Project 3 – Product Requirements – Phase II

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Submitted By: Group 3

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The purpose of this report is to outline a detailed plan for a mechatronic football player combine. For the second-generation game, players at each position will have specific quantitative design requirements that will be tested and scored during the player combine. This report will summarize the scoring system for the combine, the overall combine plan, the basic performance criteria for each robot, and the advanced performance criteria for specialized robots (quarterbacks, kickers, etc.).

Scoring System:

A graduated scoring system for the robots will measure each position player's compliance with the quantitative design requirements. Each combine event is scored on a linear scale that ranges from 0 (if the robot does not exhibit the design requirements) to 10 (if the robot performs beyond the design requirements). The head official for the specific combine event will record the combine scores for each robot after they complete each combine event. At the conclusion of the combine, these scores will be placed into a multiplier system to determine their final score out of a possible 100 points. The multiplier scoring system is shown in Table 1 below and was determined based on the relative importance of the combine events to each robot's position. The easiest way to determine the combine scores is to create a spreadsheet programmed with the scoring equations and multiplier system to track each robot's performance during the combine.

Table 1. The multipliers to calculate the final score for robots at each position

EVENT	QB'S	RB'S	WR'S	LINEMEN	CENTER	KICKERS
60-foot dash	2.0	3.0	3.0	1.0	1.0	0.25
Robo-drive drill	0.5	1.0	2.0	4.0	2.5	0.25
Turning drill	2.0	2.5	3.0	1.0	1.0	0.25
Traction drill	0.5	1.0	2.0	4.0	2.5	0.25
Throwing drill	2.5	-	-	-	-	-
Handoff drill	2.5	2.5	-	-	3.0	-
Kickoff drill	-	-	-	-	-	3.0
Punting drill	-	-	-	-	-	3.0
Field goal drill	-	-	-	-	-	3.0

Combine Plan:

The combine will take place on the Tuesday before the actual mechatronic football game at the game site. This will allow teams to make any necessary robot repairs and also gives ample time for completion of the robot prior to the combine. Additionally, the surface that the robots will be tested on is the actual game surface, ensuring that the data generated is accurate for game conditions. The officials for the event will be volunteers from the junior class of mechanical engineers, allowing them to interact with the robots before they actually take part in the project. Volunteer professors familiar with the combine event will assist them.

The combine will be three hours in duration. During the first 15 minutes, the doping test will be performed on each robot. The next hour and 35 minutes will be dedicated to the basic performance combine. Players will be separated by position (e.g. the quarterbacks from each team will be paired together), and the groups will be designated to a starting combine station. Since there are four different combine activities, each group of players will have 20 minutes at

each station with a five-minute transition time between events. The time schedule and rotation for the basic performance combine is shown in Table 2.

Table 2. Rotation schedule for the basic performance criteria combine

TIME	60-FOOT DASH	ROBO-DRIVE	TURNING	TRACTION
1:15-1:35	QBs/RBs	Centers/Kickers	Receivers	Linemen
1:45-2:05	Linemen	QBs/RBs	Centers/Kickers	Receivers
2:10-2:30	Receivers	Linemen	QBs/RBs	Centers/Kickers
2:35-2:55	Centers/Kickers	Receivers	Linemen	QBs/RBs

The final hour will be dedicated to the advanced performance combine. Once again, players will be separated by position and designated to their specific combine event. The schedule for the advanced performance combine is shown below in Table 3.

Table 3. Rotation Schedule for the Advanced Performance Criteria Combine

TIME	EVENT DESCRIPTION
3:00 – 3:30	Quarterbacks – throwing drill Kickers – kicking drill, field goal drill
3:30 – 4:00	Quarterbacks, Wide Receivers, Centers – handoff drill Kickers – field goal drill (cont.), punting drill

Doping Test:

In order to participate in the actual combine, each robot must pass a doping test. The doping test is required to check adherence to the established competition design rules. The doping test consists of five standalone tests. Each test is graded on a pass/fail basis, and failure to meet any of the tests results in disqualification from the combine and game. Table 4 below outlines the doping test.

Table 4. Summary of the doping test to be performed prior to the combine events

TEST NAME	RULE	PROCEDURE	CRITERIA TO PASS
Weight test	1.10	Weigh players on scale	Must weigh less than 25 lbs
Dimension test	1.26 1.28 1.29	Measure thickness of base Measure distance from centerline of base to surface Put player in 16”x24” box	Thicker than ½” continuously Must be 3±0.1 inches Must fit within box
LED test	1.18	Measure elevation from center of LED to playing surface	Must be 8±0.1 inches
Battery voltage test	1.6	Examine player’s electrical system and battery voltage	Must be less than 24 volts
Kill switch test	1.8 1.9	Player drives forward and kill switch is pushed Examine button to see if it is red	Must stop in less than 2 sec Must be visibly red

Basic Performance Criteria:
Each robot will be required to complete all of the basic performance combine events, regardless of the position they will play. The most important attributes for each robot were determined to be speed, power, steering, and traction. Therefore, the combine will specifically test these attributes, and the predetermined importance factor (shown in Table 1) will be placed on each event for different position players. The following is a breakdown of the measurable basic performance combine skills:

- ***60-foot dash***: The 60-foot dash measures the driving speed and the diversion distance of the robots. This performance criterion will encourage teams to select a motor that maximizes the driving speed and select wheels with excellent traction so as to increase the initial robot acceleration. The diversion of the robot from the straight driving line will also be measured during the event. It is crucial that the robot be able to drive in a straight line for robot control and operation during the game.

  During the disassembly process a majority of robots were found to have RS-545 motors with wheels of diameter 4-7/8". From this motor's specification sheet, the peak efficiency RPM of the motor is 861. Thus the speed of the robots in feet per second can be calculated as follows:

$$(4.875 \text{ in}) \cdot \pi \cdot \left(\frac{1 \text{ ft}}{12 \text{ in}} \right) = 1.28 \text{ ft traveled per rotation}$$

$$(861 \text{ RPM}) \cdot (1.28 \text{ ft/rotation}) \cdot \left(\frac{1 \text{ min}}{60 \text{ s}} \right) = 18.3 \frac{\text{ft}}{\text{s}}$$

  Therefore, if the robot were at peak efficiency and full speed over the entire 60-feet, it would take 3.27 seconds to complete the time trial. A point system was developed based on this ideal time and accounts for the inefficiency and acceleration time of the robot. Deviation from the straight line will result in a deduction of points gained during the dash. For every two feet the centerline differs from the center of the robot at the finish line of the dash, the official will assess a one-point deduction. The event is diagramed in Figure 2 in the Appendix. The scoring for this event will be based on the following linear equation:

$$\text{score} = \frac{3.5}{\text{time}} \cdot 10 - \text{deductions}$$

- ***Robo-drive drill***: The robo-drive drill measures the power generated by each robot. Power is generated by the robots in the form of torque, and increasing the power capabilities of the robot will allow robots to accelerate to their top speed faster. Power is also crucial for linemen, as it allows them to push defenders out of the way while on offense and make more tackles while on defense.

  A robot from each team will be designated as the "dummy robot" for the robo-drive drill. The dummy robot will be a lineman that is permanently in the "tackled" mode. The robot participating in the combine event will be placed against the dummy robot and have to drive the robot backwards 10 feet. Figure 3 in the Appendix diagrams the drill. Based on the motor spec sheet and observations of last year's game, the assumption can be made that the robots can generate enough torque to drive the robot at 2 ft/s. Thus, a good time

to complete this combine event would be 5 seconds, and the scoring for this event will be based on the following linear equation:

$$\text{score} = \frac{5}{\text{time}} \cdot 10$$

- ***Turning drill***: The circling drill measures the rotation accuracy and rotation speed of the robots that are crucial for the steering capabilities of the robot. These two capabilities are especially important for the running backs, wide receivers, and defensive backs during the game because they determine the agility and balance of the robots.

  During this drill, the robot will have to accurately rotate a predefined number of degrees as fast as possible. Each robot will perform the drill for rotation amounts of 45, 90, and 180 degrees. The official will determine the error in the turn by measuring the distance that the centerline of the robot differs from the target rotation amount and measure elapsed time using a stopwatch. The error will be averaged and measured in degrees. The time measurements will be adjusted to simulate turns of 180 degrees (thus the time for the 45 degree turn will be multiplied by 4, and the time for the 90 degree turn will be multiplied by 2). Figure 4 in the Appendix diagrams the test. Timing such a short period of time may be difficult for the official, but should be manageable with practice. Accuracy and rotation time will be weighted equally for the scoring during the event, and the scoring will be based on the following linear equation:

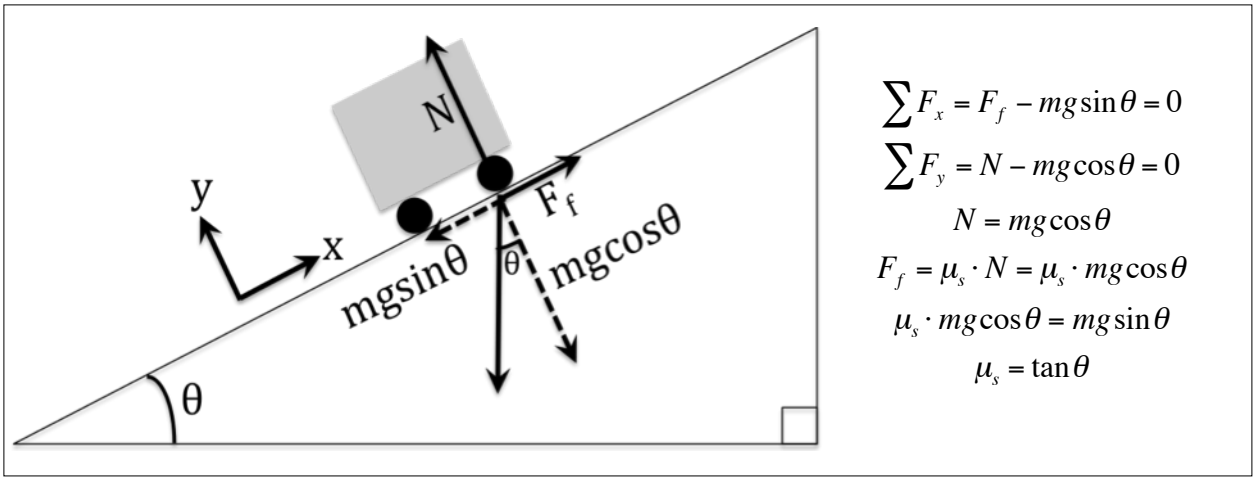
$$\text{Score} = \begin{cases} \frac{3.5}{\text{time}} - \frac{\Delta\theta}{2.5}, & \text{time} \geq 0.7s \\ 10 - \frac{\Delta\theta}{2.5}, & \text{time} < 0.7\text{s} \end{cases}$$

- ***Traction drill***: The traction drill measures the traction of the robot wheels to the playing surface. Traction is crucial to ensure that unwanted slipping does not occur and therefore maximize the torque and agility of the robot. If a robot has a motor with optimum torque but does not have good traction to the playing surface, this torque will go to waste as the wheels slip on the ground, preventing it from accelerating or changing direction. A simple traction test can be used to measure the coefficient of static friction, μ_s, which reflects the grip between the wheels and the playing surface.

  The traction drill will consist of an incline test for each robot. This incline will need to be constructed of the same material as the playing surface for the combine event. Each robot will be placed on the incline with the wheels in an electrically locked position. The incline will slowly be raised until the robot begins to slide down the incline. By measuring θ, the angle between the incline and the horizontal when the robot begins to slide, the coefficient of static friction can be calculated using the following force balance, where m is the mass, F_f is the frictional force of the wheel, g is gravity, and N is the normal force exerted by the incline. Figure 1 below diagrams the test.

  The scoring will be compared to the coefficient of static friction between a car tire and dry concrete, which is approximately 0.7. The rating will be calculated by the following:

$$\text{Score} = \begin{Bmatrix} 14.3 \cdot \mu_s, & 0 \le \mu_s \le 0.7 \\ 10, & \mu_s > 0.7 \end{Bmatrix}$$



$$\sum F_x = F_f - mg\sin\theta = 0$$
$$\sum F_y = N - mg\cos\theta = 0$$
$$N = mg\cos\theta$$
$$F_f = \mu_s \cdot N = \mu_s \cdot mg\cos\theta$$
$$\mu_s \cdot mg\cos\theta = mg\sin\theta$$
$$\mu_s = \tan\theta$$

Figure 1. Diagram for the Traction Test and Formulation to Calculate the Coefficient for the Wheels Sliding on the Playing Surface

Advanced Performance Criteria:
After all robots have participated in the basic performance combine, they will be broken up by positions again for the advanced performance combine. The following is a breakdown of the measurable basic performance combine skills by position:

- ***Throwing drill (Quarterbacks)***: The throwing drill will measure the precision of the robotic quarterback's mechanical throwing arm. Precision is likely more valuable than accuracy in this case, because it is easier for a WR's operator to adapt its route to accommodate passes that are consistently thrown a few feet short or too far to the left of the expected target, for example, than to predict mid-play where the ball will fall within some expected target area that will be hit with 100% accuracy, but is nonetheless significantly larger than the wide receiver robot itself.

  The quarterback should be able to throw its passes within a 2-foot radius for both a short-range pass (5-15 feet) and a long-range pass (greater than 15 feet). To test this, a first "pass" will be thrown and a marker will be placed wherever it lands (to be clear, there is no intended receiver in this test). A 2-foot radius will be laid out with a stiffened ring of rope (or perhaps a hula-hoop) with this marking at its center. Then, without changing the quarterback's orientation or range settings, five more passes will be thrown. A diagram of this event is shown in Figure 5 in the Appendix. A point will be awarded for each pass that lands within the circle for a total of 10 points (5 for each range setting).

- ***Handoff drill (Center, Quarterbacks, Running Backs)***: The handoff drill will measure the speed of the handoff between the center and the quarterback and then the quarterback and running back. In addition to the speed of the handoff, the ability to do this without fumbling is crucial to this combine event, since a one-point deduction will be assessed if a fumble occurs.

Based on last year's trials and in-game observations, it was estimated that an outstanding handoff time would be 2.5 seconds from the time the quarterback touches the ball to when the running back receives it. A diagram of the event is shown in Figure 6 in the Appendix. Each team's center/quarterback/running back pairs will complete a total of five handoff drills. An average time will be calculated and that average time will be used to calculate the score based on the following equation:

$$\text{Score} = \frac{2.5}{\text{time}} \cdot 10$$

- ***Kicking drill (Kicker)***: The kicking drill will measure the strength and accuracy of the kicker. The kicker will be responsible for kickoffs, punts, and field goals. One test will be conducted to examine a kicker's ability, with different scoring for the three types of kicks.

  For the test, the kicker's front face will be placed perpendicular to a 90-foot line with the centerline of the robot directly over the line. The ball will be placed in the kicking apparatus being tested and then will be kicked. The distance along this kicking direction line (x) and the deviation from this line (y) will be measured from the ball's start point to the point of impact. A diagram of the drill is shown in Figure 7 of the Appendix. Each kicker will kick five attempts of each kick type, and the average distance and deviation will be calculated for the trials. It was determined that good kickoffs, punts, and field goals should reach distances of 40 feet, 32 feet, and 32 feet, respectively, with minimal lateral deviation. Thus, the averages will be used to calculate the individual scores based on the following equations:

$$\text{Kickoff Score} = 2 * \frac{x_{avg}}{32'} - \frac{y_{avg}}{15'}$$

$$\text{Punting Score} = 2 * \frac{x_{avg}}{40'} - \frac{y_{avg}}{20'}$$

$$\text{FG Score} = 2 * \frac{x_{avg}}{32'} - \frac{y_{avg}}{4.33'}$$

Appendix:

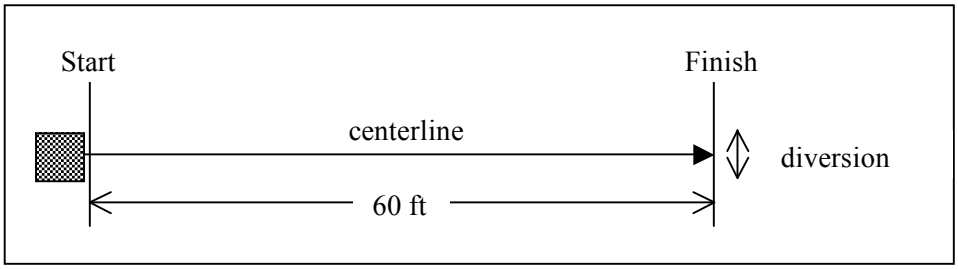


Figure 2. Diagram of the 60-foot dash combine event

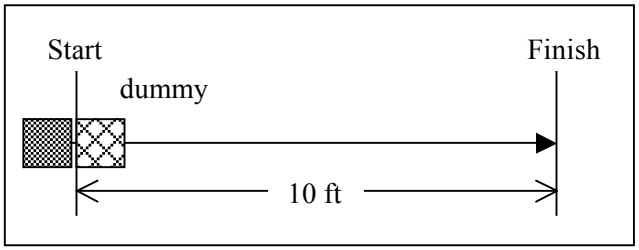


Figure 3. Diagram of the robo-drive drill combine event

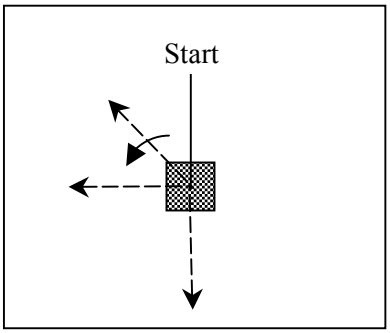


Figure 4. Diagram of the turning drill combine event

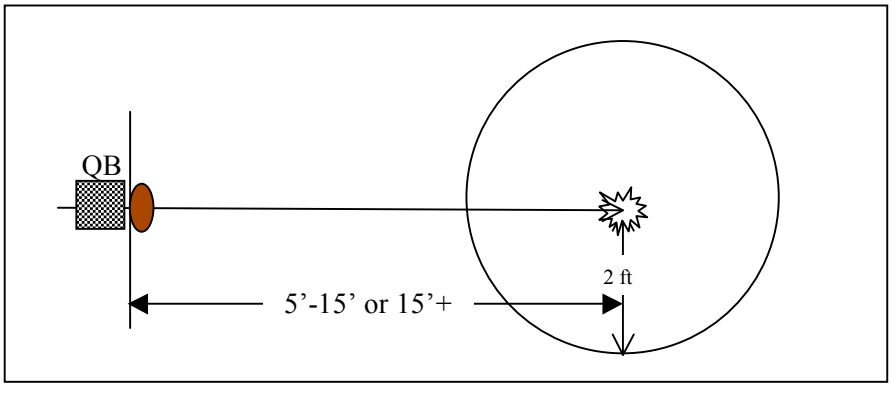


Figure 5. Diagram of the throwing drill combine test

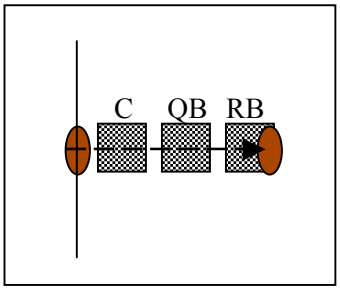


Figure 6. Diagram of the handoff drill combine test

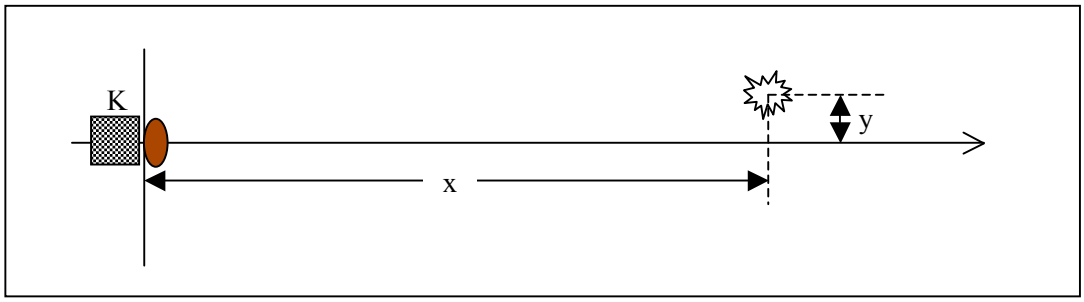


Figure 7. Diagram of the kicking drill combine test