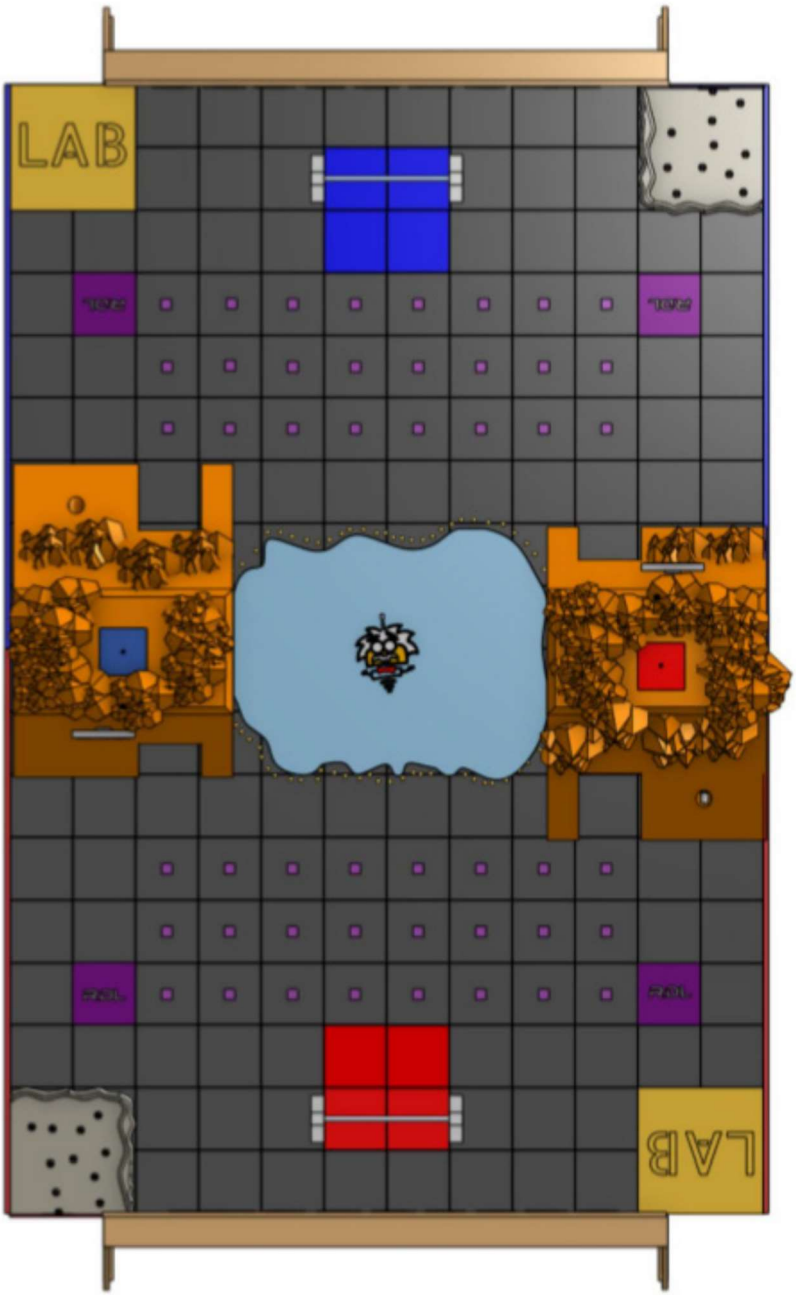
ROBOT DRONE LEAGUE

PRESENTED BY STREAMWORKS

2021 Challenge Official Manual

2021 Official RDL Field

DRAGONFLY



ROBOT DRONE LEAGUE

Three Laws of Robotics

1. *A robot may not injure a human being or, through inaction, allow a human being to come to harm.*

2. *A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.*

3. *A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.*

~Isaac Asimov

And one more….

4. *A robot may not intentionally injure another robot unless the action or inaction conflicts with the First, Second or Third Laws. ~ Scooter Willis (Creator of RDL)*

To the men and women of NASA who passionately chase the stars and share the love of learning with our children, ~ Thank You ~

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Revisions

Date	Page	Notes
09/29/2021	12	REV 1 – Alignment Tools
09/29/2021	13	REV 1 – STEM Question

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Introduction

Creativity and innovation are key elements to advancing the fields of science, technology, engineering and mathematics (STEM) into the future. The Robot Drone League (RDL) was designed to provide students with open-ended challenges that allow for creation and innovation by engaging in hands-on design, engineering, and programming of interactive robots and drones. Students are presented with the opportunity to develop real-world connections to classroom learning. Working with robots in a collaborative game format can be a very powerful tool to engage students and enhance math and science skills through hands-on, student-centered learning. Through participation in the RDL, students can develop the essential life skills of teamwork and collaboration, as well as critical thinking, project management, and communication required to become the next generation of innovators and problem solvers in our global society. The RDL "Dragonfly" 2021 Challenge, presented by STREAMWORKS, is designed to inspire students to develop a lifelong passion for learning and interest in pursuing educational and career opportunities in STEM fields by implementing real world STEM related problems.

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Challenge Overview

ROBOT DRONE LEAGUE

RDL 2021 Challenge: Dragonfly

The Dragonfly Challenge includes an exciting Robot Drone League game, centered around real-world aspects of Saturn's largest moon, Titan. Machine design and collaboration are key to scoring maximum points.

In 2017, NASA's Cassini spacecraft dove into Saturn's atmosphere. Along the way, Cassini reported back images of Titan, discovering mountains, sand dunes, and lakes made up of hydrocarbons (molecules consisting of hydrogen and carbon atoms), such as methane and ethane. Since then, scientists have found that Titan also has an interesting hazy atmosphere made of nitrogen. Because Titan receives only a small fraction of the sunlight that Earth does, the average temperature is about 94.15 K (−179 °C). These aspects create unique weather conditions such as seismic activity resulting in volcanic explosions of ice, hydrocarbons, and maybe more. Sand storms and high winds, reaching speeds up to 120 meters per second, can also be expected. In 2026, NASA will send a specialized rotorcraft, the Dragonfly, to Titan to explore promising locations thought to be similar to Earth's. On this mission, the Dragonfly will be studying the chemical processes on Titan that may be linked to previous forms of carbon-based life.

Teams are assigned the mission to step into the future role of NASA scientists to monitor seismic activity, help study a methane lake, and collect HydroPods, NitroPods, and CarbonPods to bring back to labs for molecular assembly. A friend of RDL's, the Marine Advanced Technology Education (MATE) Center, has asked that teams deploy an autonomous underwater vehicle (AUV) into Lake Photon so that the lake's contents can be studied. Teams play a vital role in uncovering the mysteries of Saturn's greatest moon.

RDL Dragonfly is played on a 7.3 m by 11 m indoor netted field, surrounded and separated into equal halves by a combination of mountains, tunnels, craters, and Lake Photon. Two teams compete against each other as either red or blue alliance. The two alliance sides are mirror images of each other. There is a total of ten (10) CarbonPods, twelve (12) NitroPods, and thirty (30) HyrdoPods per alliance where teams can score points. The object of the game is to retrieve as many scoring elements (CarbonPods, NitroPods, and HydroPods) as possible and assemble them into important hydrocarbon molecules at the team's lab station within a ten-minute match. Both red and blue alliance scoring elements are placed at different locations on the field. Each mountain contains a specific location for seismometers to be inserted, as well as landing points for the deployment of antennas. The field is equipped with various images that can be analyzed for points by implementing image recognition technologies.

The RDL Dragonfly Challenge provides an opportunity for students, with the guidance of mentors, to build a robot to solve exciting engineering challenges. Students collaborate in a teamwork format to strategically collect scoring elements and deploy the correct sensors.

RDL emphasizes the importance of programming through its drone aspect. In this year's challenge, drones' complete tasks such as deploying an AUV into the lake, safely dropping an antenna onto a landing zone placed atop a mountain, activating beacons, and recording STEM questions. Students need to work together to write the code for the drone to successfully complete these tasks.

RDL implements Next Generation Science Standards (NGSS) through Dragonfly's chemistry related tasks. Teams are required to use collected elements to assemble models of real molecules likely found on Titan.

Drone prototype developed from animated gaming platforms Photo courtesy of MedPhamRes

Game Rules

Object of the Game

Score points by moving drones and robots to complete their assigned tasks. Robots need to place the seismometer within the mountain in the team's assigned territory. To collect elements (HydroPods, NitroPods, and CarbonPods) for molecular assembly, robots must work in the opposing alliance territory until there are two minutes remaining. At two minutes left in the match, robots may collect elements anywhere on the playing field. After elements have been gathered, robots move to the alliance lab station to drop off the elements. At the lab station, the team works to assemble special hydrocarbon molecules. Teams need to use robots to survey images placed around the field and identify the contents of the images. At the same time, drones deploy an AUV into the lake, as well as an antenna on top of the mountain, and will illuminate beacons with the alliance color. Drones are responsible for providing images of the screen on the opposing side, which displays the STEM questions for students to answer. There is an end game challenge, where robots are tasked with returning to the starting position and hanging from a bar. The object of the game is to successfully complete as many of these tasks as possible within a ten-minute match, with the first sixty seconds being in autonomous function mode only.

Matches

Teams compete against one another in a double elimination style tournament. Teams are assigned a randomly selected alliance, either red or blue. Each match lasts ten minutes. The first minute requires robots and drones to use autonomous functionality only. In the last two minutes of each match, any elements remaining on the playing field become eligible for either team to compete for.

Lab Stations

For each alliance side, there is a designated area for interaction between human players and robots called the lab station. Each alliance needs to assign a lab technician who is responsible for accepting elements and assembling molecules. Robots bring collected elements to the lab station, where the lab technician then accept items. The lab technician takes these elements to assemble molecules.

Mountains

The RDL field has two symmetric mountains divided by a methane lake. The mountains both contain a tunnel, measuring 61.0 cm wide and 61.0 cm high. These dimensions limit the size of teams' robots, as robots need to be able to efficiently move through tunnels to enter into opposing alliance territory.

Mountains also have a designated location for seismometer deployment. This location is on the mountain's side. It is a 45.7 cm deep circular hole, with a diameter measuring 15.2 cm. Robots place a seismometer into the designated area on the allegiant side of the field before moving through the tunnel to the opposing side.

On top of the mountains are target landing pads to indicate where drones should drop the satellite antenna. These target zones are 45.7 cm wide and 45.7 cm long, forming a square. Drones attempt to successfully drop the satellite antenna within the specified area.

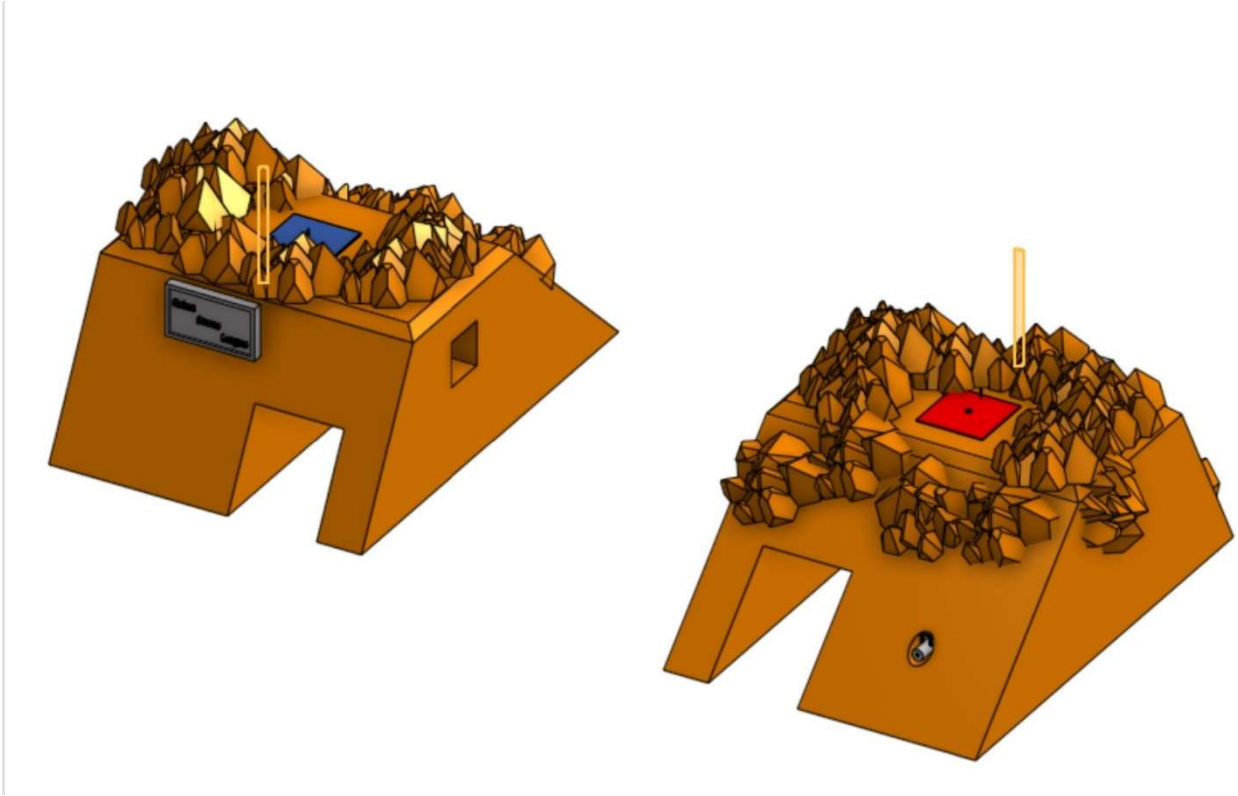


Figure 1

Starting Position

Robots and drones need to be placed in the designated starting position prior to beginning the match. The starting position is marked by two adjacent 61.0 cm by 61.0 cm squares colored to correspond with the alliance. Robots and drones may start with a scoring element or sensor preloaded at base. Human players can also load sensors at the lab station.

(REV – 1) Alignment tools and devices are allowed onto the playing as long as the tools do not interfere with the ability of the opposing alliance to retrieve game elements and score points.

STEM Questions

Each team is given the opportunity to earn points by solving 1 STEM based questions that appears after the match has started. During a 10-minute match, there are a maximum of three questions to be gained by each alliance, with each increasing in point value. Questions are displayed on screens on the opposing side of the mountain. Teams must use the drone or robot camera feed to view the questions in order to solve.

(REV – 1) The three STEM questions are aligned with NGSS, Common Core, ISTE, and P21 Standards and directly correlated to what students learn in the classroom. Question difficulty are be dependent on a team's division *(see League Overview)* which are arranged and aligned with the appropriate grade level to each division, either DIV I, II, or III. Teams must correctly answer the question and receive points from the RDL official prior to advancing to the next STEM question.

To earn additional opportunities for additional STEM relevant questions, teams must discover the location of bonus STEM ? symbols located on various scoring elements on the challenge field.

Figure 2

Figure 2 is an example of a STEM Question symbol on a Nitropod game element. On randomly placed game elements prior to each match, **?** symbols are affixed to a minimum of 6 game elements per alliance field and not visible until a team has moved the object from its resting position. Teams wishing to attempt to answer a STEM question after the automatic 1st question must retrieve a game element with the **?** symbol and place it on the ? box shelf located in the middle of the alliance driver station.

Seismometer Deployment

Teams need to measure seismic activity on Titan. Ideally, sensor deployment happens in the autonomous period of the match. Teams need to use the robot to place a seismometer into the designated location in the mountain.

There is a 45.7 cm deep cylindrical hole, with a diameter of 15.2 cm, in both mountains. Teams need to place a seismometer device into the target area anytime during the match. The seismometer is shaped as a cylinder, with a length of 30.4 cm and a diameter of 7.62 cm. The seismometer has a handle for robots to grab, as seen in *Figure 2*.

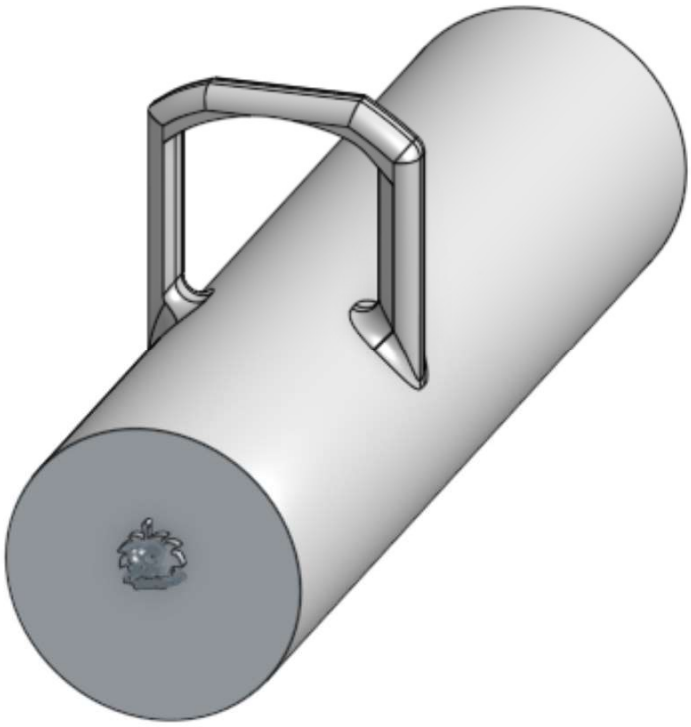


Figure 3

AUV Deployment

On the field of play, Lake Photon separates the mountains. Teams need to use drones to deploy an AUV into the lake. The AUV is cylindrical with a length of 7.62 cm and a diameter of 2.54 cm. AUVs can be deployed in both autonomous and teleop periods.

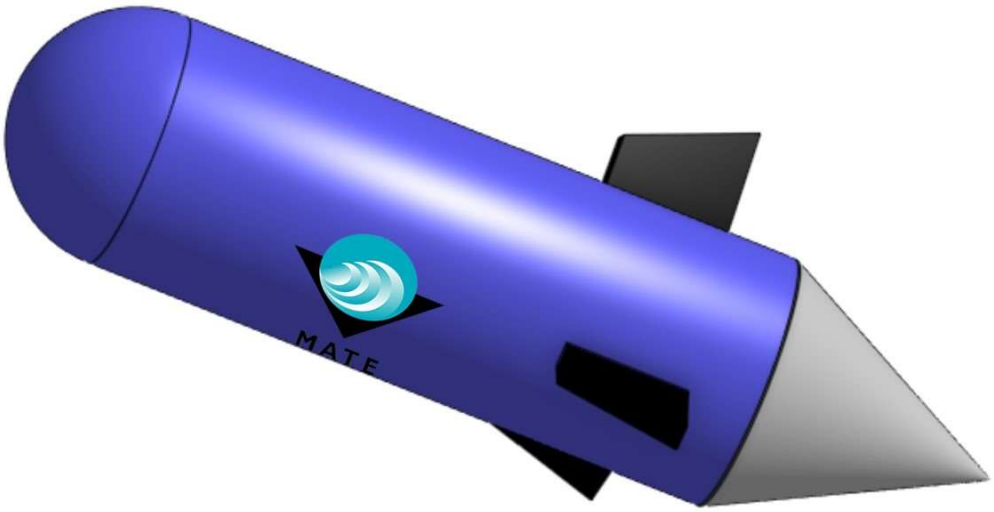


Figure 4

Satellite Antenna Deployment

Teams also need to rely on drones to drop a satellite antenna onto a target zone. The satellite monitors Titan's weather for scientists. The target zone is placed atop the team's mountain and measures 45.7 cm by 45.7 cm. The satellite antenna that teams need to drop is 7.62 cm long. Once again, it is encouraged that teams attempt this task autonomously.

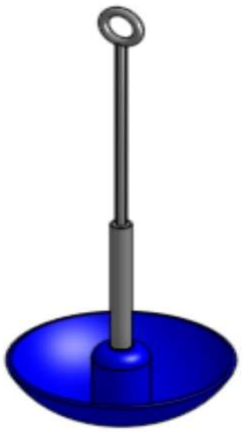


Figure 5

Beacon Activation

The satellite antenna needs to be activated to properly collect data. To activate the satellite antenna, a drone must fly over the team's beacon, which is situated within the mountain tops. The beacon illuminates with the alliance color when the antenna has been activated. Antennas may be activated, via beacons, at any time throughout the match.

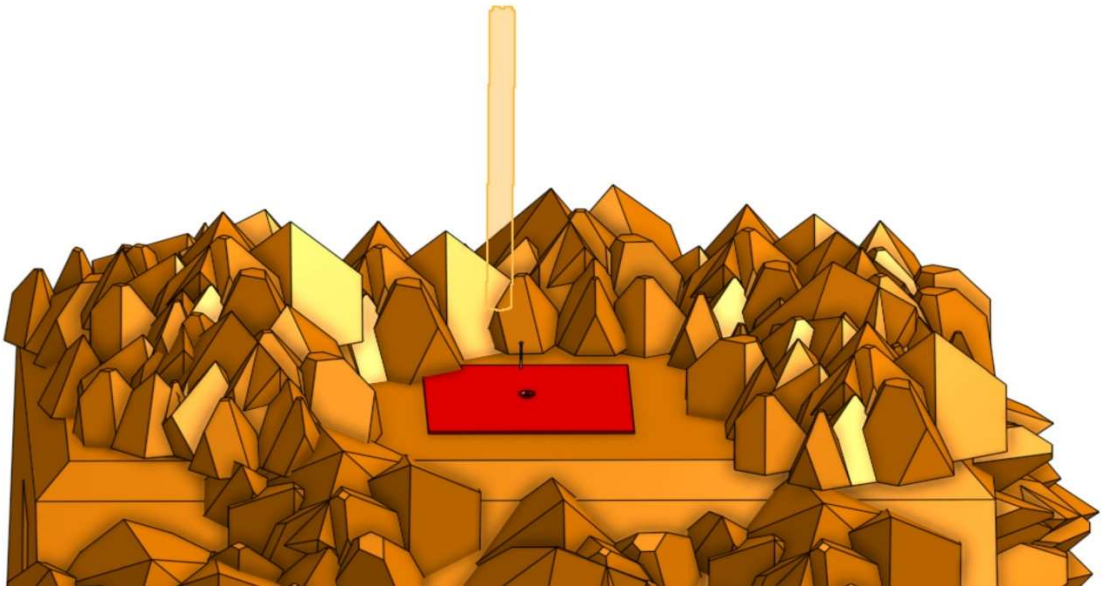


Figure 6

Image Recognition

Throughout the RDL field, there are various images of basic shapes. Each shape is colored green and correlates to a specific facet of Titan. Teams need to use a robot's camera to determine the contents of the images. Completing this autonomously results in double points. To be considered autonomous, robots must use a program to identify the shapes, as well as the shapes' corresponding meaning. The program must complete the identification without human interaction. To complete this task in teleop, teams may identify the image's contents manually, without aid from image recognition software.

The shapes are a triangle, a circle, a square, and a star. There is one shape per image. The shape is green (#00FF00), and the background is white (#FFFFFF). Each shape only appears once on the field, resulting in four images to identify. The location of each image may vary with each match. A list of shapes with the corresponding meaning is below.

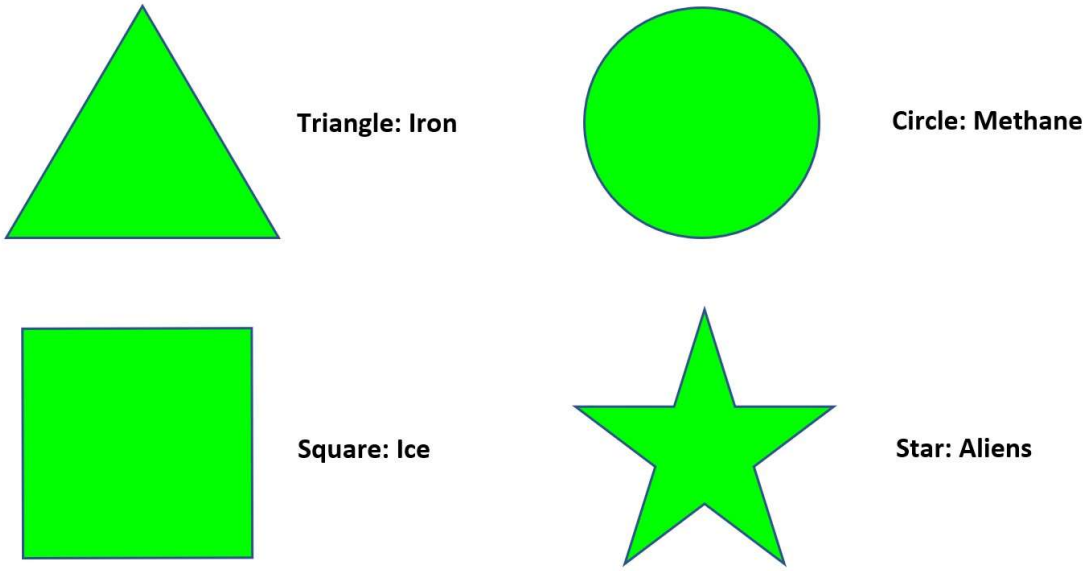
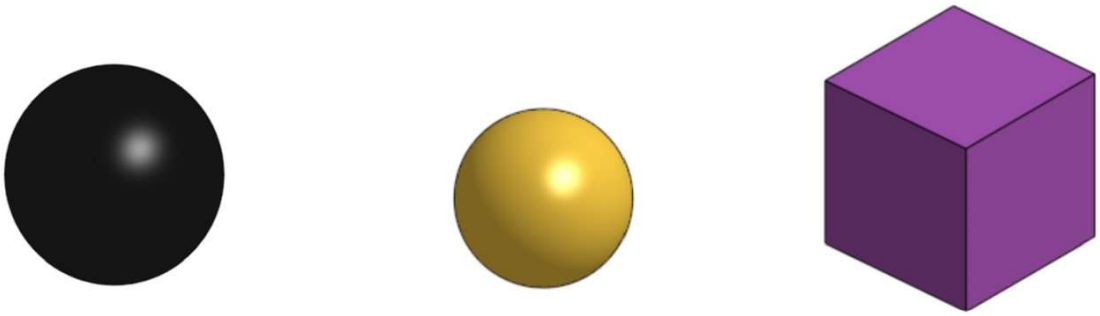


Figure 7

Element Retrieval

The RDL field has scoring elements (CarbonPods, HydroPods, and NitroPods) in various locations. Teams need to use robots to gather elements to return to the lab station. Each alliance side contains twenty-four (24) NitroPods, ten (10) CarbonPods, and thirty (30) HydroPods. Robots must collect elements from the opposing alliance side, until the final two minutes of the match.

NitroPods are represented with purple 101 mm cubes. NitroPods carry a point value of ten (10) points each. CarbonPods are represented by black 72 mm balls and carry a point value of twenty-five (25) points each. HydroPods are represented by yellow 40 mm balls and carry a point value of five (5) points each.



Black: Carbon **Yellow: Hydrogen** **Purple: Nitrogen**

Figure 8

Molecular Assembly

After the robot has collected a scoring element, it transfers the element to the lab station. At the lab station, the lab technician uses the collected elements to assemble hydrocarbon molecules. Points for correctly assembled molecules are given based on the number of HydroPods and CarbonPods used. Teams who successfully assemble molecules are awarded 125% of the point value for the elements used to build molecules. The following table contains acceptable hydrocarbon molecules and the corresponding point values.

Molecular Assemblies	Molecule Type	Carbon Amount	Hydrogen Amount	Points Each (element values multiplied by 125%)
	Methane	1	4	**56.25**
	Ethane	2	6	**100**
	Propane	3	8	**143.75**
	Butane	4	10	**187.50**
	Pentane	5	12	**231.25**
	Hexane	6	14	**275**
	Heptane	7	16	**318.75**
	Octane	8	18	**362.50**
	Nonane	9	20	**406.25**
	Decane	10	22	**450**

Table 1

Inclement Weather

During the first thirty seconds of the autonomous period, Titan experiences inclement weather. In the first fifteen seconds, the playing field becomes very hazy, causing robots and drones to navigate through a visually limited atmosphere. In the following fifteen seconds, Titan experiences a high wind storm before weather resumes normality.

End Game

At the end of each match, there is an optional end game challenge for teams to attempt. There is a bar above the staring area, 63.5 cm high. Teams who opt to attempt this challenge need to move the robot back to the starting area and suspend the robot from the bar. To earn points, the robot needs to lift completely off the ground.

Autonomous Period

At the beginning of a 10-minute match, the first 60 seconds is considered the autonomous period. Human control of the robot or drone is not allowed. Teams are awarded points for autonomous movement of the robot or drone as depicted in the scoring table below. Drones and robots may score autonomous points through the deployment of a seismometer, antenna, and AUV, as well as image recognition. Completing these tasks autonomously results in double points.

Autonomous - 01:00 minute	**Action**	**Element**	**Robot/Drone**	**Points Each**
	Seismometer	Seismometer	*Robot*	***20***
	Mate Sensor	Mate Sensor	*Robot/Drone*	***20***
	Image Target Recognition	Images x4	*Robot*	***20***
	STEM Question	#1	*Robot/Drone*	***50***
	Satellite Antenna	Satellite Antenna	*Drone*	***20***
	Beacon Activation	Beacon	*Drone*	***20***
	HydroPod Retrieval	Hydrogen Pod	*Robot*	***10***
	NitroPod Retrieval	Nitrogen Pod	*Robot*	***20***
	CarbonPod Retrieval	Carbon Pod	*Robot*	***50***

Table 2

Teleop Period

Upon completion of the 60 second autonomous period, the remaining 9 minutes is considered teleop (human control) period. Autonomous functions are not restricted during the teleop period; however, human operators must maintain hands on control of the robot or drone during the 9-minute period. If autonomous functionality is used within the 9-minute teleop period, doubled points are not awarded.

Teleop – 09:00 minutes	**Action**	**Element**	**Robot/Drone**	**Points Each**
	Seismometer	Seismometer	*Robot*	***10***
	Mate Sensor	Mate Sensor	*Robot/Drone*	***10***
	Image Target Recognition	Images x4	*Robot*	***10***
	STEM Question	#1	*Robot/Drone*	***25***
	STEM Question	#2	*Robot/Drone*	***50***
	STEM Question	#3	*Robot/Drone*	***75***
	Satellite Antenna	Satellite Antenna	*Drone*	***10***
	Beacon Activation	Beacon	*Drone*	***10***
	HydroPod Retrieval	Hydrogen Pod	*Robot*	***5***
	NitroPod Retrieval	Nitrogen Pod	*Robot*	***10***
	CarbonPod Retrieval	Carbon Pod	*Robot*	***25***
	End Game Challenge	N/A	*Robot*	***75***

Table 3

League Guidelines

League Overview

The Robot Drone League season runs from early September through January. RDL is a multi-week game where a percentage of scoring elements are changed each year, and point values are adjusted to meet the requirements of the game. Teams consist of ten to fifteen members that are required to build one robot and one drone to work together to achieve mission success. Teams should benefit from the guidance of teachers or mentors with the constraint that only the students should build the robot and compete. When faced with a challenging problem, students appreciate guidance on different methods the problems can be solved or solutions to improve upon an existing student-driven design.

Divisions

Teams will be categorized by grade level. RDL consists of three divisions: Division I, Division II, Division III.

Division I - Grades 9^{th} – 12^{th}

Division II - Grades 6^{th} – 8^{th}

Division III - Grades 1^{st} – 5^{th}

Keep in mind that teams in different divisions may still compete against each other, but the STEM questions will differ in difficulty based on division and based upon standards aligned within each grade level.

Team Organization

Teams may consist of an unlimited number of members; however, RDL recommends ten to fifteen members per team. There is a limit of four to six players allowed in the driver's station. There is a designated pit area where team members not in the driver station may stay to encourage teammates during competition. Teams compete in a double elimination style tournament, where each match lasts 10 minutes.

RDL Team Showcase

On RDL competition day, teams will have an assigned showcase time. A maximum of ten minutes is allocated to allow the team to showcase to a panel of three judges. For the first five to seven minutes, teams have freedom to uniquely present the engineering and design of the robot, as well as the programming of the drone. Teams are not be limited in presentation style. The only requirements are that all team members are present and speak, and the team's robot must be present. After the team has finished the five to seven-minute presentation, the judges

are given the opportunity to present the team members with questions for the remaining time. The RDL Team Showcase is designed to award teams with an opportunity to discuss the STEM ideas behind the teams' robots, as well as how teams are impacting communities through setting the STEM example to others. As an option, teams are allowed to include technical documents (< 10 pages), reports, posters, and published materials to aid the RDL Team Showcase in support of the team's presentation to the judging panel.

Driver Station

The primary concern during any event is safety. To ensure the safety of all participants and observers, safety restrictions within the driver station must be followed at all times. The number of team members allowed in the driver station during a match is limited to four to six. Mentors are never allowed at the driver's stations during match play. All players in the driver station must be wearing closed toe shoes, as well as safety glasses. Long hair must be pulled back and secured. No loose clothing or dangling jewelry is permitted.

Safety Check

The game has numerous scoring strategies which impact the design and construction of the team robots and the programming of the drones. Following the Four Laws of Robotics, safety is the primary concern for humans, robots, and drones related to inspection. Each robot and drone are required to successfully pass a safety check before competing in the tournament. To pass a safety check, robots and drones need to successfully meet the specifications defined below. If a robot or drone is not deemed safe, it is not allowed to compete. **Please note that when practicing for or competing in an event, safety should always be the priority. Unsafe operations of both robots and drones can result in serious injuries in the occurrence of misuse or malfunctions.**

Robot Specifications

Robots must be under 61.0 cm wide and 61.0 cm high. Robots are limited to using 30 or less amps. Wires should be attached to the frame of the robot and organized in a safe configuration. Robots must have no exposed wires. Robots must use batteries of 12V or less. Teams can use any control hub as long as it is inside the amperage limit. RDL does not allow the use of hydraulic systems; however, pneumatics may be used. For pneumatics, there is a limit of 50 PSI, and robots using pneumatics are required to have a pressure relief valve. Robots may not have any sharp edges or properties that would allow the robot to intentionally disregard any of the Four Laws of Robotics. Any robot exceeding the limits is to be disqualified.

Drone Specifications

Teams may use any drone within the size limitations. Drones must be no larger than 46.0 cm wide, 46.0 cm high, and 46.0 cm long. Teams can use any means of programming the drone. Drone propellers must be shrouded.

Team Match Participation

Team Members

During a match, a team cannot use other participants outside of the driver station to guide robots or drones. If the team is viewed as using external participants to gain an advantage, a red card can be issued. Team members are not allowed on the field during a match and must remain in the driver station or pit at all times, with the exception of the lab technician, who is in the lab station. **Under no circumstances can a team member reach past the net and onto the field.** The only human interaction with robots is to be from the lab technician. If the robot or drone is not working, an RDL official will place the robot or drone outside the playing field for the team to work on. Team members who violate the field access rules are awarded a yellow card.

Match Setup

Before each match, teams have five minutes to set up the robot and drone. Teams also have a five-minute breakdown period after each match.

Match Scoring

Each team needs to designate a scoring captain. The scoring captain is responsible for keeping track of the team's points during the match. If a scoring captain sees possible error after an RDL official has calculated the final scores for both teams, the scoring captain may bring up the issue with two different RDL officials. The two RDL officials will reconsider the team's score. Scoring captains need to present evidence for any scores to be reconsidered, including, but not limited to, video evidence.

Field Reset

After each match, RDL officials will reset the field. This reset period lasts approximately five minutes.

Penalties

Definitions

Yellow cards serve as warnings to teams. Red cards result in a fifty (50) point deduction from a team's score. A driver or pilot issued a red card is required to sit out the following match.

1. Following the intent of the Four Laws of Robotics, a robot may not purposely harm another robot, unless that somehow violates the First Law related to the safety of a human. The field is large, and it is expected that robots from each team will come in close proximity to each other. Robots should not intentionally contact another robot to play defense or prevent the other robot from accomplishing a task.
2. Purposely blocking a robot with another robot to prevent scoring or movement of the robot results in a yellow card.
3. Drones that intentionally crash into a robot as a way to prevent scoring results in a red card for the offending drone pilot. Drones that crash into an opposing robot are not eligible to be rescued during the match.
4. If a drone collision occurs, pilots are awarded a yellow card. If, in the opinion of a referee, a drone was intentionally crashed into another drone or did not show clear intent to avoid a collision, a red card can be issued for the offending drone's pilot.

Yellow Card

A yellow card serves as a warning for robot or drone behavior that is not in the spirit of the Robot Drone League. Any yellow card that is issued can be reviewed by league officials at the end of the match to determine if the actions of the robot under the control of the driver were intentional to gain an advantage and a disregard of rules. If the league officials determine that the rule violation was intentional, it can become a red card.

Red Card

A red card issued for poor robot or drone behavior will result in the designated driver's absence in the next match, as well as a fifty (50) point deduction from the offending team's final score. The driver is allowed in the driver station during the next match. A drone that is awarded a red card requires that the pilot of the drone sit out the following match.

Video Replay

If video captured evidence, by RDL, clearly shows that a yellow card or red card should not have been issued, a team can appeal to the head referee to have the penalty overturned. If, in the opinion of RDL officials, the video shows clear evidence that the penalty should not have been awarded, the penalty is removed. If RDL officials conclude the appeal had no merit and the video does not provide any evidence that the penalty should be reversed, an additional yellow card can be issued.

The 2021 Dragonfly game is designed to be a challenging and fun game. In the interest of fairness and clarity, rules may need clarification or additional rules added during the season.

Awards

World / Regional Champion – Awarded to the top team that encompasses the overall best in competition, both on and off the challenge field. The following factors are taken into consideration for this prestigious award:

Challenge field scores

Team Showcase presentation

Community Outreach

Tournament Professionalism

Collaborative Spirit

Top Score Award – Awarded to the 1st, 2nd, and 3rd place teams based solely on scores finalized at the end of challenge field play.

Professors Award – Awarded to the team demonstrating the best of community outreach that helps to promote STEM learning in their community. Submission for this award is optional and must include a team essay not to exceed 500 words. Pictures, articles, and letters of appreciation or acknowledgement are recommended for serious consideration of award. Submissions be submitted no later than midnight on December 1st, 2021.

Team Showcase Award – Awarded to the team that best presents on competition day to the judge's panel.

Engineering Award – Awarded to the team that best demonstrates innovation in design and provides best evidence of documented engineering practices to panel of SME professionals.

Judges Award* – Awarded to the team that best demonstrates team grit and tenacity no matter the scoreboard. *Note* (This award is optional and awarded at the discretion of the Head Judge).*

Top Dog Award – Awarded to the team demonstrating the highest competition autonomous scores.

Top Rookie Award – Awarded to the best of the best Rookie team competing in their first RDL season.