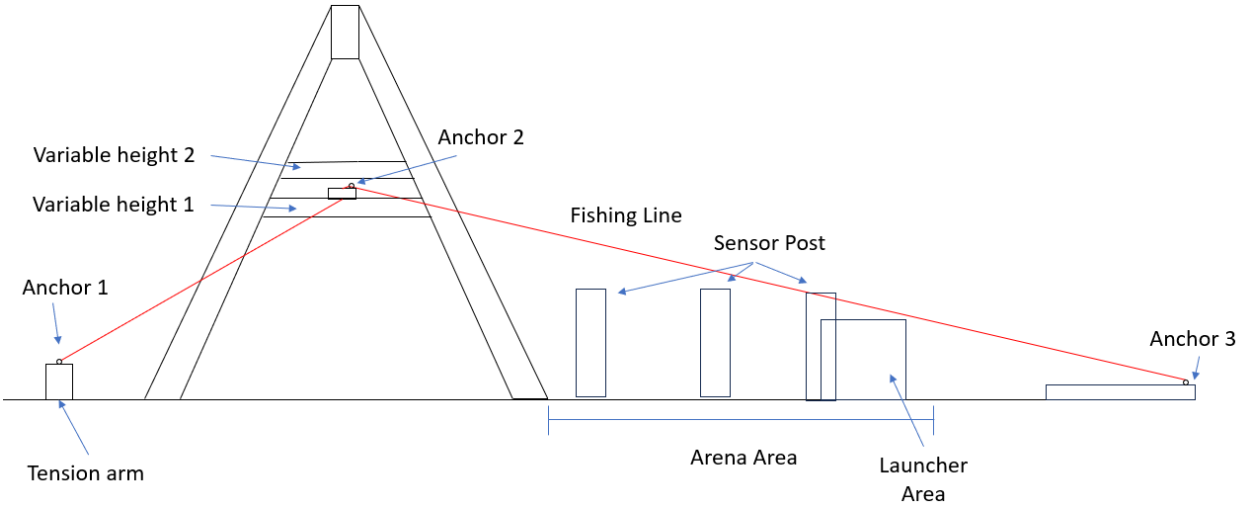

Figure 2: Sideview of complete Arena

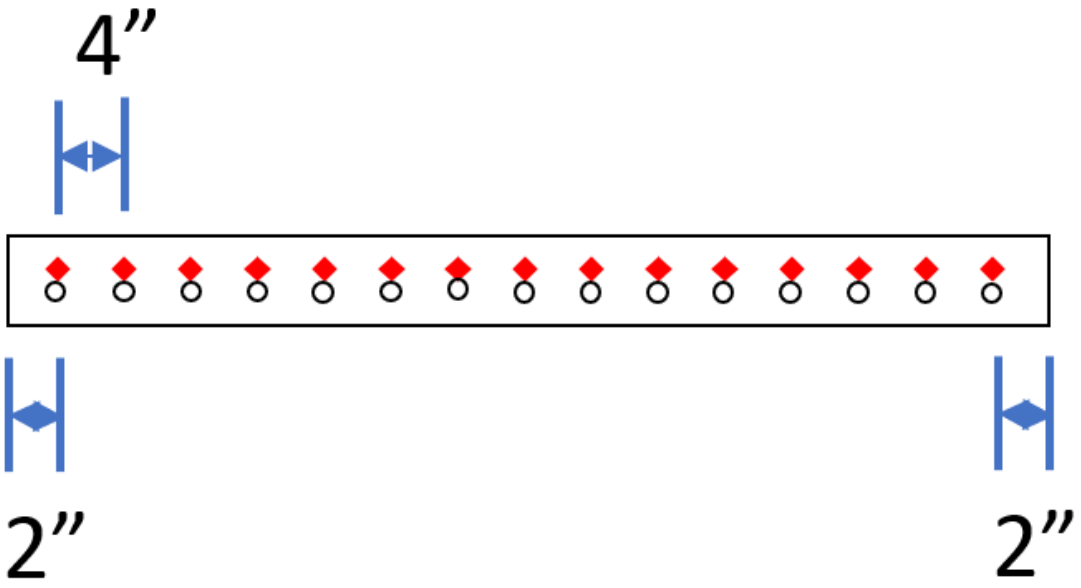

Figure 3: Aerial View of Anchor 2

The measurements for the arena are seen in **Figure 4**. A side view of the A-frame structure can be seen in **Figure 5.** A front view of the structure is seen in **Figure 6**. An aerial view of the gameboard is see in **Figure 7**.

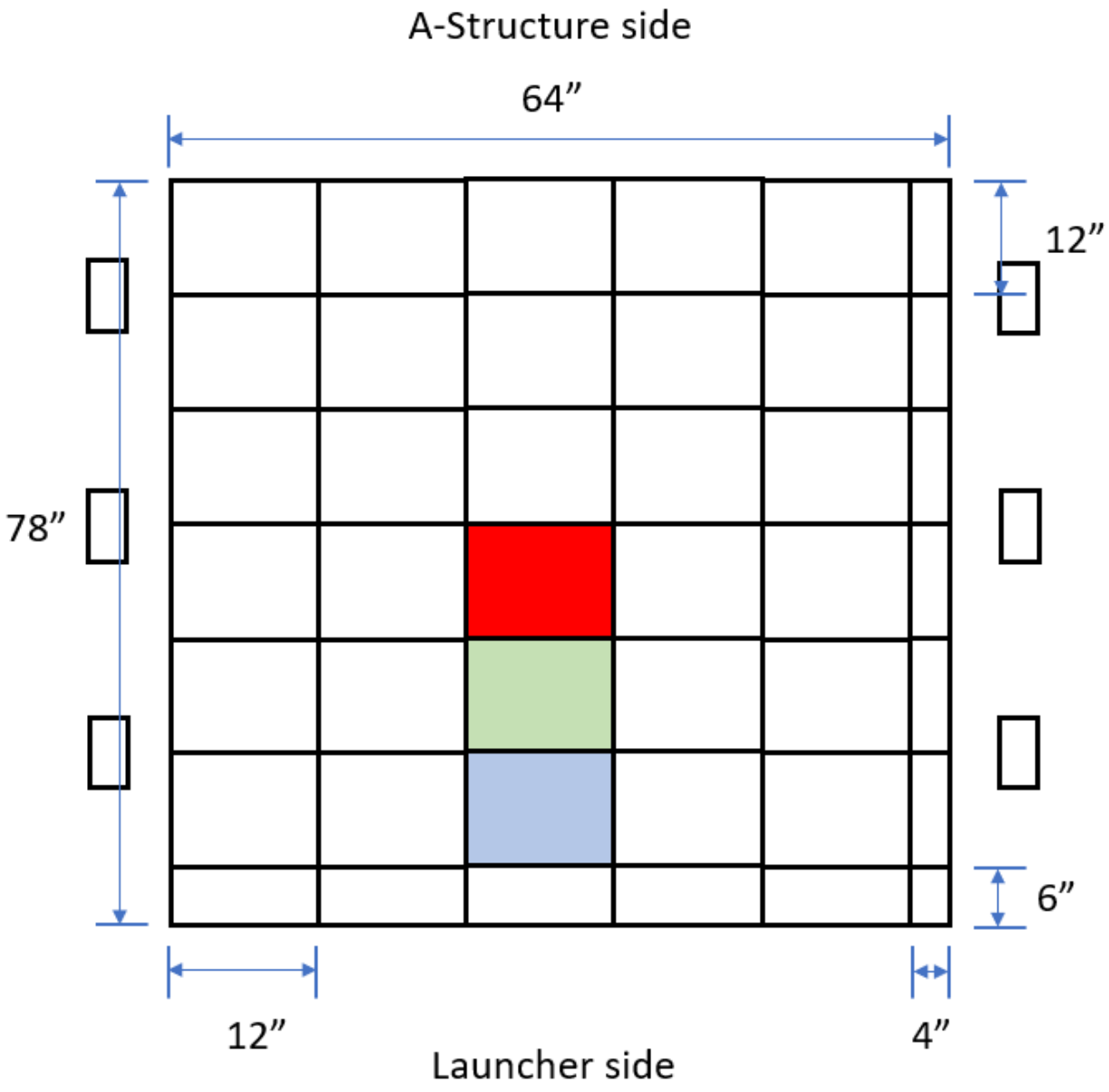

Figure 4: Aerial View of Arena Tape with Measurements

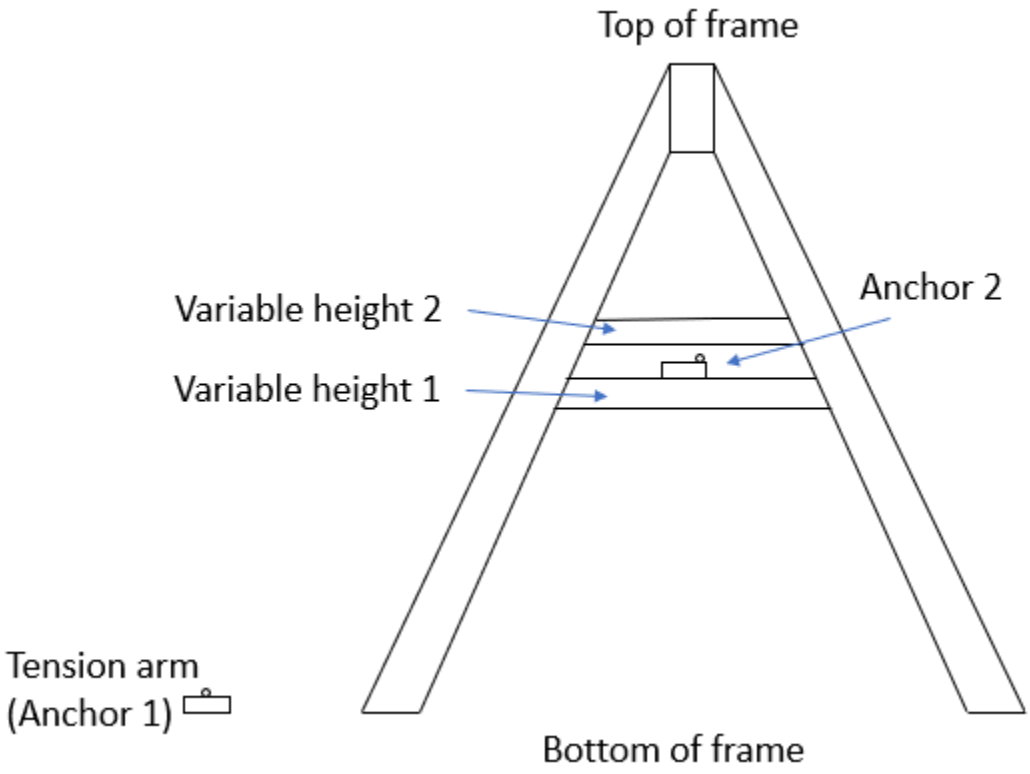

Figure 5: Side View Defining Anchor Points and Variable Heights

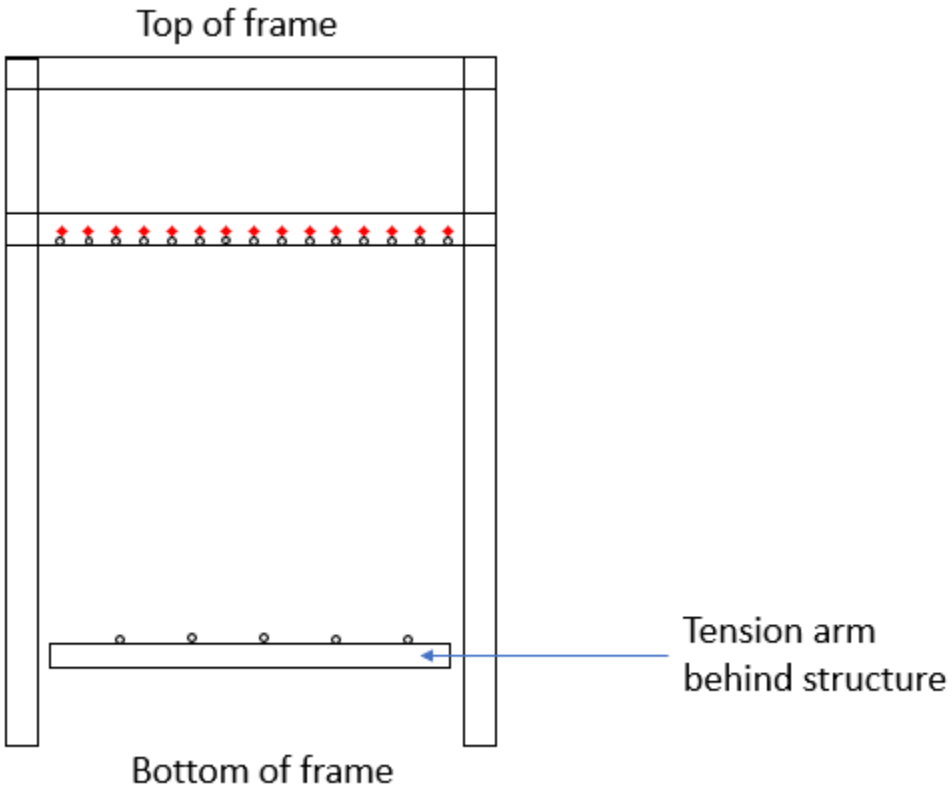

Figure 6: Front view of A-Frame

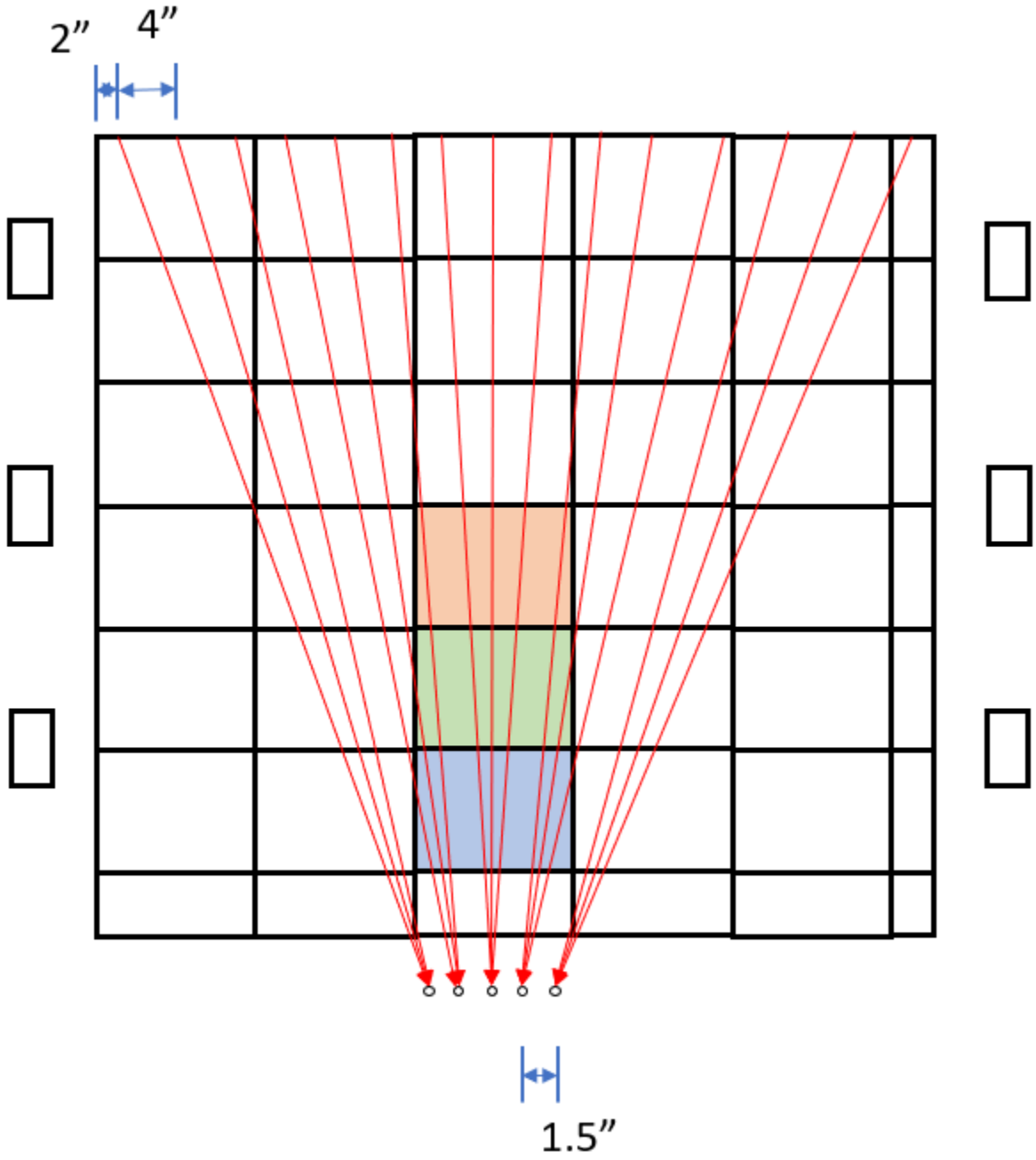

Figure 7: Aerial View of Arena with Fishing Line from Anchor 1 to Anchor 2

Additionally, the students will have access to six different sensor stands. The sensor stands will have two quarter inch holes drilled into the top of the 2’ tall 2x4. The sensor stand design can be seen in **Figure 8**. Students are allowed to put sensors on these stands; however, they must communicate wirelessly to the launcher and must have standalone power.

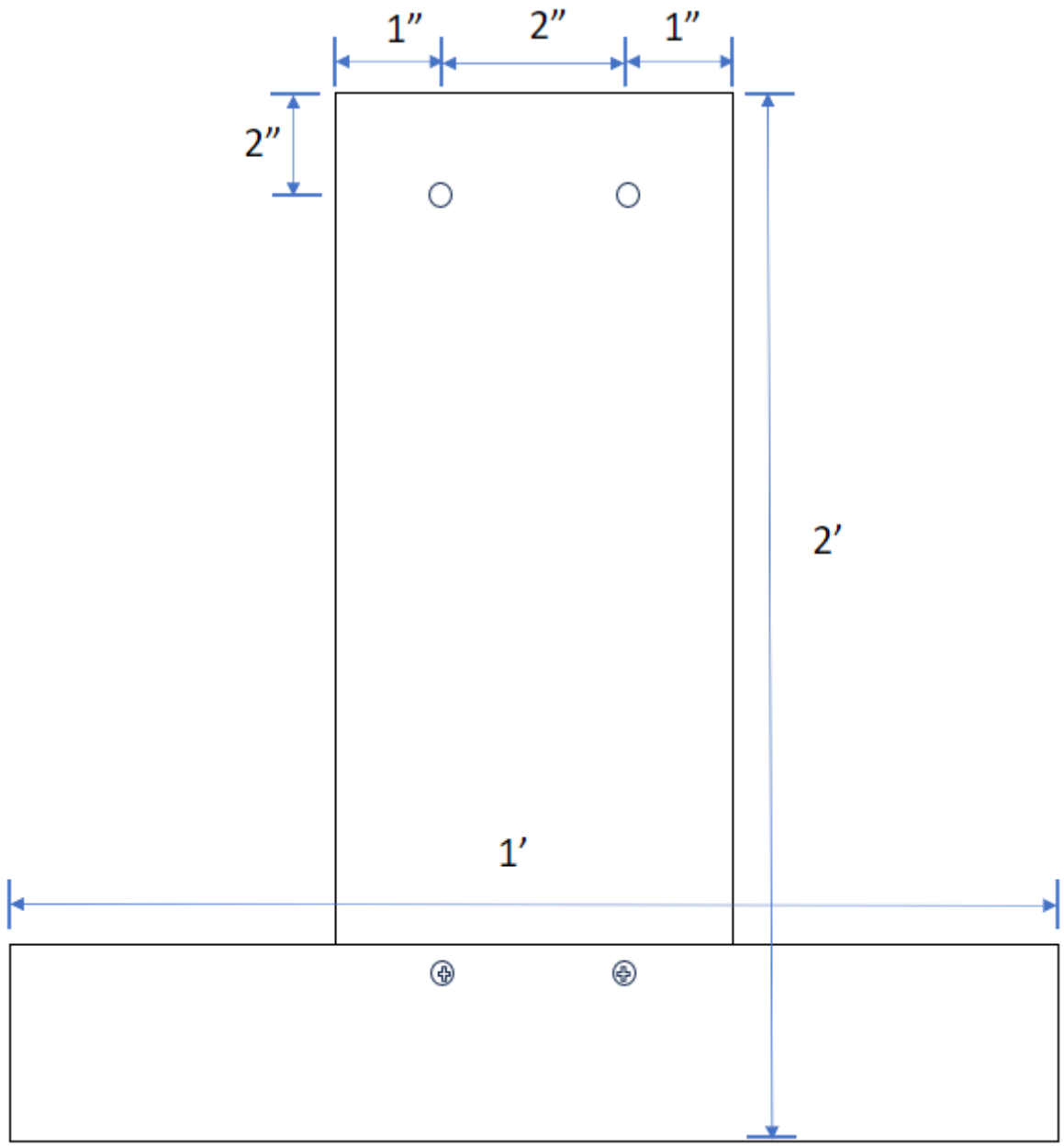

Figure 8: Sensor Stand Design

Objective

S3I has a drastic need for outreach in young students to gain interest in STEM education and the DoD. For this reason, S3I is depending on the paper wad competition to develop and integrate a safe in-class interceptor. For this reason, the Capstone class needs to develop a paper wad interceptor that can accurately intercept a multitude of paper wads. The mechanism will be referred to as the “interceptor” throughout the rules, but it is expected that the interceptor will do all required steps in detecting and intercepting the projectiles. Again, these projectiles will be practice golf balls that represent what would be paper wads.

The baseline objective will be for each interceptor to intercept three pre-planned projectiles. A sequence will then be followed of several random projectiles until the launcher runs out of interceptors, or the team voluntarily stops. The winner will be decided based off highest accumulated points described by the Total Points equation below.

Game Pieces

Arena

- (1) Blue duck brand tape
  - https://www.walmart.com/ip/Duck-Brand-1-88-in-x-20-yd-Blue-Colored-Duct-Tape/23152785?athbdg=L1103&from=/search

- (1) Black duck brand tape
  - https://www.walmart.com/ip/Duck-Brand-1-88-in-x-20-yd-Black-Colored-Duct-Tape/20683346?athbdg=L1102&adsRedirect=true

Gameboard Construction

- (10) 2-in x 4-in x 10-ft Whitewood Kiln-dried Lumber
  - https://www.lowes.com/pd/2-in-x-4-in-x-10-ft-Whitewood-S4S-Kiln-dried-Lumber/1001134500

- (5) 3/4 in. x 2-1/2 in. Screw Eye, Zinc Plated, 2 Pack
  - https://www.walmart.com/ip/3-4-in-x-2-1-2-in-Screw-Eye-Zinc-Plated-2-Pack/2744190241?from=/search

- (2) Hillman #8 x 3-in Zinc-Plated Interior Wood Screws (25-Per Box)
  - https://www.lowes.com/pd/Hillman-8-x-3-in-Silver-Zinc-Plated-Flat-Interior-Wood-Screws-25-Count/3037574

- (15) DuraSteel 1/4-in x 4-in Black Phosphate Coarse Thread Eye Bolt
  - https://www.lowes.com/pd/DuraSteel-1-4-in-x-4-in-Plain-Coarse-Thread-Eye-Bolt/1001363930

- (1) Athletic Works Practice Golf Balls, White, 15 Pack
  - https://www.walmart.com/ip/Athletic-Works-Practice-Golf-Balls-White-15-Pack/151219311?from=/search

- (1) Stren Original, Clear/Blue Fluorescent, 8lb 3.6kg Fishing Line
  - https://www.walmart.com/ip/Stren-Original-Clear-Blue-Fluorescent-8lb-3-6kg-Fishing-Line/43929539?from=/search

Interceptor Restrictions and Requirements

The interceptor must not present a danger to the judges or the audiences. There is an accepted risk where safety glasses will be worn during the competition; however, the interceptor must not contain or use any explosives, pyrotechnic, toxic, or corrosive materials. Flammables are also prohibited. A safety checklist must be followed for interceptors which is attached at the end of the document.

The interceptor is required to fit within a 1x1x1 foot size restriction. A 1x1x1 foot box will be placed over the interceptor before the team's run in the competition to ensure that the restriction is met. The interceptor is required to have a clearly marked power switch as well as a clearly marked emergency stop. The interceptor is allowed to extend past the 1x1x1 foot restriction once the power switch has been flipped on. The interceptor is allowed to use wall outlet power. The sensors attached to the sensor post are not included inside the 1x1x1 cubic foot box. The sensors on the sensor post must communicate wirelessly to the launcher and must have independent power from the launcher. The sensor posts are not responsible for stability due to the sensors being top heavy. The sensor stands will stand on their own per design described in **Figure 8**. The students are required to take structural integrity into consideration in the design phase. Any damage done to the sensor if a sensor stand falls is on the team to which the sensor belongs.

Rules

- Interceptor must work on its own. Any outside interference or assistance will cause for immediate disqualification. For this reason, one person from each team will be allowed to touch the robot from the staging area to the competition board and to operate the pause switch/button. The person, also known as the robot handler, will then be allowed to turn pause the robot and turn it off and on. Pausing will only be allowed three seconds after projectile is committed upon. Scoring will cease as soon as the person turns off the interceptor. The other team members are allowed to help in setting up the wirelessly communicated sensors on the sensor stands, but not the launcher itself. It is important to note that the pause button can not assist in shooting the projectile in any way other than taking the mechanism to a pause state.
- Interceptor must fit within a 1x1x1 foot box before power switch is flipped. Interceptor is allowed to extend past size restriction after power switch has been turned on.
- Interceptor must not present any inherit danger to the audience as the end goal of the project is to bring the interceptor into classrooms. It is accepted that safety glasses will be worn.

Competition Format

The competition will follow a round format with the first round being the three fixed projectiles 7, 8, and 9 from height platform 1. The next round will be two fixed projectiles from 5 and 11 from height two. Round three will be the last round with a fixed height from height two. Every round after this will be a randomized projectile point and randomized

height. The rounds can be seen in **Figure 9**. It is important to note that the hands-off rule still applies between each round. A team will set up their robot and will compete through each round until the team voluntarily quits or the robot is disqualified. A disqualification will result in a team getting last in the competition.

Round	# of Projectiles	Height	Projectile Point
1	3	1	7,8,9
2	2	2	5,11
3	1	2	-
4	1	-	-
5	2	-	-
6	3	-	-
7	3	-	-

Figure 9: Round Description

The gameboard previously described will have 15 different points that a projectile can come from. A depiction of this can be seen below in **Figure 10**. It is important to note that these lines are not to scale; however, the numbering of each projectile will follow as depicted.

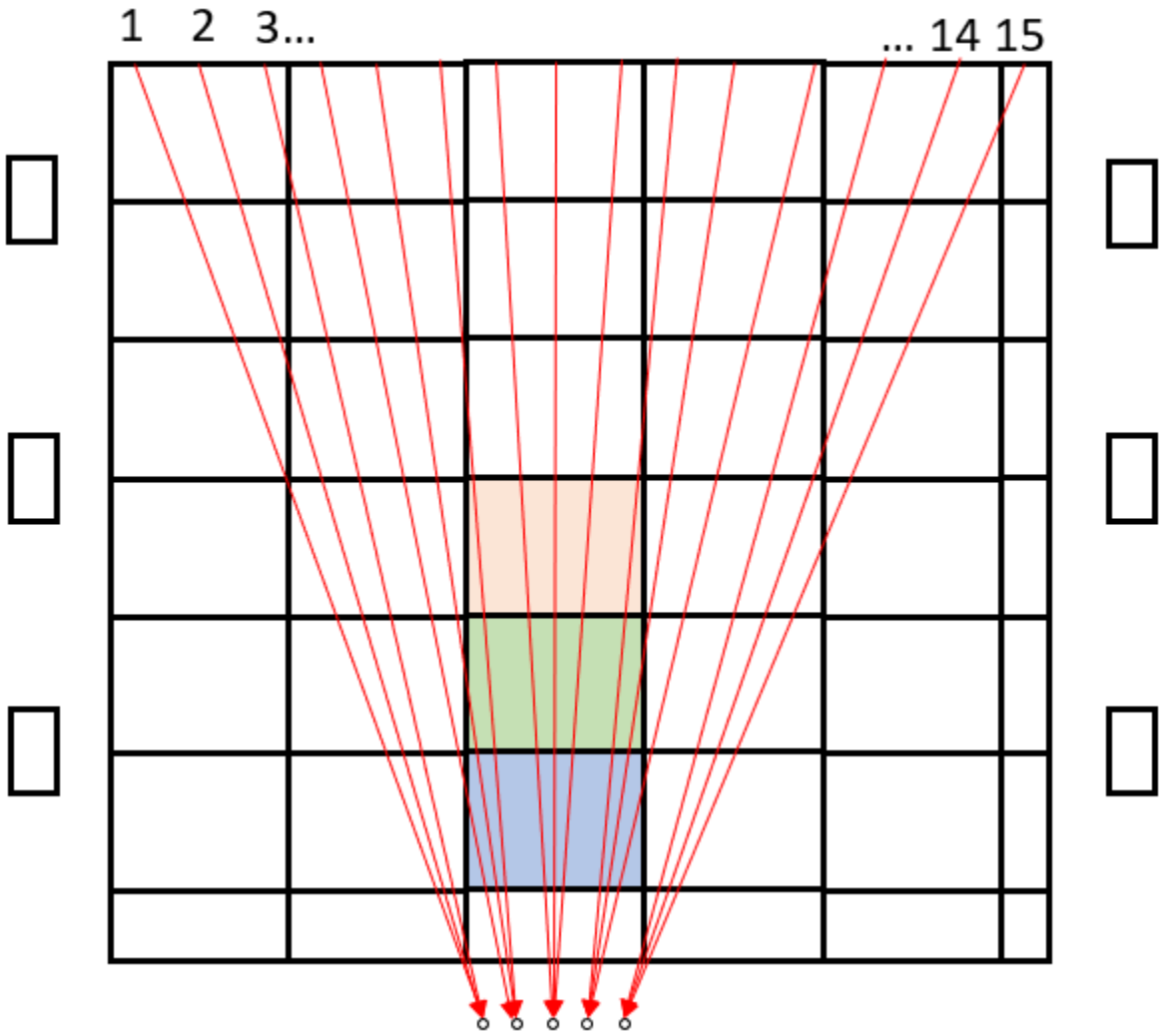

Figure 10: Line Numbering from Aerial View

Scoring

Scoring will be determined by a spectating judge. The total points will be derived from a combination of **Figure 11** and **Equation 1**. An attached Competition Scorecard is seen at the end of the document. It is important to note that competition gameboard components will not be added into cost to make. Components that fall into this category would be any component described in **Game Pieces**. It is also important to note that a multiplier is used with the points scored. The multiplier is determined by which square the launcher is set upon. The blue square results in a multiplier of 1. The green square results in a multiplier of 1.5. The red square results in a multiplier of 2.

Point	Task
+1	Each Projectile Intercepted in Round 1 and Round 2
+2	Each Projectile Intercepted in Round 3
+3	Each Projectile Intercepted in Round 4+
+1	Interceptor plays alert noise before launch
+1	Interceptor has lights
+3	Each citation a team gets
-1	Each projectile missed
-20	Damaging the gameboard

Figure 11: Scoring Metrics

$$Total\ Points\ =\ (Points\ Scored \cdot Multiplier) \cdot \left(\frac{500}{Cost\ to\ make}\right)$$

Equation 1: Total Point Equation

The alert noise described above should be played each time before the launcher intercepts the incoming target. The lights on the mechanism can be lights around the mechanism or spotlights. The decorations on the interceptor will be defined as camouflaging factors on the mechanism.

Tiebreakers

Tie breakers will be decided by which team can intercept the most projectiles without requiring a reload. First round will be three random projectiles. Second round will be five random projectiles. Third round will be seven random projectiles. The start of a tie breaker will allow both teams to reload; otherwise, the hands-off rule will still apply. If teams the teams are still tied, then round four will be all fifteen projectiles with multiple projectiles happening at once.

Schedule

Initial release of document 1/14/24. Final release of document estimated 4/30/24.

Communications

Communication will be conducted through the created discord channel where teams are able to post questions. Moderators will check discord at least once a week to answer questions. If a question requires deliberation, the moderator will react to the question to show that it has been read. The link to join is as follows: https://discord.gg/MvmpG4Td

FAQ

Q: Does it have to be a projectile and how much contact is required to consider a hit?

A: A "hit" will be defined as a notable change of direction of the incoming projectile. We are going to add red sharpie stripes on the projectiles moving parallel to the fishing line. A camera will be used by the judges to verify that contact was made that either changed the direction of the moving object or made the projectile spin. Picture representation will be provided later.

Q: How much time between ball drops? What happens if a projectile golf ball does not make it to the intended end of the line?

A: The students will need to add a switch to the shooting mechanism that will cause the system to go into a "pause" state. This will double for if a projectile does not make it and an in-between state for each ball drop. A ball will be dropped. The mechanism will fire a projectile at the target and then need to be switched into pause mode. Note that it will need to fire at multiple projectiles in a tiebreaker situation. The ball fired upon in the standard gameplay will then be moved down the track so that it is out of the way for other projectiles by a judge. The pause switch will then be switched off to which the next ball will dropped by a judge. If a ball is dropped and it does not make it down the course then it will be reset by using the pause button; however, if the mechanism commits on the projectile, then it will count for that round.

Q: How many points are awarded for using the other team's idea?

A: 3 points will be added to the points scored for each citation a team gets

Q: What happens if you fire multiple shots at a target?

A: Only one shot will count as a hit and the rest will be counted as misses. This rule will be adapted if water is used. A single shot will be considered base off what is used. For instance, a mechanism that operates like a shotgun shell will only count as one shot even though it breaks apart.

Q: What classifies a miss?

A: Does not change direction or roll rate of projectile golf ball, or hits fishing line before or after noticeably away from the projectile causing a miss.

Q: What classifies as damaging the gameboard?

A: There is an accepted risk that a fishing line may be hit as a projectile is shot at. For this reason, a mechanism's projectile is allowed to hit fishing lines next to the incoming target within reason. In saying this, a new safety checklist rule is that the mechanism cannot break the fishing line used by firing at it. If the fishing line breaks due to a committed shot, then a 20-point penalty will be placed on the team. DON'T BREAK THE LINE! Otherwise, your mechanism or your sensors should not cause harm to the rest of the gameboard or the fishing line. Any harm done to the gameboard will cause for a disqualification.

Q: What if our mechanism folds out into a higher scoring range, does that count as more points?

A: No, where your interceptor is initially placed will be the point multiplier received.

Q: Is the intent for the power switch to be that nothing on the interceptor receive power until the power switch is pressed or just that the processors & sensors on the interceptor will not receive power & therefore the interceptor will not fire until the power switch is pressed?

A: Power switch is there to allow power to the system as a whole. I am thinking that the power switch will be turned on and then it will be ready for the first projectile. An accommodation can be made if the system folds out to let it be ready for the first projectile. The "pause" switch will then be used after the first projectile. We want the system to operate in a way that once power is switched on, the interceptor is "searching" for the first projectile. The pause switch will then be the only useable switch during gameplay to take the launcher to the pause state while the next projectile getting ready.

Q: Was there an adjustment made to the height of the gameboard?

A: No, this can be overcome by the amount of tension in the line. **Figure 12** depicts distances from the back of the blue launcher area to Anchor 2 and Anchor 3. **Figure 13** and **Figure 14** depict the clearance height of the fishing line with and without the trajectory directly above. **Figure 15** and **Figure 16** depict the variable heights with the times that it took for the projectile to travel from Anchor 2 to Anchor 3.

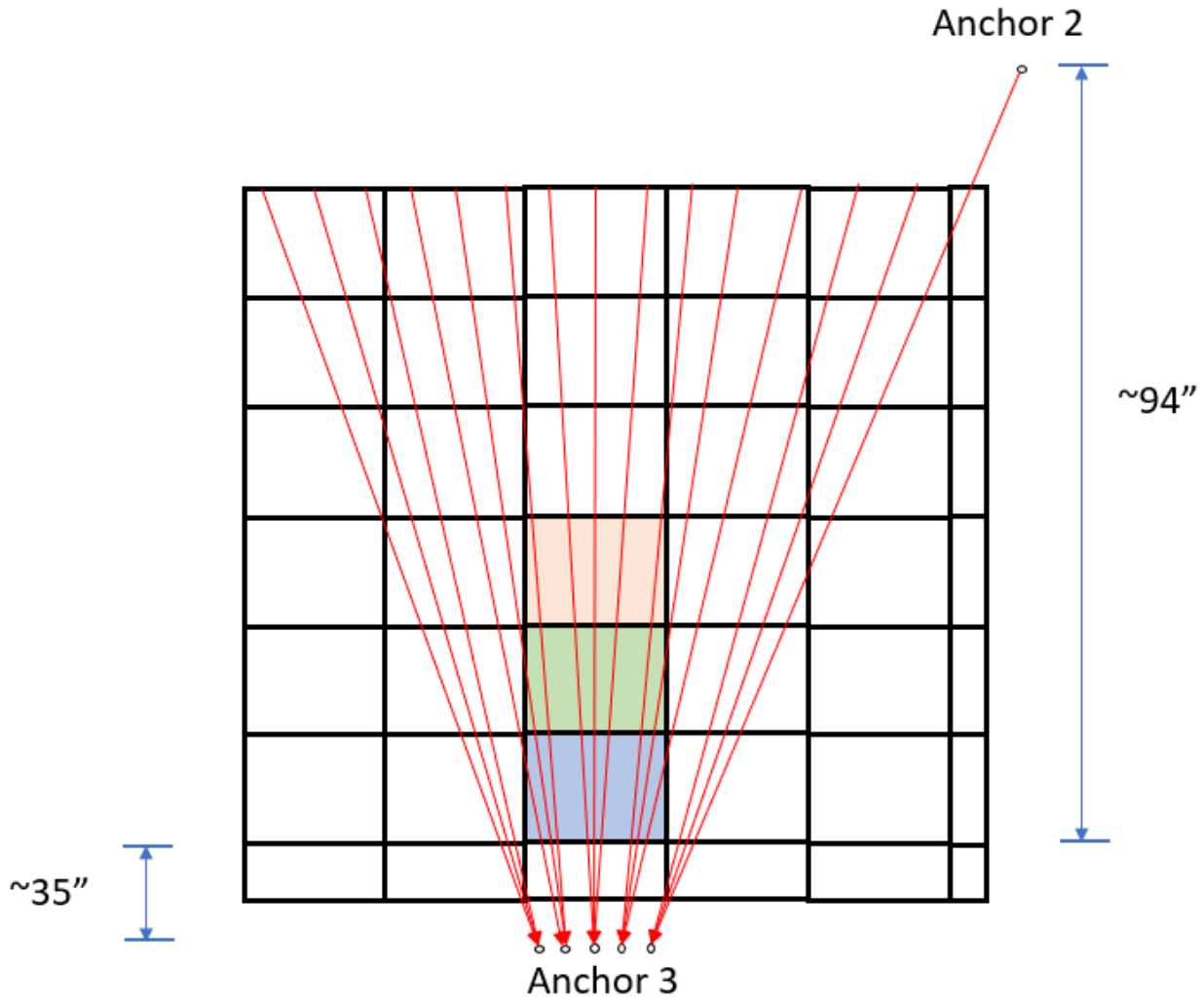

Figure 12: Distance from back of Launcher Area

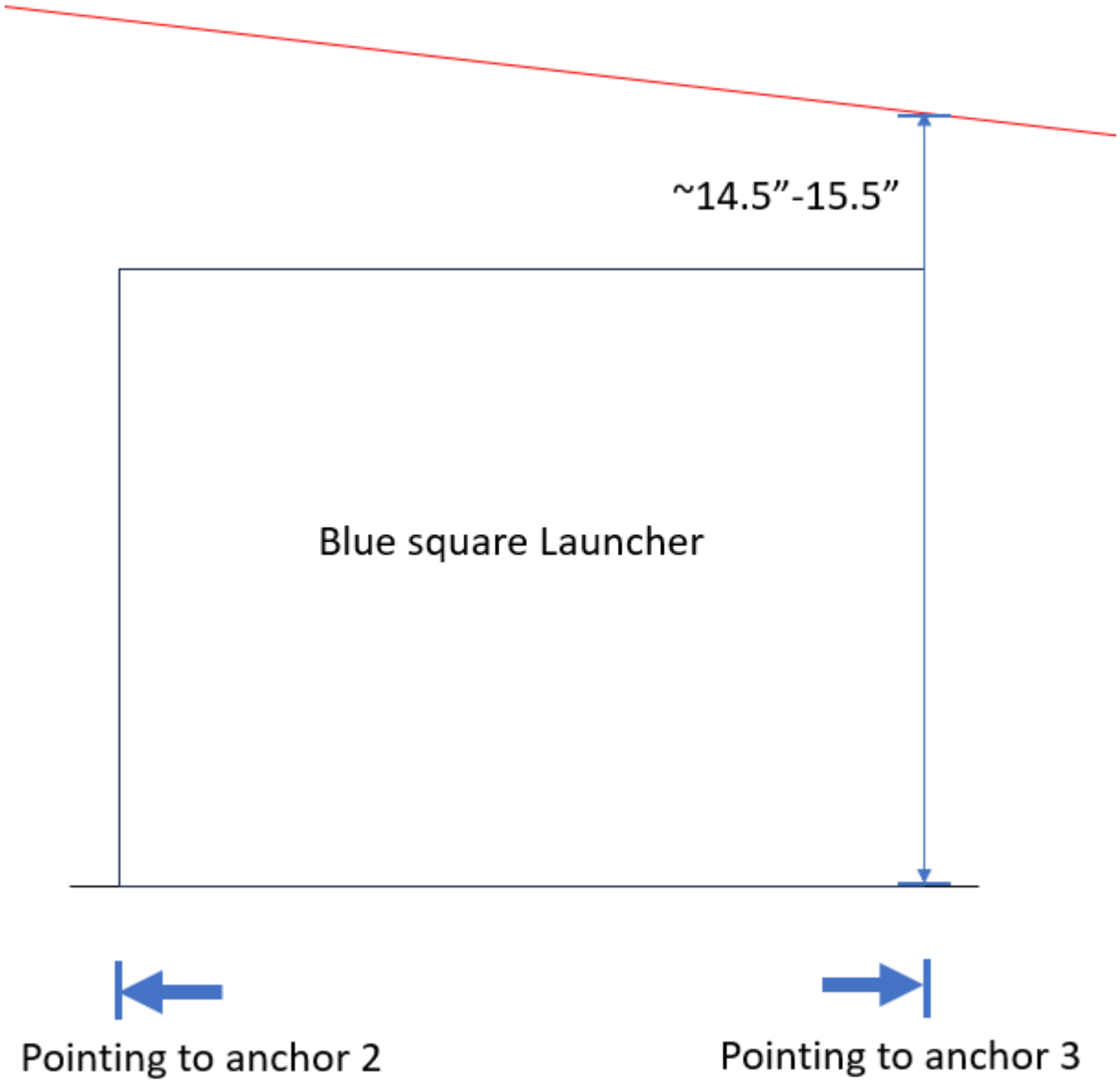

Figure 13: Fishing Line above Launcher without Load

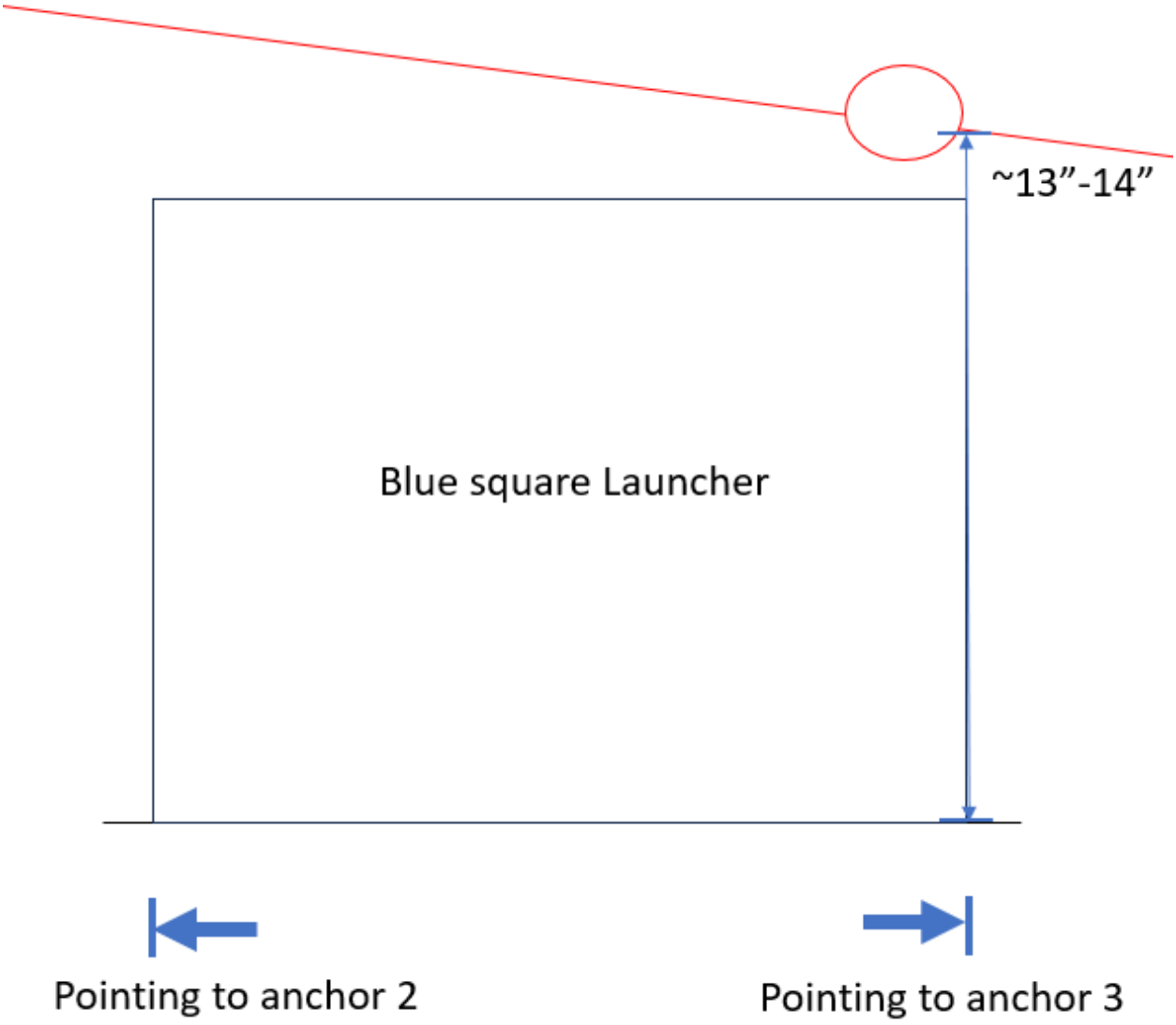

Figure 14: Fishing Line above Launcher with Load

Height 1	
Line 14	Time
1	4.68
2	5.2
3	4.77
4	4.15
5	4.82
6	4.8
7	3.73
8	4.07
9	3.23
10	3.37

Height 1	
Line 11	Time
1	3.05
2	3.12
3	2.53
4	5.07
5	3.55
6	3.83
7	3.36
8	2.73
9	3.27
10	2.66

Height 1	
Line 8	Time
1	3.22
2	3.63
3	4.32
4	3.22
5	3
6	3.28
7	6.1
8	3.75
9	4.07
10	6.5

Figure 15: Variable Height 1 Timetables

Height 2	
Line 14	Time
1	2.37
2	2.38
3	2.5
4	2.45
5	2.15
6	2.15
7	2.5
8	2.45
9	2.63
10	2.3

Height 2	
Line 11	Time
1	2.35
2	2.1
3	2.25
4	2.18
5	3.84
6	2.12
7	2.36
8	2.17
9	2.3
10	2.22

Height 2	
Line 8	Time
1	2.18
2	1.98
3	2.64
4	2.3
5	2.16
6	2.35
7	1.98
8	2.2
9	2.03
10	2.2

Figure 16: Variable Height 2 Timetables

Video Links

Describing the structure

https://youtu.be/y9G8B-Er1gM?si=J4bbOkXiuTgxTlfv

Breaking down the A-frame

https://youtu.be/AbaUn5cx7LQ?si=n9HRr1Z-19iI4QKw

Change Log

7/28/23 V1 document created.

8/30/23 V2 Major revision and simplification. First real draft.

11/15/23 V3 Major revision and gameplay changes.

11/21/23 V3.1 Minor changes to gameboard and sensors.

11/25/23 V3.2 Added check list

12/15/23 V3.3 Minor format changes

3/4/24 V4 FAQ questions added and scoring table changed

Interceptor Safety Check List

Requirement	Met or Not Met
Interceptor has power switch	
Interceptor has emergency shutoff switch that deenergizes interceptor	
Interceptor does not use explosives	
Interceptor does not use pyrotechnics	
Interceptor does not use toxic or corrosive materials	
Interceptor does not produce flames	
Interceptor in flight must not be made of metal	
Interceptor in flight must not break a piece of 8x11 paper two feet away	
Interceptor cannot shoot further than a 6-foot radius	
Interceptor can only shoot from 0-180 degrees and cannot rotate past	
Interceptor in flight cannot be made of glass	

Competition Scorecard

Task	Achieved	Point Value	Total Points
Interceptor has lights		+1	
Interceptor has decorations		+1	
Interceptor plays noise before launch		+1	
Each Citation		+3	
Damage to Gameboard		-20	
Round 1			
Projectile Intercepted		+1	
Interceptor Missed		-1	
Round 2			
Projectile Intercepted		+1	
Interceptor Missed		-1	
Round 3			
Projectile Intercepted		+2	
Interceptor Missed		-1	
Round 4			
Projectile Intercepted		+3	
Interceptor Missed		-1	
Round 5			
Projectile Intercepted		+3	
Interceptor Missed		-1	
Round 6			
Projectile Intercepted		+3	
Interceptor Missed		-1	
Round 7			
Projectile Intercepted		+3	
Interceptor Missed		-1	