

# Project 3: Phase II

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## Mechatronic Combine Group Proposal

**Group 5**

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The purpose of this concept paper is to develop design requirements, and measure the technical performance of the next generation mechatronic players to be designed and built next spring. Players will be evaluated in both basic and advanced performance tests, and will be expected to meet quantifiable design parameters.

# Basic Performance Criteria

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## SPEED TEST

**Requirement:** Game speed conducive to observation and the running of effective plays; approximately 10 s to move the distance of the field.

**Design Parameter:** Maximum straight-line speed of 10 ft/s. ( $\pm 1$  ft/s.)

**Test Method:** A start and finish line will be separated by 50 ft, as shown in Figure 1. Four robots will be lined up at the starting line, and a timer, i.e. a student holding a stopwatch, for each robot will be lined up on the finish line. One designated student, neither a timer nor a controller, will say “go” at which point the timers will start the stopwatches and the robots will move, using closed-loop control, at maximum speed until they cross the finish line. The timers will record the average speed over the time interval. Controllers will collect their robots and move on to the next station.

**Estimated Time:**  $\approx 20$  min (8 runs @ 2 min/run)

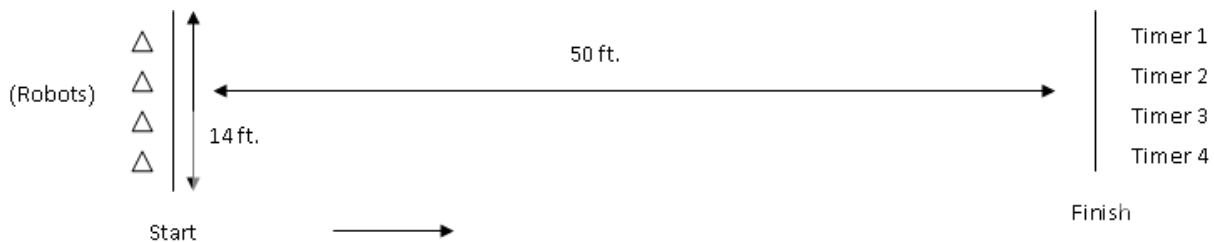


Figure 1: Speed Test

## TORQUE TEST

**Requirement:** Robots possess a motor that can generate torques required to withstand an opposing force.

**Design Parameter:** Ability to move 10 ft at an angle of  $5^\circ$  within 2-3 seconds.

**Test Method:** A ramp will be set at a  $5^\circ$  angle with start and finish lines indicating a 10 ft horizontal section of the ramp. Each robot will be individually timed as it moves up the ramp. Torques will be calculated based on times, robot weight, and wheel diameter.

**Estimated Time:**  $\approx 30$  min (22 robots @ 1 min/robot + 8 min. setup)

## STRAIGHT-LINE TEST

**Requirement:** Robots are to have stable control in straight-line movement and can move in a straight line with little deviation.

**Design Parameter:**  $\pm 3$  inches deviation from straight line path at maximum speed over 10 feet.

**Test Method:** Using close-loop control, each robot will travel 10 feet at maximum speed in a straight-line. An apparatus will be mounted on each robot that will hold a piece of sidewalk chalk which will record the robot's path on the ground surface. The red section of Figure 2 is  $\pm 3$  inches from the straight-line path marked by the yellow dashed line and acts as the robot's target section. Each robot will perform the test once.

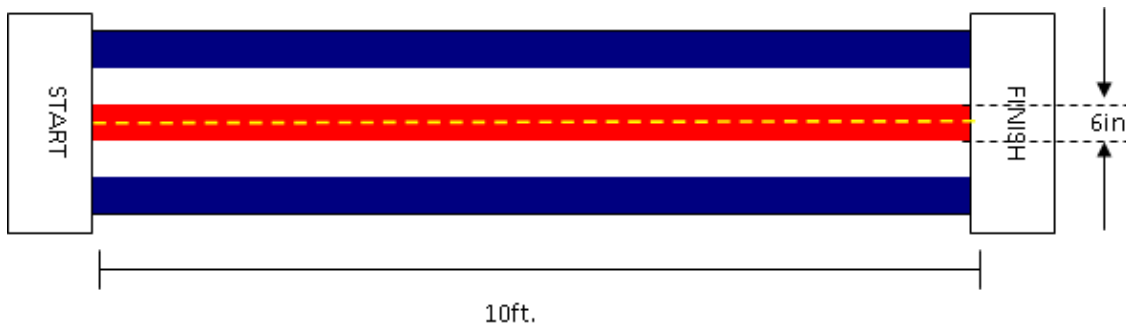


Figure 2: Straight-Line Test

**Estimated Time:**  $\approx 30$  min (22 robots @ 1-2 min/robot).

## TURNING RADIUS TEST

**Requirement:** Robots possess the ability to maneuver around other robots.

**Design Parameter:** Possess a maximum turning radius of 32 in ( $\pm 4$  in)

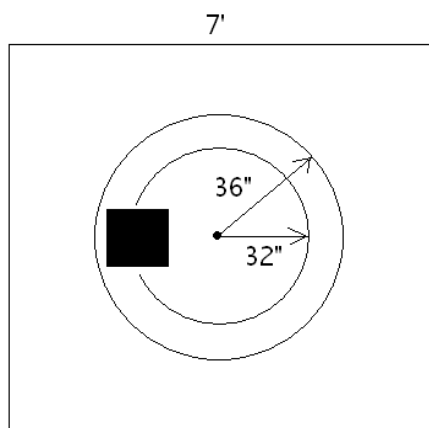


Figure 3: Turning Radius Test

**Test Method:** A square sheet of plywood (7' x 7') with two pre-drawn concentric circles (32" and 36" in radius) will be laid on the field. The robot will be centered over the inner, 32" radius circle as shown in Figure 3. With closed-loop control robots will demonstrate their minimum turning radius. A robot that completes one turn keeping its center within the 36" radius circle will have met the target value.

**Estimated Time:**  $\approx 45$  min (22 robots @ 2 min/robot)

# Advanced Performance Criteria

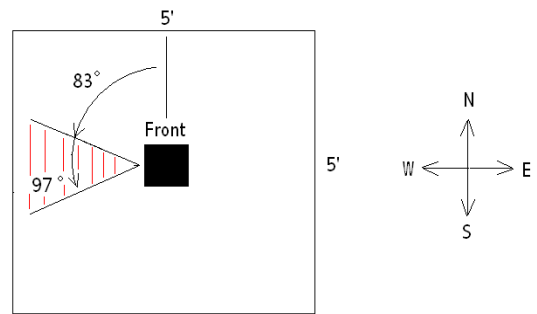
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## ROTATION ACCURACY TEST (QB)

**Requirement:** Quarterbacks' ability to position themselves in order to deliver hand-offs by stationary rotation.

**Design Parameter:** Assuming football is positioned on the outer edge of the quarterback footprint, the maximum distance the football would travel in one stationary revolution is approximately 50 in. With at least 80% of the football surface needing to be placed in a running back's clamping mechanism for a successful handoff, 4 in of total football surface length (5 in) must be in contact. The ratio of football contact length (4 in) to revolution distance (50 in) is roughly 8%, giving a target value of between  $83^\circ$  and  $97^\circ$  for a desired turn of  $90^\circ$ .

**Test Method:** A square sheet of plywood ( $5' \times 5'$ ) marked with the target value range will be laid on the field. The robot will be positioned in the center facing North, and attempt to rotate to  $90^\circ$ , as shown in Figure 4. A robot that rotates between  $83^\circ$  and  $97^\circ$  will meet the design parameter.



**Estimated Time:**  $\approx 10$  min (2 robots @ 2 min/robot + 6 min setup)

Figure 4: Rotation Accuracy Test

## GRIP TEST (QB, WR, RB)

**Requirement:** Robots can hold the football with enough force to avoid frequent fumbles.

**Design Parameter:** A gripping mechanism that provides 60-100 N of force (equivalent to a human hand).

**Test Method:** A spring will be placed in the mechanism and the grip will be activated. The displacement of the spring will be measured, and force will be determined using the spring constant.

**Estimated Time:**  $\approx 15$  min (6 robots @ 1-2 min/robot)

## THROWING TEST (QB)

**Requirement:** Quarterbacks can accurately throw to three key distances.

**Design Parameter:** A 60% accuracy for targets (16" wide x 24" tall) at 5, 15, and 25 foot distances, corresponding to a score of 30 points.

**Test Method:** The quarterback will begin at a designated line with the ball. The robot will throw five balls to the target at each distance, one ball per run of the drill. The first target<sup>1</sup> will be placed 5 feet down field of the line of scrimmage. The second target will be placed 15 feet down field. This is the minimum distance to earn points for a completed long pass.

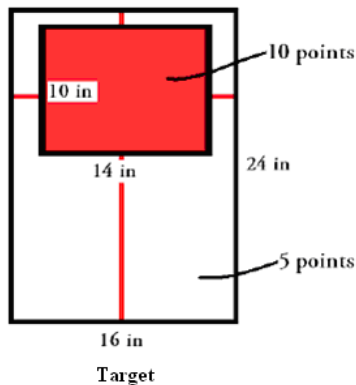


Figure 5: Throwing Test

The third target will be placed 25 feet down field. A ball striking the white area of the target, shown in Figure 5, will be worth 5 points. More accurate throws to the portion of the receiving robot where there will likely be a ball-catching apparatus will be worth 10 points. Balls that land in the circular area around the target will score 2 points.

**Estimated Time:**  $\approx$  45 minutes (2 robots @ 15 min/robot + 15 min set up)

## KICKING TEST (K)

**Requirement:** Robots have the ability to “kick” and punt the ball 60 ft at an angle of 45°.

**Design Parameter:** Kicking jigs generate  $0.3 \pm 0.05$  lb<sub>f</sub>.

**Test Method:** Each robot will attempt 6 kicks (3 with the kicking jig and 3 with the punting jig) from the center of the one-third field line, kicking in the direction of the remaining two-thirds of the field. The distance each attempt travels (measured from the robot to the point where the ball hits the ground) will yield an average kick distance and an average punt distance for each robot. These values will be used to calculate the force exerted by the kicking mechanism.

**Estimated Time:**  $\approx$  20 min (2 robots @ 10 min/robot)

<sup>1</sup> If a team uses radio frequencies or some other system allowed by the rules to designate and/or automate passing, the necessary equipment may be attached to the target or placed in the target zone.

# Framework and Logistics

**Location:** Stepan Center of the Notre Dame campus.

**Time:** Date TBD, starting at 3:00pm.

**Event Schedule:** Table 1 provides an outline of the proposed combine requirements.

Event Order	# of Participants	Estimated Time	Space Requirement	Evaluators Needed
Speed Test	22	20 minutes	50' x 14'	5
Torque Test	22	30 minutes	10' x 6'	2
Straight-Line Test	22	30 minutes	10' x 3'	2
Turning Radius Test	22	45 minutes	7' x 7'	2
Rotation Accuracy Test	2	10 minutes	5' x 5'	2
Grip Test	6	15 minutes	5' x 5'	2
Throwing Test	2	45 minutes	25' x 25'	3
Kicking Test	2	20 minutes	60' x 30'	2
<b>Total</b>	<b>100</b>	<b>3 hr 35 min</b>	<b>&gt;2800 sq. ft.</b>	<b>20</b>

Table 1: Event Requirements

The above totals are misleading in that many events can be conducted simultaneously, spacing can overlap, and evaluators can rotate stations. To stay within the 3 hour time limit, participants will be divided by their teams, with each team participating at different stations simultaneously, cutting station times in half. The order of this rotation is shown in Table 2, with 5 minutes added for rotations between stations. Note that 25 minutes are in reserve for intermission, setup/breakdown, or equipment problems.

Blue Team	Start Time	Gold Team	Start Time
Speed Test	3:00	Rotation Accuracy Test	3:00
Torque Test	3:15	Throwing Test	3:10
Straight-Line Test	3:35	Grip Test	3:40
Turning Radius Test	3:55	Kicking Test	3:55
Rotation Accuracy Test	4:25	Speed Test	4:10
Throwing Test	4:35	Torque Test	4:25
Grip Test	5:05	Straight-Line Test	4:45
Kicking Test	5:20	Turning Radius Test	5:05
<b>End Time</b>	<b>5:35</b>	<b>End Time</b>	<b>5:35</b>

Table 2: Order of Events

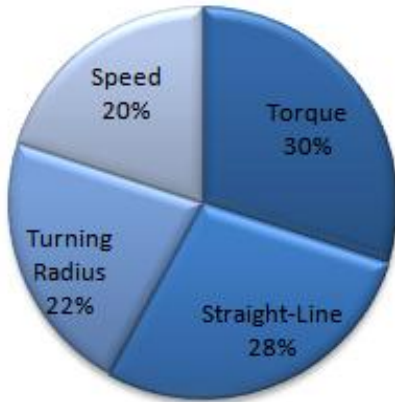


Figure 7: Basic Criteria Scale

**Event Importance:**

Figures 6 and 7 to the left and right represent the weighted significance that both the basic and advanced performance tests have in relation to the conduction of the final football game. Those with

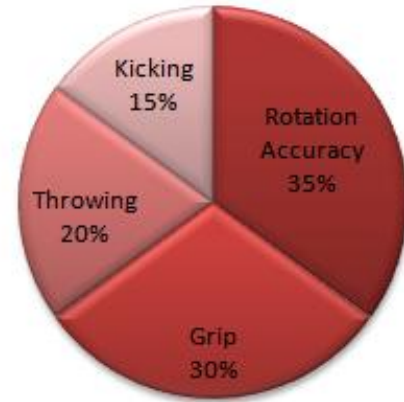


Figure 6: Advanced Criteria

higher ratings are deemed more necessary design requirements and as such may take priority over lower ranked requirements in the design process.

## Conclusion

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It is the goal of this combine to both set the standards for mechatronic football robots, and examine how successful designers were in meeting these standards. With not all requirements equally weighted, and with design precision accounted for in allowable tolerances, students must decide what is important and what can be conceded. Most importantly, by defining quantifiable performance parameters, student designers will have concrete goals that can set the bar and put them on the path to successfully designing the next generation of mechatronic football players.