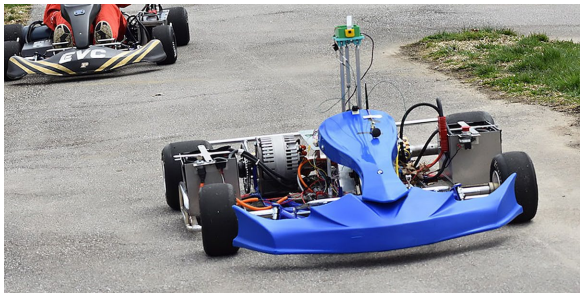
evGRAND PRIX™
AUTONOMOUS

APTIV
STUDENT KARTING
WORLD FINALS
PURDUE UNIVERSITY



2022 Rules and Specifications

University Autonomous Karting

Collegiate Autonomous Karting
RULES & SPECIFICATIONS

A. Introduction and Overview – General

The University Autonomous Series has been developed to provide College/University Students with the opportunity to participate in a electromechanical project that promotes the skills and abilities necessary in today's changing world. Autonomous transportation that is usually electric driven is in the immediate future of today's Engineers and Technologists.

To provide the platform for students from universities from around the world can come together and demonstrate their skills and abilities in a competition format thru the Motorsport of evKarting. A time where Automation Industry professionals can come and interact and talk with our students. Hopefully resulting in research and Internships/Job opportunities. While we may begin with more automated controls utilizing machine learning, we have a long-term objective of computer vision algorithms controlling the racing kart independent and wheel to wheel. The machine learning systems are one of the stages of advancement and development. See section C.

B. Goals

To provide project-based programming experience with a great lab venue (test/race) and a set of technology driven structured outcomes. These outcomes will progress as the series moves forward and the technology advances. To present challenges and projects that correspond with current and future autonomous industry forecasts. To advance the learning outcomes of our students to assure the talent demand is there when American Manufacturing and Autonomous Systems Development seeks out future employees with those skills. To prepare a skilled and ready workforce to keep those great paying, highly skilled jobs and business opportunities right here in the USA!

C. Series Advancement and Development

We will take steps to reach the autonomous division evGP final objectives. Working on step by step, year to year with a multi-year goal of wheel-to-wheel racing (5 or more evKarts). We will begin with Machine Learning technology and advance to integrate AI systems as that new technology develops.

We encourage the many different teams to reach out and find technical partners that may provide some funding to be involved. Each team is allowed one Industry Advisor to attend with them at competition events. Many corporations have similar but different autonomous systems. The goal would be to see many Industry companies participate as the program grows.

The progression in the annual events will lead us to systems that utilize advanced software and hardware methods for reliable decision making on track and will take our students to a level that they know and understand the safety concerns necessary for ISO Certification on a system they design. We will be able to race wheel to wheel at speed with more than 2 Karts on track in each Heat Race. We will get there!

Autonomous/Automated Karts

C1.0 Stage 1 was about showing up and operating in "remote control mode" to make sure all was good with the encoders and servos as well as all mounting hardware was correct before a team or teams attempted automated or autonomous runs.

C2.0 Stages 2 and 3 are Timetrials to complete several laps at a respectable speed in autonomous mode. The Kart with the fastest overall lap time and demonstrating basic object detection capability wins the event. The Karts are not expected to detect and avoid other moving vehicles. Starting and ending the timetrial on the track simplifies the programing but still demonstrates vehicle operation independent of human operation in real-time steering, brake, or throttle operation. Teams may use the GPS or Vision or both for location and simple vision or lidar for detection.

C2.1 Karts must adhere to the RaceControl track flags of Green and Red (Emergency Stop) sent via WIFI. At this stage of competition standard 4G or 5G or Wifi signal for "race control" will be provided thru "hot spot". The only signals that will be allowed sent **to** the Kart while on track would be a GPS reference, green flag to start a run and red flag (emergency control stop signal).

C3.0 Stage 4 (2023) goals are for one or more (2 maximum) Karts on track and bring the track laptime to within 80% of the Collegiate evGrand Prix average. The 2 kart case is MATERIALLY easier than the 3-n case. At this stage of progression, decision models or track mapping for simulation software can be introduced. However, simulation models are optional and not supported by the series. This test requires some sensors (lidar, radar, camera) to detect, locate the test object.

C3.1 The goal is the software in Stage four is to become ISO 26262 compliant compatible moving forward. Machine learning alone is not sufficient.

ISO Autonomous

C4.0 Stage 5 would begin the transition to the final stage which is Head-to-head competitions. These events would begin in heats of 3 karts and progress to heats of 5. Speeds as reference in C3.0 this

stage is more focused on Computer Vision Algorithms or AI. With a goal of wheel-to-wheel racing with the approaching and passing thru the race done solely by the autonomous software stack making the decisions on board.

C5.0 Stage 6 the final objective would then continue from year to year and be the same as Stage 5 except speeds would need to increase to 45mph lap times as referenced in C3.0 with passing of multiple karts racing on track.

C6.0 The evGrand Prix Steering Committee will make all decision when to advance to another Stage.

D. Other Items

D1.0 The Purdue Grand Prix Track will furnish standard Wifi in the immediate / track area. Check with Event Officials before bringing your own Wifi or GPS Beacons or if you have special needs for Wifi.

D2.0 No traffic cones will be provided track side after in 2022. No cones are expected in future years.

D3.0 No kart battery charging in the Pit area at the Purdue Grand Prix Track.

D4.0 No tent or canopies allowed in the Pit Area of the Purdue Grand Prix Track.

D5.0 Each team will furnish their own Co2 Fire Extinguisher in the pit area and with their kart at all times.

D6.0 The pit area will be only for Teams on Track, Teams Preparing to go on Track next. All other activity needs should be performed in your Paddock area (around your trailer).

D7.0 The Karts shall have April tags on standard kart number plates mounted forward near the nose and likewise at the rear near the rear bumper centered on the Kart pursuant to Appendix A to facilitate detection.

E. Collaborative Activities

E1.0 Track coordinates data exists for those interested. UC San Diego and University of Hawaii were kind enough to collect this data in 2021. Another data set from Purdue is available as well.

E2.0 Competing Universities are encouraged if they want to use the data for a simulator application and possible winter simulation-based challenge.

F. Compliance and Safety

F1.0 All participants agree to comply with all rules and policy of the evGrand Prix Series. As well as the rules of the Purdue University Grand Prix Track while there.

F2.0 The Race Director will have final say on issues of competition.

F3.0 The Safety Director will have the final say on all safety and security related items and issues.

F4.0 The Event Director will settle all issues of non-competition or non-safety related in nature.

F5.0 Any and all disputes of the rules will be presented in a written protest with a copy to all three of the above Directors. Within 3 days of the issues occurrence.

G. World Finals Venue and of Note

This Autonomous Karting competition takes the academic challenge to a new level and brings to light the up-and-coming disruptive technology facing the transportation industry today. Combining the mechanical design of traditional auto-racing with the cutting-edge software controls of driverless vehicles, autonomous go-karts are the perfect platform to design and test this new technology. At a price point affordable to all.

evGrand Prix Autonomous Series is an educational platform that will reach the objectives required for respectable motorsports speeds with wheel-to-wheel racing as the final format. The evGrand Prix Autonomous Series will by design, mimic a more traditional race situation with several other competing autonomous karts on the track racing at respectable speeds. The obstacle avoidance eventually comes in the form of navigating around other autonomous karts and through the track as fast and efficiently as possible.

evGrand Prix is once again pushing the limits of electric vehicle technology and challenging students across the world to learn, design, and build the vehicles of tomorrow.

Danny

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1.0 Jurisdiction

1.1 **Interpretation –** All subsequent rules and specification in this document will be interpreted by the technical inspection team who will determine the acceptability of the vehicle and the safety equipment for the competition. Any discrepancy will be resolved by the Event/Safety Director.

1.2 **Inspection Stickers –** An inspection sticker, indicating a race vehicle has been accepted for competition shall be positioned at a conspicuous place on the race vehicle chosen at the time of the technical inspection.

1.3 **Deviation Requests –** Any deviation request must be submitted by April 1 with action reported back by May 1.

1.4 **Workmanship –** The Technical Director has the right to question poor workmanship and the resulting safety hazard it presents and require the team to repair the deficiency

1.5 **Team Eligibility –** All of the criteria below must be met for a team to compete in the Autonomous Series.

1.5.1 At least two members of the team must be present to compete in any event or testing.

1.5.2 Each team must have a dedicated kart independent from other teams. For example, a university may not field four teams by using only one kart.

1.5.3 Only registered full-time students of a recognized institution of higher education are eligible to participate. Proof of class registration will be required if requested. One Sponsoring Industry Representative can be trackside with the Team.

1.5.4 No student can officially be a member of more than one team

1.5.5 A University (or a collaboration of multiple Universities) may field more than one team and therefore more than one Kart.

2.0 Race Vehicle Specifications & Requirements

2.1 General Vehicle specifications

2.1.0 **Vehicle Type –** The race chassis specified and certified for the competition is a commercially available “Sprint Kart” EV chassis from Top Kart USA.

2.1.1 Chassis Frame –Teams must race with a commercially available Top Kart USA.

2.1.2 Sidebars – The side bars that come standard on the Top Kart EV chassis must remain intact and functional so that any side impact will be transferred to the main chassis frame directly. This protects fragile and expensive equipment installed within the sidebars/frame.

2.1.3 Wheelbase – The Standard IKA for "Sprint" type chassis will be the standard for wheelbase. Distance must be 43" maximum and 39.75" minimum. Wheelbase measurement is taken on a line beginning at a point perpendicular to the rear axle centerline forward to the point on the horizontal spindle front axle centerline on which the hub rides nearest the kingpin bolt. Both sides must meet this max and min rule.

2.1.4 Tread Width - Minimum tread width is 28" as measured from the outside of one tire to the inside of the opposite tire. Maximum tread width or kart width is 55 1/8" as measured from outside to outside of the widest point of the kart.

2.1.5 Tires - The approved tire for the series will be manufactured by HOOSIER Racing Tire. The compound is H60B. The sizes are 4.5/10.0/5 fronts and 7.1/11.0.5 rears. Tires must be run as supplied by the manufacturer, no alterations or additives allowed. Those found to have altered a tire(s) will be subject to disciplinary action. Tires must be mounted for the proper rotation as prescribed by the manufacturer arrows on the tires. Penalty will result in loss of practice session, loss of qualifying time, or disqualification from the race. Replacements for a puncture will be handled on a case-by-case basis by the Director of Competition.

2.1.6 Wheels – All wheels shall be of racing quality and void of any defects. Wheel bearings shall be of ground ball or roller type only. Axle nuts shall be castellated and secured with cotter pins of at least 1/8" in diameter or nylon nuts with clips. Safety wire or bolts through the axle are not acceptable.

2.2 Bumpers and Bodywork

2.2.1 Front Bumper – All karts must be equipped with a commercially available front crushable (which is standard on a Top Kart chassis) attached to the front bumper to minimize shock in the event of a front impact. The front crushable must be a Top Kart or CIK nose.

a. Impact Bumper –Exempt

2.2.2 Rear Bumper – All karts must have rear protection that extends from the outside of the rear tire/wheel assembly. This can also be a CIK style plastic rear bumper.

a. Front and rear bumpers are **mandatory**. Teams can purchase these from Top Kart.

2.2.3 Side Bumpers – Side bumpers are optional however a kart's sidebars / nerf bars should be able to withstand a side impact. Proper protection should be in place to protect battery packs and other components that are mounted on the side (see 2.6.6). If bumpers are used, they must not extend beyond the outer edge of the rear tires.

2.2.4 Dislodged Or Missing Bumpers – If a bumper or side pod falls off or becomes dislodged, the flagman may show a black flag and the kart would be required to return to the pits.

2.3 Propulsion System

2.3.1 Motor Batteries – All race vehicles must be powered from electricity supplied by a battery. For the Autonomous Series, it is mandatory that teams use the affordable and easy-to-use lead acid batteries. The Interstate SLA1155 or SLA1156 (12v, 35Ah) batteries are used in the High School Series and are mandatory for Autonomous karts. This rule is in place to maintain affordability and keep the engineering focus on autonomous systems. Teams are encouraged to participate in the collegiate evGrand Prix (driver) division if they wish to design and race advanced powertrain systems.

Batteries must display all original manufacturers' labels.

2.3.2 Motor Battery Voltage – Battery packs and all other electrical components must not exceed 48-volt nominal voltage (54 volt maximum fully charged). Teams should be aware of a battery pack's nominal voltage versus its fully charged voltage.

2.3.3 Motor Battery Capacity – Teams are responsible for providing manufacturers specifications showing amp-hour and voltage.

2.3.4 Motor Battery Enclosure – The Top Kart lead-acid battery box is mandatory for Autonomous karts. This box is affordable and available from TopKart and will help all karts look professional on the track.

2.3.5 Autonomous Battery / Enclosure – The teams may power the autonomous electronics by a separate battery power system. Any battery technology and charging technology may be used as long as a) the university advisor signs off the design is deemed to be designed with safety in mind, b) the batteries are mounted in a metal container and protected from damage in the event of a crash or rollover, c) the battery box is firming mounted to the kart structure, and d) the master safety stop fully disconnects the batteries from all electronics as close to the battery box as reasonable.

2.3.6 **Wiring –** All wires must be rated to handle the voltage and current load that can be applied through the circuit. For clarification, please consult the wire size chart located in the National Electrical Code Article 400 Table 400.5(B). In all cases, manufacturer data will supersede the general information from the NEC. Wiring must be well insulated and securely attached to the vehicle. All wiring must be kept free from moving parts and protected from chafing. Wires that pass through a hole with sharp edges or through sheet metal must be protected by an insulating grommet or other suitable device. Terminals must be secured and protected so they will not come loose or short out during competition. No electrical terminals may be exposed. No part of the electrical system may use the vehicle frame as a conductor and the frame must remain ungrounded. The vehicle will be checked for maximum frame to electrical leakage during Technical Inspection. Maximum voltage allowed is 5 volts measured from the most positive and the most negative of battery pack to frame with vehicle in run position. Voltage must dissipate to net zero upon application of a 10,000-ohm resistance.

2.3.7 **Fusing –** A fuse or circuit breaker is required for the electrical circuit between the battery and any electrical load. All fuses or circuit breakers will be mounted in electrically rated enclosures as close as practically possible to the source of power. All fuses or circuit breakers will be sized to protect the wiring to which they are connected. Fuses will be sized to carry no more than 85% of the maximum allowable current for the wiring. This means the peak current of the fuse has to be less than the peak current of the wire being used at all times. The main traction drive fuse will be inspected for appropriate type, voltage, and current rating. If the fuse must be replaced, the kart will need to be re-inspected prior to allowing the vehicle to operate in the event.

2.3.8 **Emergency Switches –** An emergency stop circuit must be employed on the vehicle. The circuit will consist of a kill switch located on the rear of the vehicle in a location which is easily recognizable, labeled, and accessible to emergency personnel. The main kill switch and the emergency stop switch will be wired in series with the solenoid coil of the main contactor. Interrupting the current to the solenoid coil will turn off the main contactor and isolate the battery pack(s).

a. The power circuit will contain a contactor (also known as solenoid relay) for the purpose of isolating the motor and autonomous battery pack when not in use and during an emergency. This contactor must have a current rating that exceeds the maximum peak current draw of the vehicle

b. An indicator light must be included to signal when the main contractor is closed. The light must be placed near the emergency stop switch and must be visible to track personnel.

2.3.9 Power Limit – The traction drive power system must not exceed 10,000 watts at any time during the race. Power shall be defined as the instantaneous voltage multiplied by the instantaneous current delivered by the battery. A Power and Energy Monitoring Device may be installed to measure instantaneous power drawn from the battery. The voltage used for this calculation is not the battery pack nominal voltage but the actual voltage, so teams must be aware of any overvoltage present in their packs when setting control limits.

2.3.10 Energy Limit – The total energy onboard a kart shall not exceed 3,000 watt-hours as calculated by multiplying the nominal voltage of the battery pack by its listed amp-hour rating.

2.3.11 Power and Energy Limit Enforcement – Only enforced in Stages 5 and 6. The power and energy limit (10Kw and 3,000 watt-hours respectively) may be enforced by the race officials using a Power and Energy Monitor (PEM) data collection box installed during kart inspection prior to the race event. Each race vehicle must pass technical inspection prior to installation of the PEM. Teams will prewire and prepare a mount on their vehicle as specified in rule 2.5.6. PEM must be secured in place using fasteners that comply with rule 2.3 and in line with the Anderson SB175 Connectors.

a. The PEM must always remain visible on top of the battery box. An area of 6”x14”x8” is needed for the box. The PEM will be connected using Anderson 175 amp red-style connectors.

b. **See Appendix A for PEM details and mounting/installation requirements.**

c. If a team exceeds the maximum power limit during the race, an indicator light will go off and they will be blacked flagged. The team may be disqualified from the race if it continues to race over the power limit.

d. The vehicle is subject to re-inspection at any time**.**

2.3.12 Motor Specifications – The brushed DC Motor (Motenergy ME0708) that comes standard with the high school kart kit/autonomous kart kit is the spec. motor for the series. Its specs are 48v 100amp, 3200 rpm, 4.8kw and 14nm torque.

a. Beginning in 2022 as a Brushless alternative the teams may run a Motenergy ME1718 setup at 48v, 100amp and 3200rpm standard configuration or a GoldenMotors HPM5000B setup for 48v, 100amp and 3200rpm. The intent of this rule is to assume the motor are function equivalents. No modifications are allowed to any motor and motors must

comply to these specs.

b. Note the Motor Battery voltage is fixed at 48v and the spec SLA batteries noted above are required for the motor and to be wired in series for 48v.

c. Motors meeting the above maybe acquired from any sources.

2.3.13 Controller Specifications - The Alltrax Controller with brushed DC motor noted above is used in the High School series and is available through Top Kart. This is usually the most affordable option.

a. Beginning in 2022 the following Brushless Motor controllers are approved for the Brushless motors above. The VESC 75/300 and the VESC 100/250 controllers as well as the GoldenMotors VEC300 controller.

b. Controllers meeting the above maybe acquired from any sources.

2.3.14 Kart Speed –A respectable speed is expected. Those speeds are listed in the beginning section as we define Stages of Development. The speeds increase with experience and higher technology.

2.4 Vehicle Identification

2.4.1 Numbers – Karts may use any number from 2-99. Kart number 1 is reserved for the previous year's winner. Numbers for each event are reserved on a first come first served basis. You may be asked to select an alternative number should your number be unavailable.

2.4.2 School Affiliation – It is recommended that a decal displaying school affiliation be placed on the side pods of the kart.

2.4.3 Series Sponsor – A 4" x 4" area on the front panel of the race vehicle will be reserved for a series sponsor decal. Series sponsor decals must be displayed at all events during the season.

2.4.4 Race Sponsor(s) **–** A 4" x 4" area on each side panel of the race vehicle will be reserved for race sponsors decals. These must be displayed at all times the event is running.

2.4.5 Team Sponsor(s) – evGrand Prix encourages the recruitment of commercial sponsors (marketing partners) for individual team entries. Teams must assure no alcohol, tobacco, political or offensive promotional materials are displayed and ensure compliance with their affiliated school guidelines on that topic before entering into any agreement. Again, no team may be sponsored by any organization or business associated with alcohol or tobacco, or things of a sexual or denigrating nature. Purdue Engineering has final say on any discrepancies with the rule. Advertising of sponsors on the racing vehicle shall be limited to signage located on front, rear and side panels and crushable of

the race vehicle. The advertising in the front shall be kept at least 3 inches from each side of the front number panel.

3.0 2022 Autonomous Qualifying & Race Format

3.1 Practice – Teams will be given practice time on the track on both event days. We are aware that autonomous systems require as much track time as possible to feed and learn its algorithms. We will attempt to provide two private test days before the event when possible and weather permitting.

3.2 Time Trial / Qualifying – For Stage 4 (2022) a single kart timetrial will include a collision avoidance test.

3.2.1 Teams will be allowed 5 laps during their time trial session. Teams have two attempts to begin their official time trial session.

3.2.2 The Crew Chief can withdraw their kart from a session any time before the 3rd lap begins.

3.2.3 Any kart entering a 3rd lap or has already withdrawn once cannot withdraw.

3.2.4 Lap times for a withdrawn session will be thrown out and not considered.

3.2.5 Kart not completing a qualification run shall be designated DNF.

3.3 Obstacle Avoidance – In 2022 an obstacle will be placed into the track during each kart's 5th lap of their time trial run.

3.3.1 The test object will be a simple cardboard box 3 ft wide and 1 ft tall as viewed from the kart and painted black to match a CIK bumper to generally simulate a stationary kart.

3.3.2 For detection purposes a standard kart number plate with an April tag will be mounted in the center of the box at a height of approximately 9in to the bottom of the number plate.

3.3.3 he April tag shall be available to all teams for practice by the end of February.

3.4 Penalty Seconds – Penalty seconds (10) will be added to a kart's fastest lap time if there was a collision with the obstacle placed into the track.

3.5 2022 Event Winner – The kart that completes all 5 laps (or most of the laps) and has the fastest single lap time after any penalty seconds are added is the Autonomous Race winner for Stages 1 thru 4. Industry standard race qualifying and racing are expected for Stages 5 and 6.

4.0 Autonomous-Specific Rules

4.1 Fully Autonomous Kart Definition – First and foremost must be able to certify at ISO 26262. Fully autonomous means there can be no human interaction with the kart while it is operating (exception: a remote kill switch signal and race control. A fully autonomous kart must be able to locate and navigate a track completely on its own with no incoming data signal using sensors and computers mounted on the kart. Throttle and steering commands for path navigation are examples of control signals to

be calculated by these computers. No human input may be used to determine speed, acceleration, or steering angle of the kart during autonomous operation. No driver assist is allowed when preparing the Kart for competition.

4.2 Automated Kart Definition – Utilizing machine learning algorithms to create decision models to execute tasks such as object detection, object identification, object classification, object location and predictive movement and effectively maneuver a race car around a racecourse. Eventually mapping multiple lines on the course for obstacle avoidance or passing. Some early systems used actual driver inputs from driving around the track and then mimicked the driver feeds in automated mode.

4.3 Manual Propulsion – At no point during practice or time trial laps may a kart (or its instruments) be manually steered or propelled by a human around the track. All steering controls and throttle commands must also be capable of remote control.

4.4 Remote Control – Teams are allowed to remote control their kart around the track during practice in stages 1-4 of the competition. Teams may use this opportunity to calibrate sensors and feed their machine learning algorithms. However remote-controlled operations will NOT be allowed during time trial or racing laps at any time other than moving to position at the start finish line.

4.5 GPS Data – GPS sensors (including RTK GPS) will be allowed. The series highly discourages teams from simply navigating GPS points and diminishing the importance of obstacle avoidance/true autonomous planning.

4.6 Team to Kart Communications – The Teams shall only communicate to the kart according to the following rules. Any other communication may be deemed a breach of the rules.

- 4.6.1 Each team will get a static IP for the kart and the Pit station for use for Wi-Fi communication during the event.
- 4.6.2 To minimize delay / lag in the traffic teams shall keep the Wi-Fi turned off until staging the kart on track and during the on-track runs.
- 4.6.3 In practice sessions the teams may send and receive any information and provide control signals messages to the kart.
- 4.6.4 During Competition only the Red Flag (emergency stop) may be sent by the team.
- 4.6.5 The Team may receive up to 1 Mbs of telemetry messages from the kart during practice and during the competition to monitor the vehicle.
- 4.6.6 The RaceControl Green and Red flags will be sent across the WIFI and acknowledged by the Kart. Details are TBD.

4.7 Remote Kill Switch – A remote-controlled kill switch will be installed onto each kart and validated each time in Tech Inspection. Teams are required to design their own braking systems for their karts normal operation. This kill switch system will be supplied by each team and shall be redundant to existing braking systems. The switch shall be installed in-line with the kart's contactors solenoid/coil circuit.

4.8 Minimum Speed – In the spirit of racing, all karts will be expected to maintain a

respectable speed on the racetrack. This competition is different than other Autonomous Challenges as top speed is a priority over technical course navigation. There are no stop signs to obey or intersections to cross. Karts are expected to keep an average respectable speed. Like every racing event, evGrand Prix officials reserve the right to black flag and/or disqualify karts that cannot maintain the expected track speed. The Stages of Development of the Series will be a big factor in determining a minimum speed, if any.

4.9 **Kart Collusion –** Communication between vehicles is prohibited. Teams may not collude to manipulate race outcomes.

4.10 **Altering the Course –** Competitors may not attempt to alter anything on the track including but not limited to covering of reflective surfaces or addition of markers throughout the course.

4.11 **Deception –** No part of a kart may be used to deceive other vehicle sensor systems. Teams may not intentionally implement any form of jamming or sensor disruption to slow other karts. Such modifications will be reviewed at the discretion of the Advisory Committee under sportsmanship.

4.12 **Poor Sportsmanship** - One cannot add lights or paint to deceive another competitors LiDAR.

For questions please contact:

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