BELL VERTICAL ROBOTICS COMPETITION

EARTHQUAKE SEARCH + RESCUE

2021 GAME MANUAL

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1 Introduction

Bell is home to pioneers willing to challenge what's possible. From breaking the sound barrier to developing the tiltrotor, Bell engineers have redefined the experience of flight for over 86 years. Today, Bell pushes boundaries with revolutionary commercial and military helicopter, tiltrotor, and unmanned aerial vehicle designs. But more importantly, Bell is focused on the future of flight, which lies in the hands of the next generation of inspired engineers who will reimagine designs for transport, emergency medical services, search & rescue operations and more.

The 2021 Search & Rescue Challenge is an exciting opportunity to test your technical, teamwork and communication skills. In this competition, good sportsmanship is the result of a disciplined effort to respect yourself, your opponents and contest officials. With that in mind, remember the following sportsmanship statement: “We will be gracious in both victory and defeat. We will uphold the responsibility of sportsmanship by demonstrating leadership, positive attitudes, and respect. We will pursue excellence with excitement, integrity, and honor”

This manual outlines all rules, regulations, and restrictions for this year’s competition. Rulings of referees and judges will be based on this manual, but all rulings defer to the final decisions of the Head Referee and their interpretation of both the language and spirit of these rules.

Details for all aspects of the competition are given in the Game Manual sections below.

2 Overview of Competition

The competition consists of each team competing in three matches of the Search & Rescue Challenge plus a Presentation. The highest scoring team for the combined points from the three Challenge matches plus their Presentation score will be declared the winner!

2.1 Search & Rescue Challenge

An earthquake has crippled a popular tourist destination on the beach! Roads have been blocked, hikers have been stranded, and people need critical supplies delivered to the buildings. The Search & Rescue Challenge requires a series of missions to be executed by combining flight operation, ground based robotics operation, mission logistics and the opportunity to program autonomous operations.
Teams will use their unmanned aerial vehicle (UAV) and Ground Vehicle to complete the following three missions:

1) **Surveillance Mission**: Provide aerial surveillance to identify the open mountain tunnel paths and to assist the Ground Vehicle to navigate to the Hikers when it is beyond line-of-sight.

2) **Rescue Mission**: Rescue the stranded Hikers from the Forest Maze and transport them to the Forward Operating Base (FOB)

3) **Supply Mission**: Deliver critical supplies to the buildings

Teams will play in five-minute (5:00) matches, earning points for completing the stages of each mission. Points are awarded by completing mission stages of varying difficulty. The object of the challenge is to complete as many missions as possible to obtain the highest score possible.

### 2.2 Presentations

Throughout the day of the competition, each team will have a scheduled time to make a presentation to the judges. Presentations will be limited to 12 minutes and consist of two parts as described in Section 6.

### 3 Overview of Search & Rescue Field

The Bell VRC Earthquake Search and Rescue Challenge is played in a 15ft x 15ft x 40ft netted court as illustrated below.
Key elements of the field are described below (going from left to right):

- Forward Operating Base Island where the UAV takes off (with the Army Ranger onboard) to rescue the Hikers from the Forest Maze (behind the Mountain range)
- Ocean body of water leading to the Beach front
- Beach front where the Ground Vehicle starts and the Landing Zone (LZ) is located
- City with multiple buildings of various sizes – all damaged from the earthquake
- Three (3) Roadways that lead from the beach, through the city, tunneling through the Mountain to the Forest
- One (1) Escape Highway that leads from the Forest, tunneling through the Mountain, over a Drawbridge back to the beach
- Mountain range which blocks the view for the Ground Vehicle to see the Hikers location.
- Tunnels going between the front and back of the Mountain range.
- Rockslides which block some of the Mountain tunnels.
- Forest Maze for Hikers to navigate to the rendezvous point with the Ground Vehicle

Teams will operate the following

- Four (4) Sphero Mini Robots – Three (3) represent Hikers, one (1) represents the Army Ranger
- One (1) Sphero RVR – Represents a tracked Army Ground Vehicle
- One (1) custom VRC Drone – Represents the Unmanned Aerial Vehicle (UAV)
4 Definitions

4.1 All key words defined in this glossary will be capitalized throughout the game manual as a reminder that these are defined words for the competition.

4.1.1 UAV – The physical Unmanned Aerial Vehicle (UAV) platform to be used by the Teams for the Vertical Robotics Competition events.

4.1.2 Team – A group of students representing a single high school or club, who coordinate efforts to prepare for and participate in matches. Members of the team may not be on multiple teams.

4.1.3 Competition Court – A single playing field surrounded by netting. Detailed layout of the Court is provided in Appendix A, including dimensions of the court layout, the Roadways, the Buildings, the Mountain, and the Forest Maze. This will allow Teams to replicate the Courts if needed for testing and practice during the 6-week design period.

4.1.4 Match – One Match is one iteration of the Search & Rescue Challenge. A Match starts when a buzzer indicates the beginning of the challenge, and it ends with a buzzer when the time is expired. The time clock will start at 7:00 minutes and countdown to 0:00 minutes.

4.1.5 Powered – The state of a UAV being connected to a battery, with the flight controller receiving power. The UAV may only be Powered in designated Hot Zones.

4.1.6 Hot Zones – These are the only areas in which a UAV may be Powered. Hot Zones are only the netted areas which include the Competition Courts and the Practice Courts. The pit area is not a Hot Zone!

4.1.7 Armed – The state of a UAV’s flight controller being in “Armed” mode, which allows the motors to begin spinning.

4.1.8 Radio Controller – Also known as a transmitter, the Radio Controller is the controller used to operate the UAV. The Radio Controller is used by the UAV Pilot to fly and to activate auxiliary functions.

4.1.9 Hikers – The term used for the Sphero Mini robots in the Search & Rescue Challenge. The Sphero Mini robots represent Hikers who will be rescued from the Forest Maze, loaded on to the Ground Vehicle and transported safely to the Beach. Each Team will be provided with 3 white colored Sphero Minis. Team members are encouraged to use their artistic creativity to paint or mark the Sphero Minis to look like Hikers.

4.1.10 Drive Team Members

4.1.10.1 UAV Pilot – The student who operates the VRC Drone

4.1.10.2 Ground Vehicle Driver – The student who operates the Ground Vehicle

4.1.10.3 Ground Control Operator (GCO) – The student who assists the UAV and Ground Vehicle Operators

4.1.10.4 Army Ranger – The student who operates the Army Ranger (Sphero Mini)

4.1.10.5 Hiker – The student who operates one of the three (3) Hikers (Sphero Minis)
4.1.11 Packages – The term to be used for the emergency supplies which are being delivered to the Buildings. There are 3 different colored Packages for 3 different supplies:

4.1.11.1 MED Package – Colored Red for Medical Supplies
4.1.11.2 GEN Package – Colored Green for Generator Supply
4.1.11.3 H2O Package – Colored Blue for Water Supply

4.1.12 April Tag – The graphical images placed on top of buildings and on Mountain Tunnel Paths used for autonomous operations and for improved position orientation for the UAV.

Note: All April Tags are oriented with the number on the East side. The Forest is the North end of the Court.

4.1.13 Drive Stations – Locations where the team members stand during a Match. The drive stations are along the sides of the field.

4.1.13.1 Oceanside Drive Station – Where the following team members stand: UAV Pilot, Ground Vehicle Driver, Ground Control Operator
4.1.13.2 City Side Drive Station – Where the Army Ranger stands (alongside the Hospital Building)
4.1.13.3 Forest Side Drive Station – Where the Hiker team members start the match.
4.1.13.4 NOTE: The Hiker team members move to the Oceanside or Beachside Drive Station at the end of the challenge for the transfer of the Hikers from the Ground Vehicle to the UAV.
4.1.14 **Event Coordinator** – The overall manager for the volunteers, venue, event management and other event considerations. The Event Coordinator does not interpret rules for the teams but may be consulted by the Head Referee at the Head Referee’s discretion.

4.1.15 **Head Referee** – The impartial volunteer responsible for enforcing the rules in this manual as written. Head Referees are the only individuals who may discuss ruling interpretations or scoring questions with Teams at an event.

4.1.16 **Open Route** – One of the three Routes (Red, Green or Blue) that is not blocked at the tunnel path by the rockslide. The Open Route is used by the Ground Vehicle to rescue the Hikers.

4.1.17 **Points of Interest**

4.1.17.1 **Beach** – The location between the City and Ocean

4.1.17.2 **City** – The area of the City is from the Beach to the Mountain and consists of buildings and roads. Key buildings that are used in the Supply Mission are highlighted with red arrows below.
4.1.17.3 **Drawbridge** – An obstacle on the Escape Highway that prevents passage until it is activated i.e., lowered.

4.1.17.4 **Drawbridge Control Station** – The small, designated area on the roof of the hospital where the Army Ranger makes contact to activate the Drawbridge. Activation is simulated by a field technician who will physically lower the Drawbridge when they see the Army Ranger making contact with this area.

4.1.17.5 **Forest Maze** – The location at the end of the Court where the Hikers start the Match. The Forest Maze is on the opposite end of the Court from the Ocean.
4.1.17.6 **Forest Path** – The route through the Maze that the Hikers must take from the Hiker Starting Position to the Open Route Rendezvous Point.

4.1.17.7 **Forward Operating Base (FOB)** – The island in the Ocean, where the UAV starts at the beginning of the match, and where the Army Ranger and Hikers are transported to at the end of the match.

4.1.17.8 **Forward Operating Base Pad** – The area on the FOB designated with an H surrounded by a circle.

4.1.17.9 **Hiker Starting Position** – The three starting gates at the back of the Forest Maze where the Hikers begin the Match.

4.1.17.10 **Landing Zone (LZ)** – On the Beach, where the UAV lands to rendezvous with the Ground Vehicle to transfer the Army Ranger and Hikers to the UAV.
4.1.17.11  **Roads**

4.1.17.11.1 **Green Route** – One of three one-way routes for the Ground Vehicle leading from the Beach to the Forest. This Route is designated by a Green LED strip which lights up when identified as the Open Route.

4.1.17.11.2 **Blue Route** – One of three one-way routes for the Ground Vehicle leading from the Beach to the Forest. This Route is designated by a Blue LED strip which lights up when identified as the Open Route.

4.1.17.11.3 **Red Route** – One of three one-way routes for the Ground Vehicle leading from the Beach to the Forest. This Route is designated by a Red LED strip which lights up when identified as the Open Route.

4.1.17.11.4 **Escape Highway** – A one-way route for the Ground Vehicle leading from the Forest to the Beach.

4.1.17.12  **Mountain** – The two-sided structure with four (4) tunnel paths between the two sides. The Mountain blocks the view for the UAV Pilot and the Ground Vehicle Driver when their vehicles are on the back side of the Mountain. The Mountain also determines the Open Route when the UAV Projection Camera detects the open tunnel from the view directly above the Mountain.
Mountain Tunnels – The four (4) tunnel paths between the front and back of the Mountain. Three (3) of the tunnels are connected to the incoming Routes and one (1) of the tunnels is connected to the outgoing Escape Highway Route. For any given Match, two (2) of the tunnel paths are blocked by rockslides, one (1) tunnel path is open, and the Escape Highway tunnel is always Open. The tunnel path that is open will have an April Tag on the roadway with a colored band (Red, Green or Blue) around the perimeter of the April Tag.

Hiker Rendezvous Point – The Forest Maze has three (3) exit rendezvous points which generally align with the 3 tunnel paths. When the UAV identifies which Tunnel Path is open, the 3 Hikers travel through the Forest Maze to all arrive at the exit rendezvous point which aligns with the open Tunnel Path (Green, Blue, or Red).
4.1.17.15 **Signal Light** – The LED lights on the UAV that indicate to all members of the team which Road is the Open Route by illuminating either Red, Green, or Blue.

4.1.17.16 **Projection Camera** – Similar to a First-Person View (FPV) camera, except for this challenge it is downward focused to provide an ariel view for the surveillance missions which will be projected to a large screen Monitor positioned at the front of the Competition Court.

4.1.17.17 **Passenger Bay(s)** – Designed components, compartments, or structures which VRC teams will fabricate to add on to the UAV and Ground Vehicle to load, secure, transport AND transfer the Hikers and the Army Ranger.

4.1.17.18 **Ground Control Station (GCS)** – An operator station from which your UAV is controlled. For the VRC, the GCS is the team laptop provided with the Phase 1 Kit and which runs QGroundControl.

4.1.17.19 **Stage Failure** – Occurs when any given Stage is not completed by the required time or in the required order. When a Stage Failure is declared, the team is given zero points for that stage.

5 **Search & Rescue Challenge**

5.1 **Overview**

5.1.1 The Search & Rescue Challenge consists of the Surveillance Mission, Rescue Mission and Supply Mission. Each of the missions has multiple stages as described below in Section 5.4 and 5.5.

5.1.2 In order to complete this challenge, the Ground Vehicle must be equipped with a Passenger Bay (or Bays) used to load, secure, transport AND transfer the Hikers. In addition, the UAV must be equipped with a Passenger Bay (or Bays) used to load, secure and transport Hikers and the Army Ranger.

5.1.3 The UAV must be equipped with a Projection Camera to provide an ariel view for the surveillance missions which will be projected to a large screen Monitor positioned at the front of the Court. The Ground Vehicle Driver will utilize the projected ariel view to identify the open tunnel path between the mountain and to help navigate the Ground Vehicle to the rendezvous point with the Hikers.

5.1.4 The UAV must also be equipped with 3 actuators which are used to drop the needed Packages to the building tops. Teams are allowed to use any method they choose to carry or drop the Packages (including using custom actuators or adding unique content to optimize the Package drop). However, Teams will lose points if they are not being “environmentally friendly,” by leaving any material behind (e.g., string, tape, delivery packaging, etc.) after the Package drop.
5.1.5 In order to gain the maximum points for the Search & Rescue Challenge, Teams are encouraged to demonstrate superior technical skills by taking on the Coding challenge as explained in the GitBook – Phase II Software Section to write an April Tag recognition program that adds autonomy elements to the Surveillance Mission and the Supply Mission.

5.2 Prior to Each Match

5.2.1 Prior to the Match, each Team will be provided index cards which have instructions regarding which Packages need to go to which Building. Each Package is labeled (H2O, MED and GEN), and the Building names will be identified. The following is an example of what could be written on the index card:

- H2O Package to the Condo
- MED Package to the Office
- GEN Package to the Restaurant

Teams will manually load the 3 Packages onto their UAV prior to the start of the Match. If all 3 Packages have not been loaded before the Match begins, the team will have to proceed with whatever number of Packages have been loaded.

5.2.2 Also prior to each Match, the Mountain tunnel paths will be changed so that the blocked tunnel will be different for each of the 3 matches. Teams will not know which path is open until the UAV flies over the Mountain with the Projection camera. The Ground Vehicle cannot begin moving on the Beach until the UAV has identified the open Roadway and signals the correct colored light.

5.3 Starting a Match

5.3.1 A total of twelve (12) minutes are allocated for the Match: three (3) minutes setup period, seven (7) minutes for the Search & Rescue Challenge, and two (2) minutes to clear the Court.

5.3.2 During the three (3) minute setup period, the following must be placed correctly:

a. UAV must be placed such that it is
   i. Making contact with the FBO Pad
   ii. Not contacting Ocean

b. Ground Vehicle must be placed such that it is
   i. Making contact with the beach
   ii. Not contacting the ocean
   iii. Not contacting any roads

c. Army Ranger must be placed such that it is
   i. Onboard the Passenger Bay of the UAV
d. Hikers must be placed such that each Hiker is making contact with one of the three Hiker Starting Positions, with exactly one Hiker per station. Violations of this rule may result in a match disqualification at the head referee’s discretion.

5.4 Surveillance & Rescue Mission – Description and Scoring Details

● Stage 1: UAV Surveillance to Activate Signal Light to Identify Open Tunnel Path
  ○ This stage may be done autonomously for additional autonomous bonus points. Reference the GitBook section on Phase II Coding Challenges: Path Discovery.
  ○ Completion of this stage is when the UAV provides surveillance over the Mountain and activates the Signal Light to the correct color by either:
    ■ Visually seeing the open tunnel path inside the Mountain using the Projection Camera projected to the large screen Monitor which is seen by the Ground Control Operator to identify the colored band around the April Tag and manually activates the Signal Light (15 points) or
    ■ Autonomously reading the April Tag on the open tunnel path inside the Mountain which then autonomously activates the LED to the correct color. (15 points + 15 bonus points)
  ○ Credit will not be given if the drone signals a color without using the visual inspection or reading the April Tag to identify the open tunnel path.
  ○ NOTE: If Stage 1 is not completed after 2 minutes (5 minutes remaining on the clock), a Stage Failure will be declared by the Referee and the open Route will be revealed and the Team should move on to Stage 2.

STRATEGY NOTE: After the above Stage 1 (UAV Surveillance to Activate Signal Light to Identify Open Tunnel Path), all of the remaining Stages for the Surveillance & Rescue Missions and the Supply Mission can be performed in any order and anytime during the remainder of the Match.

● Stage 2: Hiker to Rendezvous Point
  ○ Points are earned for 1, 2 or 3 Hikers successfully completing this stage.
    ■ 20 points for all 3 Hikers arriving at the Rendezvous Point
    ■ 15 points for 2 Hikers arriving at the Rendezvous Point
    ■ 10 points for 1 Hiker arriving at the Rendezvous Point
  ○ Hikers are not allowed to leave the Hiker Starting Positions until the UAV has identified the Open Tunnel Path by activating the Signal Light. Once the UAV Signal Light is on, all 3 Hikers can start down the path to navigate through the Forest Maze to get to the exit Rendezvous Point that aligns to the Open Tunnel Path identified by the UAV’s Signal Light.
• **Stage 3: Ground Vehicle to Rendezvous Point**
  ○ The Ground Vehicle is **NOT** allowed to move from wherever it is placed at the start of the Match, until the UAV has identified the Open Roadway by activating the Signal Light. Once the UAV Signal Light is on, the Ground Vehicle Driver will manually drive the Ground Vehicle by remote control to get to the entry of the Open Roadway.
  ○ Once the Ground Vehicle has entered the Open Roadway, the Ground Vehicle Driver can either:
    ■ Manually drive the Ground Vehicle down the Open Roadway by remote control (10 points)
    OR
    ■ Switch into Full Autonomous Mode (recommended) to travel down the Open Roadway until it goes through the Mountain Tunnel and exits the back of the Mountain (10 points + 20 bonus points)
  ○ The Ground Vehicle must arrive at the correct Rendezvous Point for credit to be given.

• **Stage 4: UAV Surveillance to Assist Ground Vehicle to Transport Hikers**
  ○ When the Ground Vehicle enters the Forest area at the back of the Mountain. Credit will be given if the UAV provides a video signal to the large screen Monitor which is used by the Ground Vehicle operator to navigate the Ground Vehicle to the Hiker Rendezvous Point. This is not dependent on picking up the Hikers. (7 points)

• **Stage 5: Hikers board Ground Vehicle**
  ○ Points are earned for 1, 2 or 3 Hikers successfully completing this stage.
    ■ 7 points for all 3 Hikers boarding the Ground Vehicle
    ■ 5 points for 2 Hikers boarding the Ground Vehicle
    ■ 3 points for 1 Hiker boarding the Ground Vehicle
  ○ Credit will only be awarded if the Hikers are fully on the Ground Vehicle.
  ○ Credit will not be given if a Hiker falls off of the Ground Vehicle prior to the Ground Vehicle moving away from the Rendezvous Point.

• **Stage 6: UAV Surveillance to Assist Ground Vehicle to Escape Highway**
  ○ When the Ground Vehicle exits the Forest area, credit will be given if the UAV provides a video signal to the large screen Monitor which is used by the Ground Vehicle operator to navigate the Ground Vehicle to the Escape Highway after picking up the Hikers. This is not dependent on picking up the Hikers. (5 points)
● **Stage 7: UAV lands on Hospital**
  ○ Credit will be given once the UAV has landed with the propellers stopped at rest. Both of the following must occur: (16 points)
    ■ UAV lands on the top of the hospital
    ■ Propellers are not rotating
  ○ Credit will not be given if the UAV lands on the hospital but does not come to rest on the hospital, i.e., falls off of the hospital.

● **Stage 8: Army Ranger activates bridge**
  ○ Credit will be given if both of the following conditions are met: (7 points)
    ■ Ranger departs the Passenger Bay of the UAV
    ■ Ranger makes contact with the Drawbridge Control Station

● **Stage 9: Ranger re-boards UAV**
  ○ Credit will be given if the Ranger is reboarded onto the Passenger Bay of the UAV and takes off successfully with the Ranger onboard. (2 points)
  ○ Credit will not be given if the Ranger does not activate the bridge (does not complete Stage 8).

● **Stage 10: Ground Vehicle transports Hikers down Escape Highway to LZ**
  ○ Once the Ground Vehicle has entered onto the Escape Highway, the Ground Vehicle Driver can either:
    ○ Manually drive the Ground Vehicle down the Escape Highway by remote control
    OR
    ○ Switch into Full Autonomous Mode (recommended) to travel down the Escape Highway, through the Mountain Tunnel, over the Draw Bridge and exits onto the Beach. (+ 20 bonus points)
  ○ Points are earned for 1, 2 or 3 Hikers successfully completing this stage.
    ■ 8 points for all 3 Hikers completing this stage
    ■ 6 points for 2 Hikers completing this stage
    ■ 4 points for 1 Hiker completing this stage
    ■ Credit will be given when the Ground Vehicle with Hikers on board is parked on the Beach within one (1) foot of the LZ.

**STRATEGY NOTE:** When designing the Hiker Passenger Bay for the Ground Vehicle, be sure to account for the fact that when going down the Escape Highway, the Ground Vehicle has to go up a 15-degree ramp to go over the Draw Bridge. Be sure to keep your hikers safe and secure in the Passenger Bay when you go up (and down) the 15-degree ramp!
● **Stage 11: Hikers Board UAV**
  ○ Points are earned for 1, 2 or 3 Hikers successfully completing this stage.
    ■ 6 points for all 3 Hikers completing this stage
    ■ 5 points for 2 Hikers completing this stage
    ■ 4 points for 1 Hiker completing this stage
  ○ Credit will be given if the Hikers are successfully transported from the Ground Vehicle Passenger Bay to the UAV Passenger Bay and the UAV successfully takes off with the Hikers on board.

● **Stage 12: Ranger to FOB**
  ○ Credit will be given if the UAV lands anywhere on the FOB Helicopter Pad with the Ranger on board (14 points)
  ○ Credit will not be given if the UAV never contacts the Helicopter Pad on the FOB

● **Stage 13: Hikers to FOB**
  ○ Points are earned for 1, 2 or 3 Hikers successfully completing this stage.
    ■ 10 points for all 3 Hikers completing this stage
    ■ 8 points for 2 Hikers completing this stage
    ■ 6 points for 1 Hiker completing this stage
  ○ Credit will be given if the UAV lands anywhere on the FOB Helicopter Pad with the Hikers on board
  ○ Credit will not be given if the UAV never makes contact with the Helicopter Pad on the FOB

5.5 **Supply Mission – Description and Scoring Details:**

- Teams are allowed to use any method they choose to carry or drop the Packages (including using custom actuators or adding unique content to optimize the Package drop). However, **Teams will lose 10 points (per drop)** if they are not being “environmentally friendly,” by leaving any material behind (e.g., string, tape, delivery packaging, etc.) after the Package drop.
- Teams will be told in advance of each Match, which packages need to be delivered to each building to complete each stage. Delivering the wrong package to the building will result in **NO points being awarded for that stage**.
- When performing the Supply Mission, Teams may pick any sequence of delivery, so long as they deliver the correct Package to the correct building to get credit for each stage.
- When dropping the Packages onto the buildings, the UAV must be in hover mode and cannot land on the building or be in contact with the building when the Package is dropped.
- Each of the 3 Packages (as provided to the Teams) have magnets on the bottom surface of the Package and the building tops have a sheet metal surface. This is designed to minimize the movement of the Packages caused by downwash from the UAV after delivery.
- However, if the Package does not land properly with the magnet adhering to the sheet metal surface, the Team will only receive point values for where the Package comes to rest at the end of the Match.
● **Stage 1, 2 & 3: Package Drop to Condo, Restaurant and Office**

  ○ Each building that is designated to have a package delivered has 2 target circles that signify the accuracy of the package drop. Points are awarded based on this accuracy.
    - A package that is contacting only the small circle and/or contacting inside that small circle earns **30 points**
    - A package that is contacting the large circle and/or contacting between the large circle and small circle earns **20 points**
    - A package that is on top of the building, but is contacting outside of the large circle earns **10 points**

  ○ An autonomous bonus of **20 points** can be earned in addition to the points earned for the accuracy of the drop. To obtain this **20 point** bonus, the team must use the April Tags to account for position and have the package dropped based on the autonomous detection of the April Tag and not by remote operation, such as a keystroke on the Ground Control Station (laptop computer) or an input on the Radio Controller. Reference the GitBook section on Phase II Coding Challenges: Supply Drop.

  ○ Credit will not be given if the package is delivered while the UAV is in contact with the building.

5.6 **Mission Time Success – Scoring Details:**

The Search & Rescue Challenge has to be completed within 7:00 minutes. For any Teams which complete all stages of the Challenge in less than 7:00 minutes, points are awarded as listed in the Scoring Rubric below. Completing a stage does not require autonomous operation, nor does getting the full point value for the stage. However, some points do need to be earned for the stage to be considered completed.
## 5.7 Scoring Rubric for Search & Rescue Challenge

Below is a summary of all the Search & Rescue scoring opportunities as defined above.

### Scoring Point Values:

<table>
<thead>
<tr>
<th>Mission</th>
<th>Stage</th>
<th>Points</th>
<th>Autonomous Bonus Points</th>
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<tbody>
<tr>
<td>Surveillance Mission</td>
<td>Stage 1: UAV Surveillance to Activate Signal Light to Identify Open Tunnel Path</td>
<td>15</td>
<td>+ 20</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 2: Hiker to Rendezvous Point</td>
<td>20/15/10</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 3: Ground Vehicle to Rendezvous Point</td>
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<td>Surveillance Mission</td>
<td>Stage 4: UAV Surveillance to Assist Ground Vehicle to Transport Hikers</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 5: Hikers board Ground Vehicle</td>
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<td>Stage 6: UAV Surveillance to Assist Ground Vehicle to Escape Highway</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 7: UAV lands on Hospital</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 8: Ranger activates bridge</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 9: Ranger re-boards UAV</td>
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<tr>
<td>Rescue Mission</td>
<td>Stage 10: Ground Vehicle transports Hikers down Escape Highway to LZ</td>
<td>8/6/4</td>
<td>+ 20</td>
</tr>
<tr>
<td>Rescue Mission</td>
<td>Stage 11: Hikers Board UAV</td>
<td>6/5/4</td>
<td></td>
</tr>
<tr>
<td>Rescue Mission</td>
<td>Stage 12: Ranger to FOB</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Rescue Mission</td>
<td>Stage 13: Hikers to FOB</td>
<td>10/8/6</td>
<td></td>
</tr>
<tr>
<td>Supply Mission*</td>
<td>Stage 1: Condo</td>
<td>30/20/10</td>
<td>+ 20</td>
</tr>
<tr>
<td>Supply Mission*</td>
<td>Stage 2: Restaurant</td>
<td>30/20/10</td>
<td>+ 20</td>
</tr>
<tr>
<td>Supply Mission*</td>
<td>Stage 3: Office</td>
<td>30/20/10</td>
<td>+ 20</td>
</tr>
<tr>
<td>Mission Success</td>
<td>Complete all stages with 0:01 – 0:30 time remaining</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mission Success</td>
<td>Complete all stages with 0:31 – 1:00 time remaining</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Mission Success</td>
<td>Complete all stages with 1:01 – 1:30 time remaining</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Mission Success</td>
<td>Complete all stages with 1:31 – 2:00 time remaining</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Mission Success</td>
<td>Complete all stages with 2:01 – 7:00 time remaining</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

* **Note:** Environmental Tax of minus (-)10 points will be deducted for any Supply Mission Package Drops which leave behind any materials (e.g. string, tape, packaging material, etc.)
6 Presentations

6.1 Overview

6.1.1 The presentation portion of the competition is designed to challenge students to think critically about their lessons learned throughout the competition.

6.1.2 The presentation will consist of a description of the team’s design process and lessons learned.

6.1.3 **Teams will be given 3 minutes to set up and 12 minutes to present.** The first 3 minutes of set up are not scored. This is followed by 9 minutes for presentation material that includes the design process, lessons learned, etc. followed by 3 minutes for Q-and-A from the judges. Teams will be cut off from their presentation at 9 minutes, although they may end the presentation early. Teams will be cut off again at the 12-minute mark to end the Q-and-A session.

6.1.4 It is expected that at least 3 students on the team speak during the presentation. Points will be deducted for less than 3 students taking part in the presentation portion prior to the Q-and-A. All members of the team, regardless of whether they are given speaking roles, must be present during the presentation.

6.1.5 Teams must bring the following to their presentation

   a. VRC Drone, Ground Vehicle, Sphero Robots (if graphics have been added)
   b. Engineering Notebook (Encouraged but optional)
   c. Visual aids including PC laptop (with HDMI connection) if showing a slide presentation.

   **NOTE:** Engineering Notebooks are optional but add significant point value to the Presentation score. For Teams that have Engineering Notebooks, they are to be submitted at the beginning of the Event Day as part of Team Check-In. Judges will evaluate the notebooks during the day but will provide them back to the Team for the Presentation Session.

6.2 Details

6.2.1 Each Team can use any visual aids they deem necessary (e.g., PowerPoint, Prezi, videos, collages, etc.) Video shown during a presentation may not exceed 2 minutes in length.

6.2.2 For Teams keeping an Engineering Notebook, guidelines are provided in Appendix C. Usage of the Engineering Notebook during the Team presentation is encouraged.

6.2.3 The design process portion of the presentation should include any specific design process, communication/planning methods, and project management strategies used (e.g., rapid prototyping, agile, etc.)

6.2.4 TEAMS should include any winning strategies they devised for the competition.

6.2.5 Note that there is a trophy for the best Presentation and Engineering Notebook Award.
6.3  Presentation Scoring

6.3.1  Teams will be scored based on eight categories, which cover a number of aspects of the presentation, including content and style. More points will be awarded for extra research, truly innovative thinking, and synthesis between competition experiences and professional engineering skills.

6.3.2  Judges will be instructed to score subjectively on a full 0-25 point scale

6.3.3  The full rubric for presentations is shown in Appendix B.

7  Tournament Logistics

7.1  Overall

7.1.1  Treat everyone with respect. All Teams are expected to conduct themselves in a respectful and professional manner while competing in Bell VRC events. If a Team or any of its members (Students or any Adults associated with the Team) are disrespectful or uncivil to event staff, volunteers, or fellow competitors, they may receive a match disqualification from a current or upcoming Match. Team conduct pertaining to may also impact a Team’s eligibility for judged awards. Repeated or extreme violations of could result in an event disqualification, depending on the severity of the situation.

7.1.2  Bell VRC is a student-centered program. Adults may assist Students in urgent situations, but Adults may never work on or program the UAV or Ground Vehicle without Students on that Team being present and actively participating. Students must be prepared to demonstrate an active understanding of their construction and programming to judges or event staff.

During a match, adults may not coach the team on what to do or what strategy to employ. The Drive Team Members are the ones who are responsible for completing the missions and communicating amongst themselves. Violations of this rule could result in a match disqualification at the head referee’s discretion.

7.2  Event Schedule

Each team will be assigned to compete in exactly one of the three VRC Events. The top 3 teams from each of these events will advance to the Bell Championship Event.

There will be 9 teams at the Championship Event.

7.2.1  Each of the Bell VRC Search & Rescue Challenge Events will take place over the course of one (1) day.

7.2.2  Teams will be ranked based on the sum of their scores after each MATCH; ranks will be displayed publicly and updated as often as possible.

7.2.3  Teams will compete in the Search & Rescue Challenge three (3) times, and deliver their presentation once.

7.2.4  Even if TEAMS do not rank in the top three places of the competition, all Teams who compete at the VRC will be eligible for any of the Judges’ Awards outlined in Section 11 of this game manual.
7.3 Overall Scoring

7.3.1 The weights of points will be as follows:

<table>
<thead>
<tr>
<th>Event Iteration</th>
<th>Weight</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
<td>18%</td>
<td>250</td>
</tr>
<tr>
<td>Match 1</td>
<td>27%</td>
<td>387</td>
</tr>
<tr>
<td>Match 2</td>
<td>27%</td>
<td>387</td>
</tr>
<tr>
<td>Match 3</td>
<td>27%</td>
<td>387</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>1411</td>
</tr>
</tbody>
</table>

7.4 Referee Rulings

7.4.1 The Head Referee has ultimate authority on ruling decisions during the competition.

a. The Head Referee may not review any photo or video match recordings to determine a score or ruling.
b. The Head Referee is the only individual permitted to explain a rule, disqualification, or warning to the teams.
c. The Head Referee must give the rule number of the rule violated when issuing a disqualification or warning to a Team.

7.4.2 The team is permitted to immediately appeal the Head Referee’s ruling. If a team member wishes to dispute a score or ruling, they must do so within the same round as the match being disputed and not after they have played their next match.

To dispute a score or ruling, the team member (not the coach) must present the rule in question to the Event Coordinator who will then get in contact with the Head Referee. The Head Referee, in consultation with the Event Coordinator and appropriate parties such as team members or other referees, will make the final decision and from that point, no more appeals may be made.

7.4.3 Match replays are allowed, but rare. Match replays, i.e. playing a Match over again from its start, are at the discretion of the Event Coordinator and Head Referee and will only be issued in the most extreme circumstances. Some example situations that may warrant a Match replay are as follows:

a. Game Elements not starting in the correct positions.
b. Game Elements detaching or moving beyond normal tolerances (Not as a result of vehicle interactions).
c. The field is reset before a score is determined.

7.4.4 The team must arrive at the field ready to play. Teams must quickly set up their equipment and be ready to play when they arrive at the field. The Head Referee may give a match disqualification if the team is delaying the event beyond a reasonable amount of time. See 5.3.1.

7.4.5 Event Disqualification – When a team receives an Event Disqualification, the score for all of the team’s matches will be recorded as zero points with zero time remaining on the timer. If the team has remaining matches, those matches will not be played and will be scored as zero points and zero time remaining on the timer.
7.3.6 **Match Disqualification** – When a team receives a Match Disqualification, the score for the match will be recorded as zero points with zero time remaining on the timer.

7.3.7 **Match Disablement** – The state of a vehicle. When a vehicle has been ordered to be disabled it must be brought to rest and not operated for the remainder of the match. There is no further penalty for a Match Disablement i.e., it does not remove points that have been earned prior to the disablement.

8 **Vehicle Specifications and Build Guidelines**

8.1 All vehicles fielded in the 2021 competition must follow the guidelines below – any vehicles found to be in violation of these specifications will be prohibited from flying or driving.

8.2 Safety violations deemed to be intentional will be considered a SERIOUS FOUL (See Section 9.0)

8.3 **General Drone Requirements**

8.3.1 Teams must have *propeller guards mounted on* the UAV any time the vehicle is ARMED. This guideline applies throughout the competitive season and should be followed during all testing and flying.

8.3.2 UAVs must all clearly and legibly display their team's number.

8.3.3 There are no weight limitations for the UAV.

8.3.4 All UAVs must mount the Projection Camera to compete in the Search & Rescue Challenge.

8.3.5 Repairs may be made to the UAV in the pit area during breaks between MATCHES. Attempts to repair a UAV in the COMPETITION AREA are prohibited.

8.4 **Electronics**

8.4.1 UAVs may ONLY use VRC KIT-provided electronic components, including batteries, flight controllers, flight computers, peripheral computers, motors, electronic speed controllers, receivers, transmitters, and cameras.

8.4.2 EXCEPTION: Teams can purchase different servo actuators for actuation, so long as they are operated and activated by the Radio Controller or Computers provided in the Bell VRC Kit.

8.4.3 No exposed wiring of any kind is allowed.

8.4.4 All wiring connections must be covered by either heat shrink or electrical tape.
8.5 Airframe
8.5.1 UAVs must be configured as a quadcopter.
8.5.2 Beyond physical constraints from the required electronic components, there are no dimensional or weight limits for any UAV.
8.5.3 Airframes may be built from any material, including materials outside the KIT of parts.
8.5.4 Airframes may not have sharp/jagged edges or any other clearly unsafe components.

9 Safety
9.1 This competition will follow the necessary FAA (Federal Aviation Administration) safety regulations to guarantee the safety of students, spectators, and teachers. Safety in this competition is paramount, and violations of safety regulations and guidelines will result in consequences for Teams.

9.2 General Safety Guidelines
9.2.1 Due to the high power of the UAV’s brushless motors, propeller guards must be assembled and attached around the rotors any time the UAV is ARMED.
9.2.2 When inside the netted court or when participating in a Match around the outside of the netted court, all competitors must wear safety glasses.
9.2.3 Any time a UAV is ARMED, no competitor may enter the netted flight zone.
9.2.4 During all ground-based testing of aircraft systems, including configuring, calibrating, and testing a UAV’s motors or actuators, all propellers must be removed.
9.2.5 DRONES may not be POWERED outside of designated HOT ZONES.

9.3 Guidelines for Flying
9.3.1 The VRC drones are only to be flown indoors and inside of a netted area. NO EXCEPTIONS – Flying the VRC drone outside of a netted area is considered to be a Serious Safety Foul as defined in Section 9.7 below.
9.3.2 PILOTS must avoid flying in a way that creates a dangerous environment or threatens the physical safety of others.
9.3.3 PILOTS must always be accompanied by a SPOTTER.
9.3.4 In no circumstances should any individual enter a netted area while a UAV is flying.

9.4 Competition Safety Rules
9.4.1 UAVs (especially non-KIT additions) must be robust. At the discretion of the head referees, a UAV may be disallowed to fly if it is deemed unsafe.
9.4.2 If a UAV crashes or becomes inactive during any challenge – regardless of whether the pilot is in control of those circumstances – NO ACTION may be taken by TEAMS to continue flying.
9.5 Safety Violations

9.5.1 In the hectic competition environment, especially because of the number of TEAMS flying at any given time, safety is paramount.

9.5.2 Any UAV found in violation of any safety guidelines, or otherwise deemed unsuitable to fly by any referee, can and will be prevented from competing.

9.6 Serious Safety Fouls

9.6.1 Serious fouls apply to egregious violations of the rules, reckless disregard for the safety of others, intentional actions that disadvantage other TEAMS, and cheating.

9.6.2 Penalties for serious fouls are not codified. Instead, all allegations of serious fouls will be evaluated by the head referee and event coordinators.

9.6.3 Possible penalties for serious fouls may range from the nullification of scores from a MATCH to the disqualification of an individual or TEAM from the competition.

10 Honors and Awards

10.1 Overview

10.1.1 There are two categories of awards: three (3) Competition Awards and four (4) Judge’s Awards.

10.1.2 All TEAMS, regardless of their placement in the competition, are eligible for Judge’s Awards.

10.1.3 Judge’s awards will be evaluated by presentation judges, referees, event staff, and other volunteers.

10.2 Competition Awards

10.2.1 Competition awards will be given to the 1st, 2nd, and 3rd place Teams based only on points received in the 3 Competition Matches plus the Presentation points.

10.2.2 These ranks will be evaluated once all Teams have competed in all of their challenges.

10.3 Best Overall Design Award

10.3.1 The Best Overall Design Award will be given to the TEAM that demonstrates the best overall design for their UAV, Ground Vehicle and Spheros.

10.3.2 This award will be evaluated primarily by judges of the presentation event, in conjunction with the referees who observe each UAV in competition.

10.3.3 Judges will consider uniqueness of design, aesthetics and form factor of the platform, intentionality of design decisions, functionality of systems and modules, innovative controls, and reliability/durability.
10.4 Exemplary Team Award

10.4.1 The Bell Vertical Robotics Competition prides itself on the simultaneously competitive and collaborative environment it cultivates for participants. Because of this, an award will be given to the TEAM that best demonstrates professionalism, passion, and respect to both fellow competitors and event staff.

10.4.2 This award will be judged by the behavior of students in the competition arena, pit area, and the venue as a whole. It will be based on a combination of spirit and sportsmanship.

10.4.3 This award will be given to the team most enjoyable to compete against, and will recognize Teams that demonstrate Team spirit, coordinate colors/cheers, assist and support both competitors and teammates, and demonstrate superior professionalism.

10.5 Presentation & Engineering Notebook Award

10.5.1 This award will be given independent of performance in the competition, and instead be based solely on the TEAM’S performance in the presentation event and the submittal of their Engineering Notebook for the judges’ review.

10.5.2 TEAMS must submit an Engineering Notebook in order to be considered for this award. An example outline for an Engineering Notebook is included in Appendix C.

10.5.3 This award will be evaluated solely by the presentation judges.

10.5.4 This award will recognize the team with the cleanest presentation, meaning helpful and well-crafted media, well-spoken and confident presenters, clear indication of practice and effort, clear structure of the presentation, quality and thoroughness of ideas and the content and quality of the Engineering Notebook.

10.6 Judge’s Choice Award

10.6.1 The Judge’s Choice Award will be given to an outstanding team that doesn’t necessarily fit into the category of one of the other three Judge’s Awards.

10.6.2 This award will recognize TEAMS that stand out among their peers, either in superior subject matter expertise, attitude, communication and teamwork ability, or other qualities that the judges deem worthy of recognition.
Appendix A: Field Specifications

A.1 There is one (1) competition court in Bell VRC Earthquake Search & Rescue. Dimensions for the court are given in detail throughout Appendix A for Teams to construct their own practice court.
A.1.1 The overall dimension of the Court is 39’ 2” x 14’ 2”

A.1.2 Road view angles and Guard Rail
A.1.3 Drawbridge Dimensions

A.1.4 Building dimensions
A.1.5 Mountain dimensions

A.1.6 Forest Maze dimensions – Typical spacing is 2.5 – 3.25 inches
A.1.7 Roadway dimensions
# Appendix B: Presentation Scoring Rubric

## B.4 Presentation Challenge

<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Approach and Process</td>
<td>/25</td>
</tr>
<tr>
<td>Demonstrated Engineering Skills</td>
<td>/25</td>
</tr>
<tr>
<td>Game Winning Strategy</td>
<td>/25</td>
</tr>
<tr>
<td>Lessons Learned</td>
<td>/25</td>
</tr>
<tr>
<td>Teamwork and Communication</td>
<td>/25</td>
</tr>
<tr>
<td>Quality of Materials and Presentation</td>
<td>/25</td>
</tr>
<tr>
<td>Demonstrated Effort and Research</td>
<td>/25</td>
</tr>
<tr>
<td>Quality and Content of Engineering Notebook</td>
<td>/75</td>
</tr>
<tr>
<td>Overall</td>
<td>/250</td>
</tr>
</tbody>
</table>

Team Name: ___________________  Judge Name: ___________________

**Comments:**

*Design Approach and Process*

*Demonstrated Engineering Skills*

*Game Winning Strategy*

*Lessons Learned*

*Teamwork and Communication*

*Quality of Materials and Presentation*

*Demonstrated Effort and Research*

*Quality and Content of Engineering Notebook*
Appendix C: Engineering Notebook Guidance

The engineering notebook is not mandatory but highly recommend, not just for the point value, but for learning a discipline for future projects.

The engineering notebook is a documentation of the Team, Team plans, and the vehicle and robot designs (VRC Drone, Ground Vehicle, Sphero Mini – Hikers and Army Ranger). This documentation should include sketches, discussions and team meetings, design evolution, processes, obstacles, and each Team member’s thoughts throughout the journey for the entire season.

TEAMS may use either classic pen and paper to create the notebook (Spiral notebooks, lab notebooks, loose pages, or a combination of any or all of these), or they may keep an electronic version on a computer or tablet or on a shared resource such as Google Drive. Notebooks should contain notes of all team meetings, sketches of changes and modifications, any engineering calculations used in the design, and photographs of the build and the team activities. For those teams who elect to take on the autonomous challenges for the LED activation and the Package Drops, the notebook should include a copy of the programming code that was created on the Vehicle Management Computer (VMC) to activate the Peripheral Control Computer (PCC).

Notebooks submitted for judging MUST be printed on paper and submitted in a single 3 ring binder with a ring diameter of no more than 3 inches. Handwritten material may be scanned for inclusion in the final notebook. All materials must be fastened to pages, no loose materials will be accepted. The Team Number MUST be printed on the outside of the notebook.

Engineering Notebooks are to be submitted at the beginning of the Event Day as part of Team Check-In. Judges will evaluate the notebooks during the day but will provide them back to the Team for the Presentation Session.
Suggested Guidelines for Engineering Notebooks:

1. Title page
2. Summary page with important pages noted and reasons why they are important (Summary is ONE page only)
3. Table of contents (Labeled tabs for the notebook are nice but not required)
4. Sections:
   A) Team bios including role and contributions to the team (First Names only)
   B) Safety Processes
      i. Meeting Discussion
      ii. Workshop Safety
      iii. Flight Safety
   C) Vehicle Designs – This would be the design and development of elements beyond the basic VRC drone kit and the Sphero kits (RVR and Sphero Minis). This should include initial designs and implementation and then changes over the course of development showing application of the engineering design process.
   D) Game Strategies – This would be the determinations of where the team will focus the strategy as they play. This should include any decisions and developments made over time.
   E) Artistic Elements – Any extra efforts to make the designs realistic (Vehicles finished to have military look, Sphero Minis to look like people…….)
   F) Team Meeting/Work Session Documentation – This can include:
      i. Date, time, and location of meeting/work session
      ii. Attendees including coaches and mentors (if any)
      iii. Meeting/session goals (if defined)
      iv. Accomplishments – Including lessons learned through training, practice, and through failure
      v. Design decisions made including sketches, calculations, notes, and photos. This will include the design items from above but here they are spread throughout the timeline of work vs. the design section where they are all pulled together.
      vi. Game strategy planning
      vii. Event and presentation discussions
      viii. Processes followed including safety processes
      ix. Issues (if any)
      x. Reflection

The documentation should include enough detail for another person to look at your notebook and be able follow the steps your team took to get to your final designs.