

Indy Autonomous Challenge Powered by Cisco
Passing Competition Rules



Version 1.0.0
Texas Motor Speedway Edition
November 11, 2022

Version	Date	Author	Key Revisions or Versioning Rationale
0.9	9/9/2022	Kris Kozak	Initial rules: pre-release draft
0.9.1	10/20/2022	Kris Kozak	Additional right-of-way clarifications. Following distance under waiving green clarification in <i>4.15. Attacker Obligations</i>
0.9.2	11/4/2022	Kris Kozak	Add passing start line coordinates, remove placeholders for pit road slow zone, eliminate warmup laps from passing competition, make the time trial event optional and clarify resulting seeding
1.0.0	11/8/2022	Kris Kozak	Remove draft watermarks and release as v1.0.0

1. Overview

This competition will be conducted as a single elimination tournament consisting of multiple rounds of head-to-head matches culminating in a championship match. Two cars will participate in each passing competition match. The two cars will take turns playing the role of leader (**Defender**) and passer/follower (**Attacker**), and passes will be attempted at ever increasing speeds until one or both cars is unable to successfully complete a pass.

This new passing competition will consist of the following primary differences from the prior competition:

1. The Defender will have a wider range of choices of racing line
2. The Defender will have more freedom to vary speed
3. The Attacker and Defender must “negotiate” right-of-way when entering turns
4. The first round will start at a higher speed than the competition at CES
5. The shorter passing zone is eliminated in favor of a two lap limit for passing attempts
6. Manual interaction with the vehicle will be limited
7. The time trial event will consist of more than one round

2. Competition Bracket

The competition will be conducted as a single elimination tournament. The bracket will be set based on the number of cars that qualify. The details of the bracket will be set after the time-trial seeding event which is to be held on a day prior to the main competition among the qualified cars. Note that any one of several different bracket configurations may be chosen at that time, including brackets that would give a bye to one or more teams, or brackets that require lower seeded teams to “play in”.

The winner of the championship round will be the overall winner of the tournament/competition. The loser of the championship round will be the second place team for the competition.

3. Qualification and Seeding

All teams must qualify for the main competition in order to participate. Qualification will consist of several requirements and an assessment of competition readiness by the IAC.

3.1. Qualification Requirements

- Q1. Teams must create a safety document (or update an existing one) to be peer-reviewed by fellow teams and approved by IAC

- Q2. Teams must be able to safely pass a simulated “ghost vehicle” at the target defender speed for the first round (100 mph)
- Q3. Teams must demonstrate the ability to reliably detect other cars in a sample dataset from the 2022 Las Vegas competition
- Q4. Teams must demonstrate a controlled stop from 120 mph on receipt of a red flag

3.2. Qualification Requirement Exemptions

A team may be exempted from qualification requirement Q2 if they demonstrate actual passing of another car on the track at the first round target speed or greater during a practice session at TMS that is witnessed by an authorized representative of the IAC.

3.3. Qualification Requirement Deadlines

Track time will not be allocated specifically for qualification demonstrations. Teams must use their own track time for qualification demonstrations and must coordinate with IAC staff to witness the demonstration(s).

- Q1. Safety Document: Due by October 7 (Peer reviews are due on October 14)
- Q2. Ghost Vehicle Passing (Q2 or exemption): Must be demonstrated at TMS by the end of practice on November 3
- Q3. Vehicle Detection on Recorded Data: Must be demonstrated by October 24
- Q4. Red Flag Stop: Must be demonstrated at TMS by the end of practice on November 3

3.4. Seeding

Tournament bracket seeding will be determined by the scores from the time trial event.

4. Match Execution

The top-seeded team (the team with the best score from the time trial event) will start as the attacker. The bottom-seeded team will start as the defender. A match will progress in the following order:

4.1. Speed Level Stair Step

- 1. A single head to head match will consist of multiple rounds.
- 2. A single speed level for the defenders will be set for each round.
- 3. In every round each car will be given a passing attempt (see description of an attempt below) at the speed target for the round.
- 4. If both cars successfully complete a pass during the round, a new round with a new speed will begin.

5. If only one car is able to successfully complete a pass during a round, they will be the winner of the match.
6. If neither car is able to successfully complete a pass during a round, the match will end in a tie.
7. If the first attacker in a round fails to complete a pass, a reordering operation to reverse the roles will be carried out.
8. A progression of speed levels will be decided before each match. A speed level progression might look like the following (in mph): 100, 115, 125, 135, 145, 150, 155, 160, 165...

4.2. Tie Breaking

If a match ends in a tie, the following criteria will be used to break the tie and determine a winner:

1. Each car's successful passes will be given a score (see table below).
2. The car with the highest passing score will advance.
3. If both teams have the same passing score, the team with the highest achieved speed during the match will advance.
4. If both teams have the same passing score and same top speed, the team with the better (lower) seed will advance.

Lap	Section	Points
1	Extended front stretch (Passing start line – Turn 2)	2
1	Back straight (Turn 2 - Turn 3)	0
2	Extended front stretch (Turn 3 - Turn 2)	1
2	Back straight (Turn 2 - Passing start line)	0

4.3. Passing Start Line

A passing maneuver may be carried out anywhere on the track, however a passing attempt will always start at the "passing start line," a fixed location on the track between turns 3 and 4 defined approximately by the line from 33.040560°, -97.280084° to 33.040694°, -97.280041°, shown in Figure 1.



Figure 1: Approximate location of passing start line

4.4. Passing Attempts

Each attacker will have up to 2 laps per speed level to successfully complete a pass. Each passing attempt will begin at the passing start line and will be signaled by a “waving green flag” issued by scoring prior to either car crossing the passing start line. The passing attempt will end after a successful pass is completed or after the attacker fails to pass the defender within the two lap limit.

4.5. Initiation of a Passing Maneuver

A passing maneuver will be considered as initiated when the attacker has closed the gap with the defender to less than 10 meters (2 car lengths) and is on a non-intersecting race line. A pass can only be initiated after receiving the waving green flag and crossing the pass start location.

4.6. Completion of a Pass

For a passing attempt to be considered as successfully completed, the attacker must overtake the defender, open a 15 meter (approximately 3 car lengths) longitudinal gap, and return to their defensive racing line. The pass will be considered as complete as soon as it is clear that the attacker has resumed its racing line. After completing the pass, the attacker should maintain a speed greater than or equal to 90% of speed level for the round until the roles are reversed, and may brake as a defender would. The pass must be completed before either car crosses the passing start line for the third time (the end of second lap).

4.7. Formation Laps

Formation laps are (extra) laps used to reposition the cars or close a too-large gap between cars. Formation laps will only be given under certain circumstances at the discretion of the Race Director and Scoring. Formation laps will not be explicitly designated by a flag. Rather, the waving green flag will simply be withheld as the cars approach and cross the passing start line. During a formation lap, the defender should maintain its normal behavior, and the attacker should close the gap with the defender.

4.7.1. Large Gap Formation Lap

Under normal circumstances, after a pass is completed, and the roles are reversed, the new attacker is expected to close the gap with the new defender as quickly as possible. However, a single formation lap may be granted if the new attacker has clearly attempted to but not succeeded in closing the gap (to within 50 m) on the back straight, prior to crossing the passing start line. In such a case, the waving green flag would be withheld until the formation lap is complete and the cars approach the passing start line again. If a formation lap is granted, the waving green will be sent, regardless of whether the gap has been closed, before crossing the passing start line again. If the new attacker has not clearly made an attempt to close the gap upon role reversal, a formation lap will not be granted.

4.7.2. Role Reversal Formation Laps on Failed Attempt

If a passing attempt is unsuccessful but a role reversal is required to decide the match, one or more formation laps may be used to reconfigure the cars. The necessary flag sequence for the reconfiguration will be determined by scoring, but may include a yellow flag to the new defender to slow its speed and give the new attacker a chance to close the gap quickly. Conversely, if deemed safe based on the configuration of the cars – such as if the previous attacker is even or ahead of the previous defender – the previous defender may be sent a yellow to allow the previous attacker to move ahead and create a gap before switching roles and starting one or more formation laps.

4.8. Racing Lines

When a car is designated as the “defender,” it must follow a set racing line. Each team is free to choose their own racing line within a set of basic constraints. The racing line that is chosen by each team must be maintained for an entire match, but teams may vary racing lines between matches. When a car is designated as the “attacker” it is free to choose its racing line freely, without constraint; however, the car must automatically move to its defensive racing line upon completion of a passing maneuver.

Teams must submit their candidate defensive racing lines (no more than 3) to the IAC for approval prior to the competition. Minor alterations (lateral adjustments of less than 1 meter) of the approved lines are permitted for use in the competition without further approval.

4.8.1. Racing Line Constraints

The racing line must adhere to the following constraints:

1. Lateral motion is allowed at the entrances and exits of all turns, including the “double dogleg” turns on the front stretch.
2. The car must be fully to the right or to the left of the centerline for the majority of the back straight (the car should not dwell on or near the centerline)

4.8.2. Racing Line Deviations

The defender is not permitted to actively block the attacker. To be clear, the defender is generally not permitted to deviate from its line (as judged visually by the Race Director), except when it is necessary for the defender to give way to the attacker (including if the attacker violates the lateral safety distance and encroaches on the defender). When yielding to the attacker, the defender is permitted to remain off its line while in a turn or so long as the longitudinal safety distance is not met, but it should return to its line as soon as it is safe to do so. Other significant deviations from the racing line may result in disqualification of the offending team.

4.9. Safety Distances

Under all flags, except for waving green:

The attacker must maintain a longitudinal distance from the defender, regardless of driving lines, of at least 30 meters (approximately 6 car lengths).

Under a waving green flag:

The attacker is responsible for maintaining a longitudinal safety distance of at least 10 meters (approximately 2 car lengths) prior to initiating a pass. Once a pass is initiated (see above), the cars must maintain lateral spacing of at least 2 meters. Both cars have responsibilities for maintaining lateral safety distances while within the longitudinal safety distance during an overtake maneuver. To be clear, the lateral safety distance applies to the instantaneous lateral position of each car on the track, and not to the racing lines. For example, if the Defender is 9 meters ahead of the attacker and has the outside edge of its left tires on the track centerline, and if the attacker is on an inside line, the right edge of its tires must be at least two meters from the centerline.

Violations of these safety distance rules may lead to an immediate end of a match and disqualification of the offending car, if, in the judgment of the Race Director, such violations lead to unsafe conditions (even if neither car is harmed) or result in an unfair advantage for the offending car.

4.10. Simple Right-of-Way Guideline

The IAC recognizes that comprehensive rules of engagement can be quite complex, both in form and in adjudication. As such, for this competition, the safety distance rule will serve as the primary guideline for determining right-of-way. When the cars are within the 10 meter longitudinal safety distance (during a passing maneuver), each car will be assumed to have the right of way along the corresponding lateral track position. For example, if the attacker has started its passing maneuver on the inside, and is closer than 10 meters longitudinally, then the attacker has established the right of way on the inside line and the defender may not “close the door.”

In addition to the safety distance rule, the attacker should also avoid making aggressive or high closing speed passing maneuvers near the entrance or exit of a turn. Such maneuvers are more likely to result in ambiguous (uncertain) determination of right of way, and can lead to unsafe interactions if the cars disagree on which car should have the right of way.

Similarly, if the defender has a non-negligible lateral speed at the moment the attacker closes the gap to 10 meters, the defender is not required to instantaneously stop its lateral motion, even if the lateral motion would result in a violation of the lateral safety distance. However, in such a situation, the defender must constrain its lateral motion and leave enough room (at least 6 meters or ~3 car widths) for the attacker to complete a pass on the relevant side. Moreover, once the lateral motion has stopped or reversed, the defender must fully abide by the lateral safety distance requirement.

Generally speaking, for any cases where the claim to right of way can be reasonably understood to be ambiguous, the defender will be assumed to have the right of way. The Race Director will be given ultimate discretion in judging violations of right of way.

4.11. Speeds

The target speed of each round will serve as the maximum speed of the defender. The defender is free to modulate its speed below the target speed to a minimum of 85% of the maximum, but it should not slow or stop abruptly. Unexpected and/or unsafe decelerations may result in disqualification of the offending team.

4.11.1. Braking

Active braking, under a green or waving green flag (and no vehicle emergencies or faults), is only permitted for the lead car in the entrances to turn 1 and turn 3. Decelerations during braking should be no greater than 5 m/s^2 . Other abrupt decelerations elsewhere on the track by the lead car may be deemed unsafe by the Race Director, and the match may be halted. The following car is permitted to brake as necessary anywhere on the track.

4.12. Flag Logic

The passing-specific flags should be interpreted as follows:

Track condition flags:

1. Green flag: No passing allowed. Also, the green flag has additional specific meanings depending on the associated vehicle signal flag:
 - a. Vehicle signal flag is Null (0) or No active flag (1): Green (or yellow) flag indicates that the car is on a warm up lap
 - b. Vehicle signal flag is Defender (5): Green flag indicates that the car should move to its defensive racing line and set its speed according to the speed target for the round.
 - c. Vehicle signal flag is Attacker (7): Green flag indicates that the car should close the gap with the defender
2. Waving Green flag (start the passing attempt): The attacker may initiate a pass upon the next crossing of the passing start line. This flag indicates the passing is now allowed, but the passing still must only occur after crossing the passing start line.

Vehicle signal flags:

1. Defender (5): The car should move to and stay on its defensive racing line and set its speed according to the speed target for the round.
2. Attacker (7): The car should close the gap (under green) and attempt a pass (under waving green). The attacker is primarily responsible for maintaining the safety distance with the defender, except where right of way is concerned (when the defender crosses the centerline).

4.13. Speed Limits

- **Yellow Flag:** Maintain speed between 60 - 80 mph except in pit lane
- **Black Flag:** No limit until entering pit lane
- **Pit Lane:** Speed limit is 60 mph except in the “slow zone” for which the speed limit is 30 mph, and consists of the section of the pit lane next to the active pit boxes as well as an approach buffer.

4.14. Defender Obligations

Key obligations for the defender include the following: The defender must stay on its defensive racing line except in the exceptional conditions defined above.. The defender must give way to the attacker according to the criteria defined above. The defender must maintain a speed of 85-100% of the target for the current round.

4.15. Attacker Obligations

Under a green flag, the attacker must close the gap with the defender, but not pass or close the gap to less than 30 m. Under a waving green flag, the attacker may further close the gap, but

must wait to initiate a pass until after crossing the start line of the passing zone. The attacker must yield to the defender in turns unless it has the right of way.

4.16. Crashes

Prior to the Championship round:

1. In the event that a crash occurs that disables both cars, the Race Director may decide to advance a previously eliminated car, or determine an alternate outcome based on the circumstances.
2. If only one car is disabled in a crash, the other car will immediately advance, unless it was determined by the Race Director to be at fault in the crash and subsequently disqualified, at which point an alternate car would be chosen to advance as described above.

During the Championship round: In the event that a crash occurs that disables one or both of the cars the Race Director will determine the winner according to the circumstances

5. Judging Adherence to the Rules

The Race Director and race stewards (as relevant) will have sole discretion in determining whether any violations of the rules have occurred and will assess appropriate penalties.

6. Passing Competition run sequence

Vehicle Startup and Engine Fire:

1. The two teams competing in a passing competition match will prepare their race cars to fire their engines
2. When the race starts, Scoring will issue an orange flag to fire both engines, and the teams will confirm to Scoring that the engines have fired.

Match Run Start:

1. Scoring sends a yellow flag to the lead car, which will autonomously exit the pit box and proceed to the track
2. When the lead vehicle is safely ahead, scoring will send a yellow flag to the second vehicle, which will also autonomously exit the pit box and proceed to the track
3. Once both cars are on the track, Scoring will send a green flag to both cars starting formation laps for the first round. The attacker should begin closing the gap with the defender at this point.

Match Execution:

1. After completing the initial formation laps a waving green flag will be sent to both cars to indicate the start of the first passing attempt
2. Completion of an attempt:

- a. Successful: after a successful passing attempt a role reversal will be triggered by scoring , and the appropriate vehicle signal flags (attacker and defender) will be sent to the cars.
 - b. Unsuccessful: after an unsuccessful passing attempt, where a role reversal is still required, scoring will send a sequence of flags to choreograph the reconfiguration.
3. The new defender should move to its racing line and the attacker should begin closing the gap
4. A waving green flag will be sent to trigger the start of the next passing attempt
5. This process will continue until the match is complete

Team Interaction with the Vehicle and Scoring:

1. The teams will view telemetry from their race car (via CURWB network) in their pits during the entire run
2. Some telemetry for the other vehicle in the match will be available via the MyLaps interface
3. Lap distance for all cars will be provided to all cars via MyLaps. This will provide coarse location information that can be used by the attacker to locate the defender when outside of sensor range and to automatically close the gap (note that resolution or accuracy of this data may be reduced)
4. The following are exceptions to the limit on sending commands:
 - a. If a car fails to overtake the lead vehicle and a reordering of the cars is required
 - b. If a team is explicitly instructed by scoring or race control to send commands

Match Completion:

1. When the match is complete, scoring will issue appropriate flags (yellow, black and red) as needed to automatically bring the cars to the pit.

7. AC @ TMS Time Trial Seeding Event

The Time Trial Seeding Event will be carried out on Wednesday, November 9, prior to the passing competition. All qualified teams may participate. Each team will have two attempts over two rounds (one attempt per round) to post speeds.

Overview:

- One race car will compete on the track at a time
- The run order for the first round will be determined by a blind draw
- The run order for the second round will be the reverse order of the first round
- Each race car will receive a maximum of 10 full laps (preceded by an “out lap” and succeeded by an “in lap”) for each attempt.
- The score for an attempt will be the highest lap speed on any of the completed laps
- The total score for the time trial will be the average score of both rounds.

Contingencies:

- If a team is unable to launch their car from the pits during their allotted time, they may be granted an additional attempt during the round at the discretion of the Race Director.
- If a team fails to complete a lap during a round, they will receive a score of zero for that round.
- Teams are not required to participate in this time trial event. Any teams that do not compete will receive a score zero for determining seeding for the passing competition.
- In the event of a tie, the team with the lower blind draw (the earlier to compete) will be given the advantage.

Speed Limits:

Speed limits are as follows, and apply to both the passing competition and the time trial seeding event:

- **Yellow Flag:** 80 mph
- **Black Flag:** No limit until entering pit lane
- **Pit Lane:** Speed limit is 60 mph except in the “slow zone” for which the speed limit is 30 mph, and consists of the section of the pit lane next to the active pit boxes as well as an approach buffer.

Team Interaction with the Vehicle and Scoring:

1. Teams are permitted to manually adjust the target speeds of their cars during their run