Spintel Research

A Systematic Study of Sensors in Sports

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Executive Summary

Technological advances in sensor-based technologies have changed the way we live and play. Consumers can wear wristbands like Fitbit and Jawbones to tell them how many calories they burned and how many steps they've taken. Athletes can embed sensors into their equipment to alert others on how hard they've been hit. Spintel research will show that both types of sensors can fit into a much larger data-driven landscape then previously imagined.

The sections of this paper are split into three separate categories: exploration, technology review, and analysis. The beginning sections fall within the exploration title. The exploration sections introduce the landscape of sensor- based technologies. This category introduces the problem space and the controlled vocabulary. It will explore the issue of head traumas and the 5 major uses cases: player safety, officiating, skill development, player selection and fan experience. The sections within the exploration category show the possible uses of sensors, and the current health risks that sensors could fix.

The middle sections of this paper fall within the technology review category. The technology reviews cover both the hardware and software in the sensor market. The reviews reflect how hardware and software can fulfill some of the possible uses cases from the exploration sections.

The last sections fit into the analysis classification. These sections are meant to understand the stakeholders affected by sensors, the competitive analysis of the market and interview needs assessment. These sections show how the stakeholders view and use sensors in the market on many levels.

Problem Space

Spintel research would like to study the ever-changing landscape of sensors in sports. Spintel is a systematic survey to organize the different applications and use cases of sensors in sports. Spintel research's problem space is how to bridge the sensors gap between consumer wearable sensors and sensor embedded sporting equipment, and how to apply the best features to increase the "smartness" of games. Incorporating sensors and tracking into wearable sporting equipment could turn every player on a field from passive data points into many active ones. This also applies to the game implements on the field, such as game balls and pylons. The new tracking ability could uncover new relationships never tracked before.

There are many different tradeoffs to investigate within the survey. The tradeoffs include: wellness vs. safety, real-time and retrospective data, and individual vs. team data analysis. The first tradeoff features safety (helmet concussion sensors) against wellness (wristbands that track total steps and calories) which also highlights the different user bases. Safety is based more for the athletes who are at risk for injury or trauma. Wellness is for the average consumer who is seeking to gain metrics for better health. The next tradeoff is between real-time and retrospective data, or when the user can get the data. Real-time could be for immediate health issues, like concussions while retrospective could be for performance metrics such as force production. The last tradeoff is between individual and team data analysis. This is the difference between an individual's force production and two players combined force production over he course of the game.

There are two trends in the consumer sector of the sports and wellness industry, a trend of wearable tracking systems and a trend of physical trauma tracking. The domain of fitness tracking system is in its infancy. The two systems that control the most of the market are Fitbit and Nike+ FuelBand. These systems are meant for consumer markets, they act as a bracelet around a wearer's wrist. These systems will track simple things like steps taken in a day, or distance covered and converts that data into calories burned. The user can retrospectively look on their computer or on their smartphone to look at how they have progressed. There are also social aspects of these systems by pegging how the user compares to a national average. There is also the possibility to

compare how one does compared to their friends and family, with another possibility to post results on social media. There are few serious options for tracking movements as a whole system on an enterprise level. One cannot wear a Fitbit or a Nike+ FuelBand bracelet on a football field for fear of adverse effects. Wearing jewelry of any kind could make an athlete susceptible to injury by giving opponents something to grab or by breaking and possibly shocking a player. Spintel's research would like to find how those features into embedded equipment athletes already use.

Violent sports such as football, entertain fans through the physical nature of the game. In every single contact sport there is always a tradeoff between physicality and danger. As athletic training methods and nutrition become more and more advanced, that level of danger increases as well as the physicality. This danger is not only at the professional level, but every level. On a professional level, players are one hit from sustaining a brain injury that could impair their short-term memory. While impaired they may line up again, and sustain another hit that could do some serious permanent damage. Parents may watch their kids take a hit their head, and worry that one wrong hit could affect their development.

As major institutions begin to recognize the severity of brain injuries, there has been an exponential level of awareness, especially over the last 3 years. The National Football League (NFL) has been tracking concussions in that time, and in 2013-2014 season alone there were at least 152 concussions (Breslow). To combat the amount of concussions, the NFL has held seminars to teach players about the effects of brain injury, they also started fining players for hitting another player while leading with their head. The biggest fines were 50,000 dollars to Dunta Robinson and 75,000 dollar fine to James Harrison, both for head-to-head hits (Florio). The 152 concussions were only the ones that were diagnosed, this does not account for acute ones that players may have failed to seek medical help. These numbers also do not account the extra damage sustained between the play that a concussion actually occurred and when the player was finally pulled off the field. These are the concussions on the highest level; the cases may be higher for lower levels of play. It is the hope of Spintel that we can make a game safer for the players that may be most susceptible to these injuries: children and teens. As the awareness of concussions rises, many companies have attempted to make

systems that can track and diagnose concussions. These systems are in their early stages. On a rudimentary level, these systems place g-force sensors in helmets that can register how hard someone had gotten hit in Newtons or Gs. There are some systems that can notify medical staff when someone gets hit with a force that could cause a concussion. The major issue with these systems is that they use a “one size fits all system” when it comes to force thresholds. This means that in high-level leagues, a 190 pound player and a 300 pound player getting with 2.8 Gs would register as a “concussion hit” for both. This is an issue because these systems cannot calibrate to different players, meaning that 2.8G hit may cause a concussion to a 190 pound player, but would not cause a concussion to the 300 pounder. Spintel research is looking to uncover how calibrating hit threshold to players could impact safety.

Spintel research would like to survey how sensors could be embedded into the apparel, implements, protective equipment and field objects that would otherwise be passive into data points. Each data point for each play could provide new insight into how games are being played. As the data gets culled, the big data will be processed to find interesting relationships within the corpus of data. There are three main types of data that Spintel would like collect: G-forces, linear/lateral speeds, and linear/lateral acceleration. G-forces measure how hard someone had gotten hit. Force is a combination of how quickly someone is accelerating combined with their mass.This is the main measure to see if someone has sustained a particularly hard hit that could cause a concussion. Linear/Lateral speed is a study of how quickly someone traverses some area over time. Linear speed is in a straight line, and lateral is how fast someone moves in a sideways direction. Linear/Lateral acceleration is the study of the difference in speed over a time. In the same manner, linear is in a straight line and lateral is side-to-side. There are a couple more types of data that can be tracked, such as location on the field as well as heart rate. Each type of data is discussed in more detail in the “Controlled Vocabulary” section. There are very few other systems out there that can interact as a whole to provide this collective data. It can take the corpus of known technology and data acquisition to build newer models that could change how we view the game.

Controlled Vocabulary

In order to understand what exactly Spintel is doing, one must first control and operationalize the vocabulary. The vocabulary of what Spintel should be tracking, and what kind of new statistics Spintel is trying to track. By keeping the vocabulary controlled any conversations surrounding Spintel, and what has been tracked and processed will always have the same frame of reference. Essentially, everyone will speak the same language, and will always compare "apples to apples" and not "apples to oranges". There are four main categories that Spintel seeks to track: force, speed, agility and miscellaneous.

Force

The first category that Spintel seeks to track is force and how players interact with force. "Force" on a basic level comes from physics and Newton's second law of motion. This means that the amount of force generated divided by the mass produces acceleration or F/m = a (where "F" is force, "m" is mass and "a" is acceleration). Doing some simple algebraic manipulation, F = ma or force is a product of a person's mass and acceleration. In simple terms, force is a measure of how hard someone has just gotten hit. The current method to study force sustained in contact sports is on the G-Max scale. The G-Max scale also factors in the surface a player lands on when they get hit. To measure the G-Max scale of a hit the researchers "approximates a human head and neck (about 20 sq. in. and 20 pounds) is dropped from a height of 2 ft. A low G-Max means the field absorbs more energy than the player" (Higgins). What makes force an interesting metric is because even the smallest players on a professional football field can hit someone with 1600 lbs. of force (Higgins). Although hits can approach a ton in force, it is interesting how much the human body can actually sustain. According to "John Melvin, an injury biomechanics researcher for General Motors and NASCAR, the body can handle twice that amount -- as long as the impact is well-distributed. That job usually is handled by the player's equipment, which spreads out the incoming energy, lessening its severity" (Higgins). Understanding that it is not just only how hard someone gets hit, but how the force is distributed that can cause a concussion. Given the force needs to be distributed, there are two main subcategories of force: force sustained and force produced.

The first subcategory is “force sustained”. This measure will take into account the force taken at an individual body part, such as the head or knee. This will differ from “force produced” which can be a holistic view of all force someone hits with. Force sustained will be the main measure used when judging whether someone received a hit that could have caused a concussion. Force sustained can be used mostly for player safety puposes.

The second force subcategory is “force produced”, or how hard an individual has just hit an object or someone else. According to Newton’s third law of physics, every action has an equal and opposite reaction, meaning that holistic forces are equal and opposite. This means that if an offensive lineman hits a player with 100G’s of force, he also feels that 100G’s of force. This measure can be used for skill development and player selection to study total force produced/received in gameplay.

Speed

The category Spintel seeks to track is the speed of people and objects. On a basic level, “speed” is the measure of how fast something moves over a given time, or $v = (p_1 - p_0)/t$ (where v= speed, p_0 = the initial position of person/object, p_1= ending position of person/object and t = total time elapsed). Speed is generally measured in miles per hour (MPH) or meters per second (m/s). Although speed can be calculated using a distance someone ran over a time period, there are many modern techniques used to measure speed. The first method is to use the Doppler effect (change of waves with motion) on an object as it moves (Doyle). This is used in baseball to determine how fast a baseball is pitched at a batter. This removes the margin of error if this measure was done by hand. The next measure of speed is done algorithmically using TV camera angles (Lowe). These TV cameras come with software to understand how players move to get data on their speed.

Similar to force, speed gets broken into two subcategories, with “linear speed” as the first subcategory. Linear speed acts as a measure of how fast a person or objects moves in a straight-line pattern. A straight line is the shortest distance between two points, and running in that pattern will produce the fastest speeds. Linear speed is seen in almost every sport. Examples include a batter running to first base after a hit, a wide receiver running a “Hail Mary” route (straight downfield) or a right wing chasing a puck

on a fast break. Examples of objects moving linearly include a baseball being pitches across home plate and a football being flung down the field.

The second subcategory of speed is “lateral speed”. Lateral speed is a measure of how fast someone can move in a side-to-side fashion. These bursts can be studied using sensors in shoes when pressing on the outside of the shoe. Many games use a side-to-side movement pattern in specialized roles. Basketball players are known to “slide” and move laterally when defending someone with the ball. Studying how fast they move can be used to teach other players proper movements to be effective defenders. Another example of a specialized movement comes from the first few steps a base runner in baseball may take before he decides to “steal” or advance bases. Currently, there is no need to track lateral speeds of objects because any direction that a ball will move will be considered linear. Any throw, any hit of a ball or any push of a puck, the path will always be considered linear.

Linear speed is something pivotal to every team game played. Studying it in a more granular form could provide an added edge to teams willing to put the resources behind it.

Acceleration

The third category that Spintel would like track and study is “acceleration”. In the same manner as speed and force, Spintel’s definition of acceleration stems from physics. Acceleration acts as a change of speeds over time, or $a = (v_1 - v_0)/t$ (where a = acceleration, v_0 = initial speed, v_1 = ending speed and t = time). Acceleration is generally measured in meters per second squared (m/s^2). On an intuitive level, acceleration is how much speed someone or something gains or loses over a period of time. Some people consider acceleration the “explosion” factor of a certain player/object. It is the amount of speed someone gains as they sprint from a static start to when they reach their top speed.

In the exact same manner as speed, acceleration is spit into two subcategories. The first of the two subcategories is linear acceleration. Just like in speed, linear acceleration is the change of the rate of speed over as the person or object moves in a straight line. As the shortest distance between two points is a straight line, linear acceleration is measured in tandem with speed. Acceleration is pivotal to any game that

requires contact. Acceleration is directly tied to force production. Linear acceleration has a direct application to offensive and defensive lineman who use their “explosive power” to hit each other. Linear acceleration is used in basketball as someone goes on a fast break and when soccer players run to slide tackle the ball on the pitch. Outside the medical purposes concussions protection, linear acceleration will be the most sought after metric because of its training uses. Object linear acceleration is the change of rate of speed of an object.

The second subcategory within acceleration is lateral acceleration. In a similar manner as lateral speed, lateral acceleration the rate of change of speed in a side-to-side movement. The greatest cases of lateral acceleration are baseball pitchers as they are pressing their leg off the mound before they throw the ball. Another example would be offensive lineman in pass protection. It is pivotal that offensive lineman can change direction on a dime. Using sensors could teach lineman the most effective ways to block could be a great way to insure that the quarterback stays healthy.

Miscellaneous

There are a few other things that can be tracked and followed using sensory data. Among the many possibilities of what can be tracked, the three that are the most interesting are distance covered on the field, positioning on the field and heart rate. Distance covered is defined as the total amount of space covered by a person or object during a match. This distance covered also works with positioning on the field, to study the exact movements on the field a player as they move. The training purposes are two fold. First, the coach can study how far a player has moved during practice or game. He could then tailor practice to ensure players are reaching a level of desired intensity in practice and games. Coaches could also study who’s been lagging in practice and who could use some extra work as well. By tracking the total distance moved, a coach can prepare substitutions or game plans to accommodate the data.

Another use for distance covered is positioning on the field. This metric will help coaches and players study how they move in “free space”, or the places a player moves when they do not have a game implement. Studying how superstar players effectively move without the game implement could prove to be a great teaching tool.

A great example could be studying how a hockey player like Lebron James of the Miami Heat moves on the floor. James is not a point guard, and therefore does not carry the ball, yet finds ways to get open and score over 20 points per game. Learning how he moves could prove to be a tremendous teaching tool for James' teammates because it can teach younger players how to move effectively to raise their game. Conversely, it can teach veteran players how to better mesh with his game to make him more effective to score more. The coach can also study these movement patterns to call plays and sequences that could be more effective for those superstar players. The bottom line is that this data analyzed properly, could help teams win more games. This free movement analysis could also apply to hockey and soccer. Head coaches could study players like Sidney Crosby (Canadian National Team Hockey) or Alex Morgan (USA Women's soccer) to make their national teams more effective, giving them a better shot at that coveted gold medal. National teams are generally made right before major tournaments, and this positioning could help make those teams playbooks easier to make based on those players.

The last thing that could be tracked by sensors is heart rate of the athletes. The heart is an important muscle that if anything went wrong with it, it could be fatal. Placing heart rate monitors in shoulder pads or in apparel could provide constant feedback to medical staff. This could be ever important for those players with heart conditions or sickle cell anemia. Understanding heart rates is a simple matter that could save lives. Another use for heart rate could allow a coach to monitor how hard players are exerting themselves during practice or workouts. If a coach notices that his players are not overly exerting themselves during practice he could either ramp up the intensity or could reprimand those players to make them work more. On the other side of that token, if his players are overly exerted it could put them at risk to get injured. The head coach can then fix up his practice schedule to keep their intensity high while lessening the potential risk for players to get injured.

Section Summary

It is important to control and operationalize the definitions of what kinds of data and movements Spintel seeks to track. A controlled library of definitions keep everything standardized making data easy to compare and understand. Spintel first and foremost

would like to study force and force production to make games safer for players of all ages. Studies of speed can affect how coaches can use his players most effectively. Studies of linear speed and lateral speed can actively change game plans for coaches. Studies of acceleration could change how “explosive” athletes can be on the game field. It can directly apply to how to coach players to exert more force. Finally, understanding where players are on the field so coaches could tailor practices to keep players safe. Tracking heart rates could save lives, especially those most at risk for injury from genetic traits.

Use Cases

Sensor data in sports will provide new methods for tracking movements and analyzing patterns to add continued value to the games people play and watch. If each player wears multiple sensors across every single play, every single game would produce big data. This data could be used to find new relationships for how players interact on the field. This data could affect every parts of the game and change how players, general managers, and fans view the game. Sensor data could affect skill development, selection processes, player safety/injury prevention, and officiating and fan experience.

The progression of technology allows new statistics to be calculated and tracked. This technology can also be applied in new thought processes within sports, like data driven player selection. “QB rating” is a great example of how technology changes what can be tracked and approaches to the game. To read more about QB rating refer to sidebar below. Spintel would like to research how wearable sensors could collect big data to uncover new statistics like QB rating. These new invented statistics from new trends in the data will be known as “shadow statistics”. Shadow statistics could be invented for each separate use case.

QB rating is a formula invented in 1973 that rates quarterbacks between 0 and 158.3, with 158.3 being a perfect passer. Prior to 1973, most teams simply used competition perfection or how many completions the quarterback had divided by the total passes. The QB rating uses a different formula, one that utilizes completions percentage, yards per pass attempt (total yards accrued divided the total attempts), touchdowns per attempt (total touchdowns divided by total pass attempts), and interceptions per attempt (total times the quarterbacks pass was taken away by the defense divided by the total pass attempts). The QB rating utilized more germane data of a quarterbacks’ complete play for a better comparison.

To understand how sensors effect each use case, two fictional people will highlight the uses. The first person is a freshman college offensive lineman, who shall be referred to as “Sebastian”. Sebastian will attend UC Berkeley (“Cal”) as a student-athlete on scholarship. Sebastian’s coach, referred to as “Jim” will be his offensive line coach. It is Jim’s job to help develop Sebastian’s skills, and fit him into his offense.

Skill Development

Teams are a collection of players, and each player is a collection of skills and talents that make each unique. Each player moves and performs in their role in the aims to win each game. Each play combines the movements of each player as well as the game related skills they have in the hopes they will win the match. To maintain a high level of play, players continually need to develop their sport specific skills as well as their movement patterns. It is the role of both head coaches and position coaches to teach their players game strategy while continuing to develop their players skills as well. Sensor data and new statistics could help players develop their skills while giving granular feedback to coaches as they guide their athletes through skill and strategy development.

Players will continually need to develop their skillset as individuals' careers continue to flourish. Wearable technologies and sensor data can provide players with granular data on their game-specific skills from every single game, drill and practice. These game-specific skills are things like pass blocking movements and the specific punch used for offensive line play. In our example, Sebastian could use wearable sensor data to see how much force he is producing in drill work. By adding sensors to his hip pads, knee pads, shoulder pads and shoes he could get granular details such as individual steps, foot placement, knee bend and hip roll. By continually learning from his own data Sebastian could get constant feedback to improve his game.

Coaches have the potential to use sensor and sensor data to help develop game based skills into their players. In a similar manner to how players could use sensor data to track and improve their skills, the coaches can analyze the sensor data from each game, practice and drill to provide effective feedback to each player. Jim could analyze each practice to teach players like Sebastian the intricacies of his game, and what needs to improve. In another example Jim could help Sebastian develop by comparing his data with superior players. By using data from sensors, Jim could show Sebastian all of his granular movements as they compare to an All-American. This could speed along the learning process to improve the level of play of both the individual players and the offensive line as a whole.

The data from the sensors could be used for more than just practice. Those sensors could be implanted into game equipment to compare the performance in games to how athletes do in practice. This data can be analyzed by players and coaches alike to work toward peak performance on the only days that matter, game days.

Selection Process

A. Individual Selection

Player selection is a vital part of building any team, program or organization. Players can be selected on the individual level as they get brought into new teams, and entire teams may get selected when building organizations for the Olympic games or other tournaments. College teams pay millions of dollars for recruiting, and faulty recruiting efforts could negatively effect the budget for years to come. Top tier players may cost teams millions of dollars, and faulty picks or trades could devastate a team's budget for years to come. Using sensor data as players develop their skills could help in player selection processes, player recognition, group strategy dynamics and team selection processes.

Before each season, professional sports leagues host their own draft, where individual teams will select new players to be added to their rosters. The first pick in the NFL draft on a pay scale will cost the team 22 million dollars. If a team chooses a player that does not perform, they still need to pay them out until the contract is over. Those funds could have paid many other players who could have collectively made a positive impact on the team. By studying the new shadow statistics based on skills and movement, there would be a more granular process to draft players. Games are bounded by how many different formations offenses and defenses can use to line up. Most teams will choose a select few to master in their given game plans. These formations and styles of play require different types of players with unique skillsets. Coaches and general managers could process big data sets of amateur players in the exact movement and skills for their specific styles of play. To get a better understanding of where better data could saved a team money, see the sidebar below.

An example where big data could have served a professional team comes from the 2007 NFL draft for the Oakland Raiders. In 2007, the Oakland Raiders selected Jamarcus Russell, quarterback from the Louisiana State University. Russell signed a

contract for nearly 40 million dollars, and only played 3 years in the NFL (Wyche). Prior to the draft that year, Russell made a great showing in some of his workouts. In one workout in particular, he threw a ball 65 yards from his knees (Wyche). Russell went down as one of the biggest draft busts of all time, winning only 7 games in 25 starts, costing the Raiders approximately 5.7 million dollars per win (Wyche). Using sensor and sensor data could have studied Russell's granular movements and skills to uncover how little he truly had. Sensor data could have saved the Raiders nearly 40 million dollars, and possibly a few losses on their record. Players can be chosen that fit the exact needs and specifications for their respective teams, by removing guesswork. Granular data could help teams select players for their specific styles of play to prevent "flops" or players who get selected high, paid a large sum of money, and never produce like Jamarcus Russell.

Coaches could continually evaluate players through training regiments for those players who may be on the cusp of making the team versus being released. Most teams hold some kind of training period, such as "spring training" in baseball and "training camp" for football. Coaches can use the data from practices and drills to more objectively choose the individuals to keep and release. In many leagues, "free agency" or a period after a team releases an athlete gives other teams the opportunity to pick up those players. Teams may freely exchange data for those looking to pick up free agents to benefit each other.

Players will make use of the new metrics and new statistics in their salary and endorsement negotiations. In each sport, there are players who do not have many statistics (offensive lineman in football, defenders in soccer and hockey etc.). These players could have more metrics to leverage for higher pay or better endorsements. Conversely, teams may have grounds to release or trade away players who may seem fine according to pre-big data standards, yet under produce according to the new shadow statistics.

B. Team/group selection

Although teams are made up of individuals, it is how those individuals interact with each other on the playing field that ultimately puts the team in a position to win the games. Predetermined plays are organized based on the coaches' preferences and the

personnel on the roster. Applying sensors on to individuals can show interesting relationships between players. In our example, Jim could evaluate whom Sebastian works with best on his offensive line. Jim knows his offense works best when two adjacent offensive lineman combo block (2 man block on one defender) well together. He knows that skill wise; Sebastian is best suited for center, yet he produces synergies on his combo blocks when he plays guard. Using sensors, Jim could now quantify those combo forces among his players for a better selection process to assemble the best combination of 5 players. Jim, our coach, could then put Sebastian at guard because of those synergies with his group of lineman. Using that synergy could help teams win games, and make offenses and defenses more efficient. Conversely, a head coach could figure out which current combination produces the greatest synergy to maximize its use in future game plans.

Group dynamics and shadow statistics produced from sensor data will have a carry over to individual selections for organizations. In the previous section, player selection was determined by individual skills and abilities. There is the potential to draft or trade for players based on whether they produce synergy with the person they will play with most often. Teams may save money by opting to select an “average” player that can produce that synergy than an individual “superstar” who works tremendously on their own, yet cannot produce synergy. Athletes who more frequently produce synergy could use that as a bargaining chip when they go into negotiations for contracts or endorsements. Most cases of team/group construction exist when the team is already established and owners/ general managers are looking to complement the current personnel. It begs the question, how could sensor data be used when building an entire team from scratch. Nations put together entire teams for the Olympic games as late as one year before the games. Nations could use sensor data to build their team as a combination of high-producing individuals of shadow statistics, and those who can produce synergy with those individuals. Using big data from sensor could mean the difference between bringing home a gold, and being off the podium.

Player Safety

An athlete is only as valuable as their body and how well it moves. Every athlete at some point in their career meets a harsh reality that they are not invincible, that they

can get hurt. Some of the greatest value sensors can produce stem from ensuring the safety of players and helping guide those who are recovering and rehabilitating from injury.

One of the biggest issues in sports, especially in football and hockey, is concussions. According to the American Medical Association, “Concussion is defined as a traumatically induced transient disturbance of brain function and involves a complex pathophysiological process. Concussion is a subset of mild traumatic brain injury (MTBI) which is generally self-limited and at the less-severe end of the brain injury spectrum” (Harmon). In games where 300-pound players are unleashing their full strength over 80 plays a game; these players are at high risk to sustain a concussion. If Sebastian were in a game with an embedded sensor, each hit he sustains would be monitored. If Sebastian were hit hard enough to possibly cause a concussion, a computer on the sideline would immediately notify a medical official in real time. Sebastian would then be pulled off the field and tested by a doctor to evaluate if he has concussion. What is most important about sensors in helmets is that it could save lives and save public money in future medical cost.

An important stakeholder for concussion sensors are the children who play hockey and football. Many local organizations may not be able to afford the best equipment, nor do they have specialized coaches with years experience to teach proper form and technique. By having sensors in their helmets, those children could prevent serious developmental damage for years to come. Coaches could look at the data to see what kids are at high-risk to get injured, to reinforce good practices, making it a preventative measure. Sensors for children could affect policies for safety, like if a player gets a concussion they cannot play for the rest of the season. It could help their doctors retain a log of what injuries a child has sustained over time for their medical records. This could play a vital role in treatment options for later life.

Player safety does not end at concussions, and can be used for a multitude of uses to improve player safety and diagnostics. One use works within standard bone fracture and torn ligament diagnosis. By placing sensors into kneepads, shoulder pads and elbow pads, one could get a quicker answer on what injury a player sustained. One could uncover the angle that someone got hit at, the amount force and where the hit

was sustained. By taking all of these factors into play, medical professionals could diagnose an injury much quicker, and could provide faster treatment options. In many cases the faster an athlete can get diagnosed and the faster a medical professional can combat swelling, the faster an athlete may be able to return to the playing field at full health (Hansen). Sensors placed throughout the pads that players wear can take a moment of fear and sorrow into a faster track to recovery and health.

After an athlete sustains an injury, it is a long road to regain their health. Two major aspects of rehabilitation of an injury seek to regain range of motion and strength. Range of motion is generally measured in degrees, and strength can be measured by force. To complete a rehabilitation program or to get promoted to a later phase one would need to apply their strength along a range of motion. Sensor data on recovering athletes could provide holistic data to medical professionals in both range of motion and strength. Range of motion could be measured by adding sensors to data or sleeves that go around the injured area. Strength production can be measured by sensors placed either in shoes or gloves as athletes perform their various exercises. One advantage of using sensors in rehabilitation is that it takes the stress off of medical professionals who oversee the recovering athletes. If the medical team understaffed, then they would need to pick and choose whom they should devote their time to. By looking at the data produced by the sensors, the medical professionals can get objective results from rehabilitation exercises, allowing them to be more efficient with their time. Sensors can help more athletes come back stronger and healthier while allowing medical professionals reach more of the injured players.

Officiating

There is one universal truth that each sporting contest reveals: no matter the outcome every fan agrees that the officiating was awful. Every fan has had the experience of hating an official for a wrong call or showing favoritism. Referees have a difficult time following every details of a game. There are only three basketball referees when ten players are on the floor, there are only seven officials for 22 players on a football field. Given there is so much going on during the game, it is understandable that referees may miss some calls. It is unfortunate that some missed calls could be the reason someone loses a game, misses out on a championship opportunity or can put

players at risk for injury. Sensors in the implements on the field, such as the goal posts and pylons, and on the players, like gloves and shoes, can help automate processes to correct the calls that referees got wrong.

Placing sensors on varying implements on the playing surface could help the officials make real time and accurate decisions. Placing sensors in game balls can provide granular data on where the ball is on the playing surface. Referees could know if a football crossed the plane immediately, if a baseball crossed the fence, and if a hockey puck traversed the goal line. Using sensor data would be more accurate than the current standard of video review because video review is bounded by the camera angles on the field. If the view of the implement on the playing surface is obstructed from the camera view, video review cannot be used. The sensor data is not bound by camera angles, but simply by the infrastructure that supports it. The plays that generally get reviewed via video are the pivotal plays that impact the games, making sensor data that much more important.

The use cases may begin with scoring plays such as touchdowns or homeruns, but as the sensor data becomes instance and real time, every play can be evaluated. Although there may not be much use for that in baseball and basketball, every football play could be tracked for optimal placement on the field. Referees placement of the ball after the play could make a difference in inches, and could make a difference in the game.

Officials also have the power to lobby the league to change the game. After using sensors to collect data referees and league officials could change penalties to make games safer. One instance could be finding that certain hits that used to be a 10-yard penalty could now become a 15 yard penalty and possible ejection from the game. This would make players more conscientious of their actions, and make games safer overall.

Fan Experience

Professional teams and organizations have a responsibility to ensure that their fans are having the best possible experience imaginable. Sensor data could add to the fan experience by allowing fans to get information on their favorite players on a play-by-play basis. Fans may be able to choose any of the players on the field to follow with the option receive a plethora of information. The information could be traditional statistics,

shadow statistics or other raw data from players. The fans could simply download an application for their smartphones sponsored by the team. Fans could track how many catches their favorite player may have as their lateral agility movements. Fans could learn how hard a running back hit a would be tackler, or the speed of the bat that just hit the home run.

An enhanced fan experience will benefit the sponsoring organization as well. As programs get better at culling statistics like force per step or the speed of a juke move, they could make that data available to the fans. Just like Twitter and Instrgram, fans could follow their favorite players and the institutions could track who subscribes to which players. For example, fans could track how hard Sebastian hits his opponent on a play-by-play basis. It could help teams make more personalized pitches to their prospective season ticket holders and provide access of specific players to the fans. An example from the basketball court stems from which players fans follow. Fans could choose any player to follow during the games they watch. If a team had traditionally used their shooting guard for their public appearances and marketing, yet there is a strong contingency of fans who follow their small forward, that organization could use that small forward in more marketing purposes. This could provide the fans the experience that they want, while enhancing fan relations from the club point of view.

Section Summary

Tracking players using sensors in equipment and game implements can revolutionize the approaches to skill development, player selection, safety/injury prevention, and officiating and fan experience. Each play that occurs in a game suddenly becomes dozens of data points per player. The analysis of the big data will uncover new shadow statistics that will provide even greater insights into the games we play. As the time continue to improve, lives will improve, fan connectivity as well as the games themselves.

Concussions

Since the dawn of time, people have pondered how the black box in our heads works. The field of neuroscience had its humble beginnings when people like Hippocrates started doing experiments on epilepsy ("History"). As the field began to grow, our world's greatest thinkers began to investigate our brains and our neural processes. People like Da Vinci, Plato and Locke aided our understanding in human processing, anatomy and biology. What thing that has been constant is that each generation never felt like they had a firm grasp on the human brain and what it can do. The neurological phenomena that athletics and the medical community currently struggle with are how to deal with concussions. These brain injuries occur on the field of play. The short term and long-term effects of concussions are profound to the athlete and will cost our economy millions in medical bills over time.

Concussions are brain injuries that are caused by trauma. These occur on the field of play after especially hard hits and whiplash. According to the American Medical Association, "Concussion is defined as a traumatically induced transient disturbance of brain function and involves a complex pathophysiological process. Concussion is a subset of mild traumatic brain injury (MTBI) which is generally self-limited and at the less-severe end of the brain injury spectrum" ("Results"). Concussions are considered "less-severe" because they are compared to chronic brain injuries. Contact sports are conducive to get concussions because those games are when players are likely to get "Rapid acceleration and deceleration of the brain, including rotational (angular) acceleration, linear (translational) acceleration and impact deceleration, are the primary mechanism by which concussion occurs" (Jordan). Although a football or hockey player will get hit every play, it's the amount of force and the angle that will turn that hit into a traumatic brain injury.

One of the many challenges with concussions is how to promptly diagnose and assess concussions. The only definitive way to diagnose a concussion is to use MRI machines or computer software after already having a baseline for that athlete. When it comes to on the field diagnosis, most diagnosis are done either because an athlete claims "they got their bell rung", or because they showed symptoms on the sideline. There are currently, "No devices that enable clinical diagnosis of concussion currently exist"

(Jordan). Given how hard it is to diagnose a concussion, more issues arise when a concussion goes undiagnosed and a player gets hit again. What makes concussions so potent is when a player suffers from diffuse cerebral swelling (DCS), or the effects from getting a concussion inducing hit while still recovering from another concussion. DCS can lead to some serious damage because, “DCS is the pathological substrate of second-impact syndrome... This second-hit trauma leads to a catastrophic neurophysiological response of diffuse brain swelling, cerebral oedema and brain herniation. Second-impact syndrome is thought to arise following loss of autoregulation of cerebral blood flow, which results in vascular engorgement and subsequent increased intracranial pressure and eventual herniation” (Jordan). DCS provides the greatest risks to players and the injury that causes many of the short term and long term negative effects.

The short-term effects of concussions deal with the time from when it is sustained. The most common symptoms that a recently concuss player exude, “include headache, dizziness and memory impairment. Notably, loss of consciousness is not a requirement for diagnosis of concussion” (Jordan). This means that if a player had recently gotten hit, they may lose their short-term memory. The time that follows would put the athlete at risk because they would not even recall that they sustained a hit like that. Adults in the short term, “tend to resolve spontaneously within 7–10 days” (Jordan). As there is no true recovery period for concussions like these, it can make players report that they are fine with no true measure of their health. Due to the nature of a children and adolescents growing and developing brain, “The recovery period can be much longer” (Jordan). The lack of benchmarks for recovery makes concussions a scary thing for players, especially youth players.

The long-term effects of concussions are those that last past the initial recovery of the injury. What makes these injuries so scary, “even when the symptoms of a concussion appear to have gone, the brain is still not yet 100 percent normal” (Nordqvist). If a player keeps getting hit during their respective season, their brain could experience a perpetual state of recovery from the first day in pads. According to recent studies, “there is abnormal brain wave activity for years after a concussion, as well partial wasting away of the motor pathways” (Nordqvist). These effects vary by the amount of

concussions one sustained, as well as the magnitude of those injuries. The same study also “compare[d] healthy athletes to those of the same age who suffered from a concussion 30 years ago. The results showed that those who experienced head trauma had symptoms similar to those of early Parkinson’s disease- as well as memory and attention deficits” (Nordqvist). These effects can increase when those initial hits sustained were from youth players. The long-term effects of concussions only prove that something that takes seconds could have a haunting lasting effect on that player.

Technology Overview- Hardware

Existing Hardware Companies

There are very few companies in the world that integrate sensors into sports. Even when they do, these companies are not using sensors to monitor performance, decrease injury, and increase player efficiency. Sensors have historically been used to measure how fast a ball is thrown or how many times a ball enters a goal post; very quantifiable metrics. Ohio-based *Sports Sensors Inc.,* for instance, sells radar equipment to measure speed and velocity in archery, baseball, football, golf, tennis, & paintball. These hand-held or stationary radars measure the speed of pitches or throws via the doppler effect, which emits a wavelength and compares it to a modified wavelength reflected by moving objects. A downside is that radars can only measure the speed of objects reasonably close to their emitters. This can be seen as the first use of sensors in sports, and are akin to hand-held police radar. The industry leaders in "second-gen" sports monitoring are *Zephyr*, *SportVU*, and *Catapult*. This next generation of sports sensors is made possible by smaller, faster, and more energy efficient sensor modules and microprocessors. Advances in wireless protocols like bluetooth and wi-fi enable long distance and individualized player tracking with gyroscopes and accelerometers too.

Physiological Status Monitoring (PSM) company, *Zephyr,* monitors player movement and cardiovascular activity. This is made possible by embedding accelerometers, gyroscopes, temperature sensors, and pulse rate monitors directly onto player jerseys through chest/back harnesses. This system requires multiple antennas and communication systems that can be repeated for extra coverage. Recently, the NBA began fitting minor-league player jerseys with *Zephyr's* vital-monitoring sensors. Some NBA teams are also wearing these devices during practice to monitor performance of highly paid athletes. The advantage of using sensors is that coaches and physical trainers can monitor athletes for over or under training. While this creates ethical problems (i.e. player union opposition, contract negotiation, less money for athletes), *Zephyr*'s systems have been instrumental in monitoring astronauts, medical patients, and protecting trapped chilean miners. This system is very robust, but does little to predict psycho-physiological injuries like concussions.

The player-worn model contrasts that of SportVU (separate company), which uses 6-12 on-court cameras to track player and ball movement. With regards to football, SportVU highlights speed, possession, field coverage, runs, passes, offsides, etc... Some basketball

stats tracked by SportVU are speed, distance, ball trajectory, passing frequency, rebounding, and player shooting tendencies. These are things *Zephyr* can't do because it doesn't see the full picture. SportVU can monitor how players shoot or what their shooting tendencies are because cameras can see players. Like coaches, they can spot where players are and allow more strategic play-calling. What *Zephyr* can do is provide up-to-date physiological monitoring, which can effectively tell if a player is training efficiently, dehydrated, or prone to injury due to exhaustion.

Contrasting SportVU, *Catapult Sports'* position-trackers rely on real-world GPS or "multilateration using portable satellites (or nodes) in a stadium." This requires drop-in node installation that can analyze player position indoors or outdoors. The direction, speed, and triangulation of each player is done through these nodes and visualized through proprietary software. Players also wear tracking devices and sensors on their upper backs, which are tracked by the aforementioned nodes. This is useful for formation-based sports and analyzing players for conformity to coaching, over-training, or sluggish performance. Fatigue can be recorded through the accelerometers and gyroscopes as well, so biomechanical "red flags" can be compared to athlete norms. Their proprietary algorithms are developed by elite universities and sports scientists. Catapult Sports' system is like a combination of the first systems, though lacking certain features.

Advantages and Disadvantages

Each system has its advantages and disadvantages. Where Zephyr shines is that it's actually on the players themselves. There, it can monitor players on a personal and physiological level. Where it doesn't shine is that it lacks on-court positioning and costs $1,249.95 per monitor (Amazon). Professional Athletes and college programs may be able to afford these prices, but the everyday athlete cannot. This is a barrier to entry for pee-wee football leagues, club teams, and high school sports programs.

SportVU allows real-time movement tracking in 3D space; which is important for jumping, running, and gait analysis. SportVU has an edge because cameras can follow the trajectory of balls and track player motion. It can't, however, monitor player vitals. Catapult's solution is a fusion of both, but lacks the actual physiological monitoring of *Zephyr*. Instead, it focuses on biomechanical loading problems that can lead to potential injuries through accelerometers and gyroscopes. Like with *Zephyr*, Catapult's camera and gps systems are extremely costly to implement too.

Possibilities for Cheap Sensors in Sports

Millions of dollars go into research and development of sensor hardware. From there, companies must pass FCC testing and even receive FDA clearance to be trusted in sports and medicine. This is something Zephyr has achieved, but we know it will be an uphill battle. Here are some systems we have studied for potential use in place of expensive sports sensors. They can either be developed using readily-available hardware or adapted from consumer devices.

Arduino

The arduino platform is extremely versatile, and can be low power if one were to use a penny sized TinyDuino or Arduino Teensy. The Arduino Uno is a good starting point for beginners, but one must purchase endless shields to give it the power of Arduino Esplora or Razor IMU; both of which have built in gyroscopes and 3-axis accelerometers. This simplifies the process of development, but the issue of connectivity still remains. Arduinos must use bluetooth or wireless shields, both of which can be buggy, to transmit data. While feasible, our prototypes showed that wireless data couldn't be transmitted quickly or efficiently using Arduino. It also had to be tethered to a battery station, and lacked the ruggedness of commercial systems. While the prototype was good for testing environments, we could not recommend it for on-court use.

Mobile Devices Supporting HTML5

Instead, we propose using devices people take for granted. We are of course recommending iOS-powered iPod Touches, iPhones, and cheap Android phones. An advantage is that they have gone through stringent testing for conformity and FCC regulations. They've also been drop-tested for durability and are resistant to perspiration with the right casing. Since each support HTML5, there is already a universal platform to build upon. Underutilized and scrutinized by developers, it is still quite powerful because of its Application Programming Interfaces (APIs).

For instance, Phones and iPod Touches have internal GPS navigation, gyroscopes and accelerometers that can determine position, speed, acceleration, and direction of players on a field. They also have built-in wifi, and their typical battery life is long enough to withstand the rigors of a 3-4 hour game. Pair that with an off the shelf router, and coaches

can track multiple players much like Zephyr or Catapult can. The difference is that positioning won't be as precise as Catapult Sports' indoor nodes or high-precision satellites. The implementation of HTML5-compatible databases and development of visualization systems for metrics and location will also be time consuming. The HTML5 advantage is that it's lean, agile, and interoperable with multiple database systems and even local storage on each device. This makes it flexible, adaptable, and extremely useful for prototypers and web developers.

Where Spintel Comes In

This gives many companies a window of opportunity to develop low cost sensors for sports that any team or player can use. We, on the other hand, are looking to systematically study sensors in sports. This requires information management, data analysis, new/existing data infrastructure, and reliable reporting mechanisms. We believe this is extremely important because it can prevent injuries and inform parents, fans, and players at the same time.

There is also more to sports than just physical health or performance: mindset and mental toughness are things we can detect through personality and problem solving tests. At the end of the day, an athlete should be smart, obedient, thoughtful, and hard-working to truly succeed. Spintel also acknowledges that people don't always want to be pushed to their limits. This is important because we want to monitor new athletes to keep them from getting injured and to encourage them to stay active. Every player is motivated in different ways, so Spintel must create profiles through both sensors and personality analysis.

Section Summary

Given this Technology Overview, it is prudent that manufacturing is not the purpose of Spintel. Spintel leverages existing technology, combining and synthesizing their data to create customized and highly nuanced profiles of athletes. This way, we can take the best of Zephyr, Catapult, and SportVU data and synthesize it into more accurate player ratings. We chose to use an HTML5-enabled device to monitor players on the field.

Our other main focus is on being a consultation firm. This is a strategic business decision because we do not have the tooling nor funding to manufacture chips for embedding into compression shirts. Spintel can work to design and manufacture when we

have the resources. Until then, we will focus on utilizing existing technologies and studying sensor data to create smarter and better players.

Technology Overview- Software

Software & Application Design

Spintel's main goal is to systematically explore sensors in sports. To inform players, coaches, fans, and parents about player tendencies and susceptibility to injury, Spintel requires a management system designed to monitor, implement and compare sensor data in a coherent and intelligent way. Though we would like to additionally monitor shadow statistics and intangibles (that separate great players from mediocre ones), it is our first priority to create a symbolic database system that can compute and derive meaningful conclusions from these sets of data.

To do this, we conceptualized a cross-platform HTML5 application that can register hard, quick, or jarring movements through g-force thresholds. This way, a typical mobile phone from Apple or Google can be used to perform many of the collision tests of a $1200 system from Catapult, which regularly charges $100,000 per team it signs up. Preliminary tests included a Cal Football Helmet, which was fitted with a mobile device inside, on top, and on the side. There, we tested various jarring impacts that could accumulate (or result) in a concussion. For instance, we observed that a player's head must collide with another player's body (or whip toward the ground) to initiate concussion-like hits.

This assumption helped us build a rudimentary first prototype, which literally denoted "HIT" when an impact threshold (in 3 gyroscopic planes) was exceeded. After testing for reliability in football helmets, shoulder pads, and armbands, we iterated into a direction-aware version. Our second prototype remedied false-alarms from twisting movements that mimic nodding yes/no or shaking side-to-side. The only way to accomplish this was to abandon the XYZ plane and focus on gyration metrics like tilting, twisting, and falling. From existing studies, we also learned that most head-on collisions for children 13-14 years of age happen at 29.2g and 35.0g of force (MedScape), the same magnitude as college-based athletes. We couldn't normalize our metrics to theirs due to hardware differences, so we came up with custom thresholds that could be adjusted accordingly.

After further testing and algorithmic development, our threshold monitoring prototype became a robust and direction-aware detection platform. From switching to gyration-based measurements, we could detect hits from the right, left, front, and back; in real-time and time-stamped. This meant that we could feasibly send the data to a central hub (laptop or server) and keep a running record of hits for further study. We later added a color scale to denote how hard a hit actually was.

Database Application Design

Our database requires an agile approach because it will constantly be growing and changing. Many database platforms were researched, including: Django, MySQL, NoSQL, Node.js, and SQLite. Since we were working with mobile devices and light deployment frameworks, we decided to use Python, SQLite, and HTML5 Device Cache (in case there were no networks present). For these reasons alone, we could use our sensor “standalone” or networked when available. It had to be able to store a running count of hits with timestamps, and send that to a central database. Conversely, our sensor can send the same information to a local service running on any python-enabled laptop. This makes deployment extremely cost effective, robust, and available within the range of any wireless network router. A general rule of thumb is that 802.11 b/g/n routers support a range of up to 150 feet (46 m) indoors and 300 feet (92 m) outdoors (about.com). This changes the game for most sports programs because it reduces cost, cognitive strain, and expertise generally required. It’s a turnkey solution we’re really trying to develop.

Future Developments

Everyone has technical weaknesses. We would like to create profiles based on their tendencies and body types to custom-tailor skill development. This is important at a young age and at the college and professional levels. It is also important to determine if a player moves without purpose or deviates from coaching on the court. These are intangibles coaches and scouts want to know about. Due to time constraints, however, we will focus on one such case study: the concussion sensor.

Stakeholder Analysis

Sensors and data within sports affects the players, the administrators, the officials, leagues and fans among other groups. Each group feels the effects of the sensors in one-way or another. A power-legitimacy-urgency stakeholder analysis will show how each group fits into a new sensor filled game. This analysis was first proposed by Mitchell et all in 1997 to show that every project will have people with, "power to influence the firm, legitimacy of the stakeholders relationship to the firm, and urgency of the stakeholder on the firm"(Salience). Using these relationships, a three part Venn diagram as seen in figure 1 below, with eight classifications (Salience). The first group of stakeholders is the "definitive stakeholders" or those that have power, legitimacy and urgency. There are two groups that fit into this category. The first stakeholders are professional athletes. These athletes are the ones that get paid the big money, the ones that are on television in front of millions of fans, and the ones people see in ads. These players have power because if they can sway public opinion. A few select superstars may push public opinion heavily for sensors and data if they find it truly adds to their game. On the other hand, professional athletes have legitimacy from their years of playing experience, and because they are above the top 1% at their game. Lastly these players have urgency because of a serious first market mover. If the players align themselves with something else in the sensor field, it could take major market share rather quickly. The athletes are a group that Spintel would need to keep in mind in every step while developing any of the sensor related products.

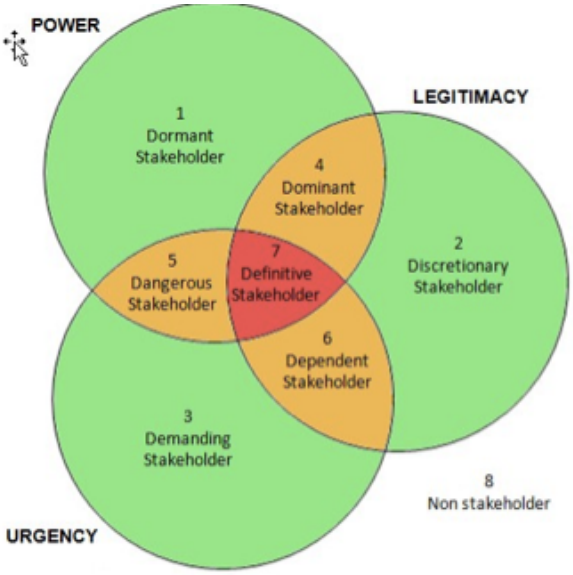

Figure 1

ESPN among other production companies are also considered "definitive stakeholders". ESPN has the greatest economy of scale when it comes to video broadcasting of games. The 2014 men's college basketball season alone consisted of

586 total games, with an average of over 500,000 viewers (Humes). This includes individual games such as the February 1st matchup between Duke and Syracuse that yeiled 4,750, 000 viewers. ESPN has power simply because no other network can claim those kinds of numbers. ESPN could cut some funding from sponsorships in deals to host conferences, leagues and schools. These broadcasting companies have legitimacy because they control the biggest portions of market share and are established with years of broadcasting experience. ESPN collectively has urgency for the same reason that professional athletes have urgency. If the broadcasting companies find a partnership that suits them well, that partner would ride the coattails of those economies of scale and could maintain that partnership for decades.

The dominant category of stakeholders combines both power and legitimacy while lacking in urgency. The only stakeholder that fits into this category are leagues/conferences. Leagues such as the NFL/NHL, the NCAA and conferences like the Pacific 12 conference have power as the governing body. These leagues can influence legislation over the organizations they govern, and make them comply after imposing it. The leagues have legitimacy because they are also the ones who control many of the contracts for television, player's image rights and scheduling. The reason that leagues and conferences lack urgency is because no serious change can occur without collective bargaining (NFL/NHL) or without serious red tape negotiations (NCAA/PAC 12).

The dependent category houses stakeholders that combine legitimacy and urgency while lacking power. There are five major stakeholders that reside in this category with the first being various players associations. Players associations like the NHLPA, the NFLPA or the NBAPA formed for collective bargaining purposes. These were formed to comply with the Sherman Antitrust Act of 1890 to combat monopolies where "A monopoly is a situation in which there is a single supplier or seller of a good or service for which there are no close substitutes" (Sherman). The player associations have legitimacy because they have the bargaining ability and have gone on strike in the past, with the most recent strike occurring in 2011 by the NFLPA (Schefter). The players associations have power because The Players associations have urgency because once they get attached to a certain system, they can use it in collective bargaining, or if

they hate using sensors they can bargain away from it. The players associations lack power because negotiations only occur once every few years. Also, if negotiations take too long, and a strike occurs, the players (the definitive stakeholder) will want to play forcing the association to come to an agreement.

Equipment manufactures are also dependent, because of their legitimacy to build game implements and the urgency to adopt something to their already widespread use. Manufactures like Schutt and Riddell have the supermajority of market share for football helmets in football while Wilson, Spalding and Nike have that same majority for basketballs. The market share alone accounts for the legitimacy, not to mention that many of these manufacturers have been partners with leagues and ESPN for years. There is an aspect of urgency because many new sensor products would need to be compatible with the existing protocols that these companies have. Just like ESPN, once one of these companies locks into a partnership with a sensor producer, that producer will immediately be pushed onto many of the existing users.

Amateur athletes such as those who play sports in college, high school and pre-high school leagues lack power, but have legitimacy and urgency. These players lack power because their institutions own all of their rights. They generally do not have the resources or the following that professionals have, so they cannot dictate serious change. These amateurs have legitimacy because there is such a large volume of them. Those in the college level may be able to garner some support, but none compared to what their institution holds. These amateurs also have urgency because they can be an early adopter to technology. If amateurs can find a sensor that improves their game, especially one that is affordable, the sensors will sell quickly.

Fans act as a dependent stakeholder, where their dependence lays with the teams and leagues. Fans have legitimacy because without fans, there would be no professional leagues, amateur leagues or television contracts. Fans can buy tickets and memorabilia, but the teams and the leagues are the ones that can buy into sensors and sensor data. If a sensor adds value on the team or league side of play, there is little the fans would be able to do about it. The urgency reflects the product that a team puts on the field. If a team uses sensors to build a better team, the fans would expect a better

product. The fans lack power because there is no way they will just completely stop watching their sports completely. Until that can happen, they will never wield true power.

The last dependent stakeholders are professional teams. They have legitimacy because they are members of billion dollar organizations that have the resources to purchase what they need to make a better product. The professional teams have access to the players' equipment and can quickly implement sensors into equipment. These teams have urgency because they are always looking for that edge to make their team better. If they can find that through sensors or a better evaluation process they will make full use of it. The professional teams lack in power because they are at the mercy of collective bargaining with their respective player associations. Any work with sensors could be easily vetoed by the players, even if it is for their own good.

The next type of stakeholder is "dangerous". These are the stakeholders with power and urgency but lack legitimacy. Clothing companies are considered dangerous stakeholders. These companies are like Nike, Adidas and Reebok will make products that players wear that may not affect the game. One example would be like an undershirt that a basketball player would wear, or the jerseys that a football player would wear. Nike and Adidas have power from their brand recognition and partnerships with major sports leagues. Nike is one of the most well known brands in the world, and could prevent progress from being made with sensors if they think they could somehow take that market for themselves later. These companies have urgency because they may become part of a "sensor race" themselves to openly compete with sensor based companies. These companies lack legitimacy because they still need to work with the leagues and players to ensure that their product can be worn on the playing field.

The next stakeholders are "demanding stakeholders" who have urgency only. Stadiums and stadium personnel are the only ones who are "demanding stakeholders". Stadiums would need to get fitted with the proper equipment to support sensors and data collection. Stadium personnel in this context mean the information technology personnel, electricians, and construction workers would all work together to build that infrastructure. The stadium workers would seek to have the earliest notification they can to put the infrastructure together to minimize overtime work and to maximize testing

time. This work to build the infrastructure will take time, and this stakeholder will reflect that.

The next stakeholder type is the “discretionary stakeholders” who have legitimacy. Referees and officials are the stakeholders who have legitimacy alone. It is their job to look over the rules, rule changes and implementation. The officials can use their legitimacy of position to claim that using sensors could impede their job. They can also agree or disagree to adopt sensor based officiating. In the grand scheme of things, even if they disagree with rule changes or using sensors, they can easily be replaced by their leagues, or forced to adopt the changes.

The biggest non-stakeholder are sponsors of events and teams. These sponsors have no power because teams and leagues will continue to use sensors even if someone like Pizza Hut or Taco Bell protests it. The reason for the protest could be anything that those brands do not see as fitting with their image. They have no legitimacy because they have no actual effect on the game, and many teams feel they can replace many sponsors. Lastly, there is no urgency because sponsors should not care about what goes into a player’s pads, nor the speed of which it gets adopted.

Needs and Usability Assessment

Interviews were conducted to gather qualitative data on how sensors could affect different stakeholders among the 5 major case studies. Although each interviewee was asked four basic questions: What is your background? What are your areas of expertise among the 5 major use cases? What are you already doing with sensors in sports? What do you see are the major issues for sensors in sports? To read the full interviews, please go to appendix 1.

To gather quality qualitative data, it is important to interview a multitude of stakeholder from across many sectors. Figure 1 and figure 2 below are our stakeholder landscapes, containing different categories of stakeholders and which interviewee fit into each category.

Figure 1: Stakeholder Landscape 1

Athlete	Coach/ Athletic Director	Conference	League
Professional Offensive Lineman	Division I Athletic Director	Division I Conference COO	National Hockey League Executive
	Division III Athletic Director	Division I Conference CMO	
		Division I Conference General Counsel	

The first stakeholder landscape deals with the roles that interviewees can hold in the athletics systems. First there is the athlete, the person who wears the sensors and equipment. They are on the ground level of the organization because they are the ones who will be studied, and whose bodies are being put on the line. One interviewee is a professional offensive lineman in the NFL who filled this category. The next category is coaches/ administration. They are the ones who would either use the data for coaching

purposes, and conversely could have the power of the pocketbook to purchase these programs. We have a division III athletic director with 20 years of coaching experience as well as a division I athletic director within this category. The next category is the conferences that house its constituent schools. The conferences have resources to provide schools in some cases to subsidize programs for health, or to provide funds for research. They also have the power to change some rules on a conference level in regards to safety. There are three conference executives that fulfill this category. The last category in this stakeholder landscape is league officials, the ones with power to change rules and regulations on a league level. There is one NHL executive who fills this role.

Figure 2: Stakeholder Landscape 2

Youth	College	Professional	Medical/equipment
		General	National Athletic
	Division I	Manager	Trainers
Pop Warner	Athletic Director	MLB	Association
	Division III		Equipment
	Athletic Director		Manufacturer

The second stakeholder landscape deals with the age, playing level and equipment. The first category is youth leagues. These contain the youngest players actively playing, as young as 5 years old. These leagues and players would have a different budget and need than those leagues with more developed players. This category spans from the earliest youth can play until the end of high school. The stakeholder that fills this category is Pop Warner football. The next category is collegiate, the level above youth but below professional. These players are still considered amateurs. The stakeholders that fill this category are two athletic directors, division I and division III schools respectively. The next category is professional leagues. These contain players who profit from their play. The stakeholder that fulfills this role is a General Manager of an Major League Baseball team. The last category is present in all levels, but at different depths, equipment and medical staff. Each player needs to wear a helmet and shoulder pads. Each player may need to get medical

attention at some point in his or her careers. To fill this category, an equipment manufacturer and a member of the National Athletic Trainers Association were both interviewed.

National Hockey League (NHL)

The first interview conducted was with Grant Nodine, the Vice President of Information Technology at the National Hockey League. Nodine mentioned his background was very strong in technology and information systems. This technical view as well as being an overall hockey fan guided his views on sensors in the NHL. When asked about his area of expertise, he noted that his was in fan experience, most notably through media. Nodine could work on the technology side of broadcasting stating, “We have fixed floor cameras with crop zoom, and fixed 4K cameras on players with HD capabilities”.

Nodine gave some great insight on to what the NHL has already done with sensors in sports. He noted, “We tried cutting pucks in half adding a sensor and putting them back together again. Despite a computer saying it should feel the same, players complained that they could tell the difference”. Nodine also mentioned that following the puck using sensors is considered “the holy grail of hockey”. The NHL has a positive view on sensors and feels it could add value to the fan experience. Nodine talked about the major barrier to entry for wearbale sensors in the NHL, “our biggest challenge is dealing with the collective bargaining of the NHLPA (National Hockey League Players association). They are adversarial of sensors and data because they fear for anything that could be used against them in arbitration”. The biggest barriers to entry to implement anything would be if the players would approve it, even if those sensors could study their brain trauma, prolong careers or improve play if there is any possibility it could be used in arbitration.

Experienced Sports Trainer

The second interview took place with an experienced sports medical trainer. This person wanted to remain anonymous as a stipulation of the interview. When asked about their background, he mentioned he was a member of the National Athletic Trainers Association (NATA). This membership complements the years of schooling, his

experience with 6 organizations and internships. Given his master's degree and year's experience, his area of expertise among the 5 major use cases is player safety.

This trainer talked a bit about some of his previous experience with sensors in sports. The trainer felt other helmet sensors were flawed because "the company [he had worked with] had a preset threshold of G forces for players could sustain before it would go off. How do they know what the threshold should be? Is it from the player's medical history? A scientific study? Prior concussion data?" Finding the right calibration could prevent false positives or it could prevent having concussion sustaining hits without any warning. Besides the calibration issue, the other major issue for concussion safety on the field comes from the expectation for non-qualified people to diagnose concussion-like symptoms. One example comes from the NFL where they have "a plan where the referees are supposed to remove any player that looks like they have concussion like symptoms. They are making people with absolutely no medical experience try to apply what they think could be an injury on top of their already big job". Concussions are a problem in collision sports, and it requires the proper people to work with them.

Pop Warner Little Scholars

Pop Warner Little Scholars (henceforth known as "Pop Warner") is a youth football league that targets children as young as four years old and as light as 35 pounds ("Ages"). It took some research to understand why Pop Warner adamantly refused to conduct an interview. Children are greatly affected by brain trauma, taking longer to heal than adult counterparts. According to ESPN, "Pop Warner saw participation drop 9.5 percent between 2010-12, a sign that the concussion crisis that began in the NFL is having a dramatic impact at the lowest rungs of the sport" (Fainaru). The same article highlights that from 2010-2012, the organization lost over 23,000 players (Fainaru). Declining numbers and worries about their perception could account for why the interview with Pop Warner was short and produced very little information.

Our team attempted to contact the commissioner to uncover what needs the organization has. After leaving a voicemail with a secretary at their office, the next call got immediately routed to a media relations department. Asking for help with graduate level research, the only response they would give was, "We refuse to make any comments on helmet sensors and concussions for Pop Warner". The organization also

refused to comment how they could choose volunteers to be a local teams' medical staff. The fact the organization replied in such manner does not give much in terms of qualitative data. The organization keeps anything that could be incriminating or could be quoted in public in-house preventing further investigation from the Spintel team. The needs that arose from the interview were implicit in nature. Pop Warner would need some kind of system that could make them above reproach for their safety measures. They need something that could instill confidence into parents and guardians alike, and could bring a better image to the league as a whole. Pop Warner may be influenced by the decisions of the NFL, and could follow the NFL in suit. There is a possibility that the converse is true, that if Pop Warner adopted a systems for tracking players and tracking concussion inducing hits, that the NFL could follow a lower league as a "proof of concept".

Billy Beane

Billy Beane is the current general manager of the Oakland Athletics (also known as the A's) professional baseball team. Beane is the subject of the best selling book and film "Money Ball". Beane's background started as a player and first round pick in the MLB draft, followed by a professional scouting career and finally as a general manager of the A's. Beane's areas of expertise among the 5 major use cases are player selection and skill development. He was the first to use data-driven selection processes to select players and develop players.

Beane has a history of innovation in sport by using data. He started using data driven selection because "As a team we have one of the smallest revenue bases in our league. If we went by convention our record of wins and losses would reflect that". He began using stats he could see with the naked eye, processing data with paper and pencil. As time progressed the A's started using data on computers to process the data, "we have gotten to the point where we can collect and understand every movement that occurs on a diamond". The algorithm made the business model simple, "A) We seek out skills we think are undervalued and add them to our roster at price we can afford. B) We sell skills that we think are overvalued so we can use those resources to gain those undervalued". When asked where Beane saw sensors going in the future, he mentioned that data is expensive. The stratification that existed before data-driven selection has

returned to the game. Those teams with high revenues can buy more data to aide their player selection.

Juliene Simpson

Juliene Simpson is the athletic director at Saint Elizabeth's College in Morristown, NJ. Saint Elizabeth's College is an all-women's college classified as a Division III school according to the NCAA. Division III differs from Division I because, "Athletes at DIII colleges and universities receive no financial aid on the basis of athletic merit, although substantial financial aid and academic merit scholarships are available at most DIII institutions" (Division). When asked about her background in sports, she won 2 basketball national titles as a collegiate player, a silver medal in the 1976 Olympics, 25 years of division I coaching experience as well as an athletic director for 5 years. Her areas of expertise are both in skill development and player safety, as both a player and division III administrator.

Simpson did not have much to talk about in regards to the current landscape of sensors in division III sports. According to Simpson, "Maybe the top half percent of division III schools with high level football teams could use sensors. They may be the only ones with the boosters to afford that". When it came to sensors for division III, the biggest issue is funding and resources. The resources are so thin; "We would almost never adopt anything by choice because we do not have the money. We have more allotted time to comply with rules than division I. For instance when the NCAA legislated that an arc must be placed inside the paint in basketball, the division I schools had to comply that year, division II had another year to get that done and we had 3 years to do that. This is mostly based on budgets". What makes budgets so interesting for division III is that most schools cannot even afford the basics, "When it comes to division III we get many things subsidized from the NCAA. We have a game tape exchange where we take our team's games, and send it to every other school in the conference. That costs us 500 dollars. The NCAA gives the conference 250 dollars per school which then trickles down to each of us".

Professional Football Player

One interview with a current professional offensive lineman shed some different insights on how current athletes' use and view sensors in sports. This player currently

plays for the Cleveland Browns and was an all-conference player in college. His expertise among the major use cases are skill development and player selection.

The current player mentioned that his team uses sensors such as GPS trackers. According to him, “We wore heart rate trackers and GPS systems all year. I felt that it didn’t do anything. I think collecting most data is useful. It just is not applicable until you get that same data for games”. The biggest gap seen by well-established leagues is finding the tradeoff between using what has worked in the past and new technologies. The future of sensors stems from a comment that this lineman made, “We hired 4 people to be our data scientists. I did not see them do anything for us at all. I think they were just paid to collect the data, but I did not see them process it. Despite collecting the data they [coaches and administration] didn't change practices”. Sensors are only ass effective as the how the organization uses its data.

Pacific 12 Conference Executives

Three interviews were conducted one after another at the Pacific 12 (Pac 12) Conference Headquarters. The three interviewees were Kevin Weiberg, the COO of the Pac 12, Woodie Dixon, the General Counsel and the Senior Vice President of Business Affairs of the Pac 12 and Danette Leighton, CMO of the Pac 12. The two major areas of expertise that these executives have are player safety and fan experience.

The current landscape in sports for player safety is changing and the Pac 12 is at the forefront of that change. To help make games safer, the Pac 12 has set up funds to aide in medical research for sports. According to Woodie Dixon,
“we have set aside a fund for 3.5 million dollars for research into head trauma. That money is set-aside for this year; we are hoping to get that money every year for continued research”. Another thing Dixon commented on was the thought that concussion data would only add lawsuits to the host institution. According to Dixon, “sensors are hitting a point that the automobile industry hit a while ago. They asked themselves if it was in their best interest to collect data on their crashes and failures or would it be too much liability. The industry collects the data and now tailors their products to be safer and more efficient”. This thought process directly contradicts how some of the other interviewees data collection.

Leighton made some interesting points in her interview as well. Her expertise was in fan experience and she made a note of the different kinds of fans, “When looking at fan experience in sensors, and fan experience in general, there are many subgroups to consider. Many are split up by age. The young generations need to be connected at all times. If they cannot post to Instragram or to twitter they are not happy. Older generations may want to vote on what song gets played next at the stadium either by the DJ or by the school band”. Her greatest takeaway was to know the fans you wish to delight, and apply the data to fit them.

Schutt Helmet Salesman

There is not much to takeaway from the Schutt Helmet Salesman interview. The major takeaway was that the two biggest players in the helmet market. According to the interviewee Schutt controls approximately 55% of the entire market share, including 36% in the NFL. What makes the 36% substantial for the NFL is because each Schutt helmet needs to be bought by the athlete who had an option to get a free Riddell helmet.

Sandy Barbour

Sandy Barbour is the athletic director at the University of California-Berkeley (“Cal”). She had been the athletic director at Cal for over 10 years, among other professional experience in sports administration. Her areas of expertise are in player safety and fan experience.

Barbour noted that some of the smaller teams have already used sensors their training, most notably GPS tracking. According to Barbour, “teams like men and women’s soccer and field hockey have used the data to work on their practice intensity. It can help show that they just had a hard day to make the next one a little lighter. It can also be used to show which players may need an extra push in practice”. The teams using these systems are ones that have a smaller roster, and are more heavily based on running than on collisions. When asked about the biggest issue around sensors in sport at Cal, Barbour notes, “The challenge for this level is how to use the limited amount of hours in a day effectively. There is video review, weights, practice, and school. How will you use it all?” Cal may have the resources to buy and implement the

sensors, however if they do not allocate the proper time to break down that data, the sensor data will just sit in its database.

Appendix 1: Interview Transcripts

Grant Nodine- NHL VP of IT interview

March 7 2014

Mark Brazinski: Grant, thanks for taking my call I hope you are well.
Grant Nodine: Its all right, we've been playing phone tag for a while a now
[skip ahead after talking about the Pittsburgh Penguins, the Flyers and about living in New Jersey]
MB: My final project deals with sensors in sports, I was wondering what you all have done so far, and where you are exploring?
GN: Before we can implement anything, our biggest challenge is dealing with the collective bargaining of the NHLPA (National Hockey League Players association). They are adversarial of sensors and data because they fear for anything that could be used against them in arbitration.
MB: If I understand correctly, the NHLPA-NHL relationship is one the rockiest amongst professional sports leagues. Is that true?
GN: absolutely. There is a huge mistrust issue on both sides. There are some difference between deals done between NFLPA-NFL and NHL-NHLPA. If an NHL player gets a 10 million dollar contract, that's all guaranteed money, the NFL is not the case. But they worry about having negotiations that start with "hey Sidney Crosby [current player in NHL] you haven't been skating as fast as years past, we think you should take a pay cut on your next contract"
MB: I could see how that could be a barrier for sensors. What about something that could extend their career like concussion sensors?
GN: Studies for concussions are very much in academia right now. We have some very top-notch universities looking into the effects of concussions.
MB: If the NHLPA was not a barrier to entry, what kinds of sensors would you want to use?
GN: Trust me, what ever is available we would use. The NBA has set a precedent; they use video tracking in the broadcast world. Although the NHL cannot place anything on

players without approval of collective bargaining, we have full power over the video and broadcasting rights.

The NHL wants this data on our players and we have responded thus. We have fixed floor cameras with crop zoom, and fixed 4K cameras on players with HD capabilities.
MB: Have you ever considered using drones with cameras?
GN: yes we have, but we are too worried about what happens in a case of failure. If the drone lands on a player that's a disaster for the league and if it lands on a fan its worse. It would be terrible PR for the league in general. We'd love that, but its too dangerous.
MB: Have you considered doing something with the puck itself?
GN: Yes, following the puck is considered the holy grail of hockey. We have yet to find a sensor that can survive the vulcanization process. We tried cutting pucks in half adding a sensor and putting them back together again. Despite a computer saying it should feel the same, players complained that they could tell the difference. To tell you the truth, I believe them. We have looked into other systems, but they require calibration based on stadiums, which we don't want.
MB: Why is calibration that bad?
GN: Well we have 1300 contests a year, we have a few games that are played in non-traditional hockey rinks like the outdoor classics. Even if it takes 10 minuets to calibrate, that just adds to what we are already doing. We don't need a longer process than we already have.
MB: Thanks for the information. So let me tell you what my team has been working on here at Berkeley. We have started with concussions sensors in helmets, but are looking to incorporate sensors into more equipment for skill development, player selections, player safety, officiating and fan experience. We are exploring many options, what are your thoughts on wifi solutions and wired solutions.
GN: There are some issues regarding wifi solutions. There will be many people trying to get onto the network could slow it down. People who can use their phone as personal hotspots could interfere with the network as well. All of those together could bring your wifi network to its knees.

Vendors are not fans of wifi network. If it messes with their point of sale system, the fans cannot get served what they want, making the overall experience that much worse. Each venue would need 300 access points, which could cost each venue at least 2 million dollars. In some markets with higher labor costs, like New York City it could be 5 million dollars. It would be much easier for outdoor games rather than indoor games. The other issue is by the time you change the stadiums to fit the new wifi solutions and build into them, the system would be obsolete.

The MLB has had some success with wifi in their stadiums. The difference is that they have 2 times as many events per venue than we have.
MB: What about other solutions?
GN: I don't think concussion data needs to be real-time for the NHL. We are all right with getting the data after the game. Something like RFID tags or infrared tracking could work without needing that infrastructure. There could be use for positional data to be real-time. This could include ice time (how long someone has been playing in a given a game), and distance traveled. These could be very useful for coaches and players alike.

Experienced Sports Trainer

March 11, 2014

(Note: Interviewee's name has been redacted at the request of the interviewee)

Mark Brazinski: Thanks for meeting with me. I am working on a graduate capstone project on sensors in sports. It is our hope we can design a system that is easy to use that can help with player safety. We are currently trying to put chips into helmets to track how hard people are getting hit on the field. Let's start out by having you give some insight of your work experience.

Experienced Sports Trainer: Yes, I have worked in the field for some time now. I have a master's degree, and I have worked a 6 different teams and institutions.

MB: Among those teams/institutions, how many would you say you were understaffed for?

EST: Every single one. I am working at a "prestigious" university now, but it's still two trainers and a handful of student interns for over 100 players.

MB: What can you tell me about concussions and do you have any experience with sensors in helmets to help diagnose concussions?

EST: When it comes to concussions, there are always the big hits that can cause them, but they can also be caused when a player repeatedly gets hit over and over hat can cause them.

I worked for a small school in Georgia, and we used a company called "Hot Heads". They originally put temperature gauges into helmets to monitor if people will overheat in the Georgia sun. As an experiment one year they put 15 sensors in our player's helmets for practice and one game. I could get the results to a PDA when anything triggered. It was good but it was flawed.

Also, we as trainers cannot "diagnose" concussions. We do not have medical credentials for that. We can only report concussion like symptoms.

MB: What flaws are you referring to?

EST: The company had a preset threshold of G's for players could take before it would go off. How do they know what the threshold should be? Is it from the player's medical history? A scientific study? Prior concussion data? We had one player, our star defensive lineman (DL) that would lead with his head every play. The PDA went off

every single play, and I would need to physically put him through some tests after every drill he did in practice. He never showed concussion like symptoms, so that threshold was wrong.

Hot Heads also took the PDA away from us during game time. We used it in practice, but they had it on the sideline come game day. That was no use to us then.

MB: How would you improve those systems?

EST: I am not sure how you would do this, but I would find a way to find better thresholds. I would make them customized for certain players and maybe certain hits. I think my experience shows the industry is in the right direction, but it needs to have better metrics and better thresholds.

If you could make the thresholds right, whenever it gets passed, that player gets immediately pulled off the field. I would then have the trainer perform a test on the sideline to see if they have concussion like symptoms. I would then comply with NCAA regulations which stipulate that anyone that shows concussion like symptoms cannot return to play.

MB: What kinds of protocols are there to protect players on the field? If this sensor data works, is there something already in place to help them?

EST: Sure, it all depends on the level you are talking about. The NFL has a plan where the referees are supposed to remove any player that looks like they have concussion like symptoms. They are making people with absolutely no medical experience try to apply what they think could be an injury on top of their already big job.

MB: Looking at your experience at your other institutions, if sensors were introduced into their regular practices and games do you think you would have been met with resistance?

EST: It all depends on the coaches and environment. I have worked at 6 places and I think at some point all 6 would have provided some kind of resistance. That resistance comes in many forms. The most obvious is if we had to pull a superstar athlete at a crucial moment because we assess that he has concussion like symptoms even though the player says he feels fine. Another issue could be because sensors are not cheap. Not to mention there are some teams, like the University of Oregon, that may have 7

helmets per player. That means the team has to either keep changing the sensors between helmets or they would need to buy 700 sensors.

MB: Is there anything else you think I should know about these concussions sensors?

EST: Yes, remember that trainers can only assess concussion like symptoms, and only doctors can diagnose concussions. Well, that's only half-true, it actually depends on what the state legislature says. But for most states, doctors or someone with credentials can diagnose concussions. So it's whoever can comply with the state regulation.

MB: You talk about credentials to diagnose concussions and assess concussion like symptoms. It is my vision to use this system for something like Pop Warner or Pee Wee football. In some of these organizations they use whoever they can to be on their staff, anyone with a medical degree. How had could it be for one of them to get those credentials?

EST: It's a hard question. Any medical professional could assess concussion like symptoms. But in the medical field if you do something out of your scope as a professional, you could get sued for infringe on someone else's license. You would get sued because you are taking away someone's business.

There is currently no good way to get a credential easily. Maybe you could develop your own online course but it would need to get passed by a medical association.

MB: What associations are you referring to? What kind of resistance do you think they would give to that?

EST: The associations are like the American Medical Association, National Athletic Trainers Association, and the American Physical Therapist Association. There is a process to make a credential, and if you fulfill it, I bet they would be fully behind you.

MB: Thanks for your time. Your insights have been very valuable to my project and my research.

EST: You're welcome. Good luck.

Pop Warner Media Relations

March 12, 2014

(Prior to this phone call, I called the Pop Warner offices and left a message with a secretary. In this call, my phone avoided a secretary and went straight to the media relations department)

Mark Brazinski: Hey there, my name is Mark Brazinski, and I am a graduate student at the University of California-Berkeley and I was hoping to talk to [the commissioner of Pop Warner] Sam Mutz.

Pop Warner Media Relations: What is this regarding?

MB: I was hoping I could talk to the commissioner about my graduate research.

PWMR: What are you studying?

MB: I study information management systems at Berkeley. My research is in sensory data in sports.

PWMR: The commissioner is currently unavailable. I am in the media relations department. I can help you out. When you say sensors in sports, you mean helmet sensors right?

MB: Among other things, shoulder pads, shoes anything that can be tracked.

PWMR: We refuse to make any comments on helmet sensors and concussions for Pop Warner.

MB: Even for research purposes on protocols and how your organization is run? That is more of what I am looking for.

PWMR: We refuse to make any comments on helmet sensors and concussions for Pop Warner.

MB: Well if you cannot comment on helmet sensors and concussions, I was hoping I could talk to you about other things regarding Pop Warner. I am an alumnus of Pop Warner and my playing career extended all the way through college. I was hoping I could ask you about your protocols about medical personnel selection. I understand in some places it may be hard to find volunteers. What are the credentials that Pop Warner uses when selecting medical personnel?

PWMR: Ask someone from the National Trainers association that question.

MB: If you are ever able to make a comment or would like to talk to me further about your protocols, please take my information and give me a call.

PWMR: Sure.

Billy Beane

April 2, 2014

Billy Beane is the current general manager of the Oakland A's, and the subject of the best selling novel and film "Money Ball".

Mark Brazinski: Hey there, my name is Mark Brazinski, and I am a graduate student and offensive lineman at the University of California-Berkeley. Thank you for taking the time to interview for my master's thesis. I am working on sensor data that can be applied to metric driven sports analytics. I was hoping you could start off by telling me about the process about getting in started using metrics and statistics, something I know you helped pioneer in baseball.

Billy Beane: In the beginning we only had public information and things that could be seen by the naked eye. This was before the rise of computers and before silicon hit the apex that it sits at currently. We took this public information and crunched it using paper and pencil. It was a much different time back then. We had to work with what we had, and make rational decisions based on the statistics that we thought correlated someway to winning. Even you called me a pioneer, but it was guys like Bill James [Note: famous baseball statistician and author] who were the true pioneer of these metrics. We were the best team to use metrics and analysis because we had to just to be competitive.

Mark Brazinski: Why would you say you were the best ones to do something like this?

Billy Beane: As a team we have one of the smallest revenue bases in our league. If we went by convention our record of wins and losses would reflect that. We could not do what those teams with tremendous revenues do. Our business plan was simple:

A) We seek out skills we think are undervalued and add them to our roster at price we can afford.

B) We sell skills that we think are overvalued so we can use those resources to gain those undervalued.

Now these metrics are completely different, everything is done on the computer and algorithms.

Mark Brazinski: Can you go into that some more. What was it like converting from pen and paper to computer? What kinds of growing pains did you have?

Billy Beane: Sure, we have gotten to the point where we can collect and understand every movement that occurs on a diamond. Every recorded movement is a data point, but there are some tradeoffs with collecting data. Data can be very expensive, and if not understood correctly can show something that is completely wrong. There is a question of how much is a club willing to spend on data and metrics to field the best 25 man roster they can.

Another issue about these computer-processed metrics is that subjectivity always taints the data. This taint can go in both directions. We can sign a player we love despite our metrics and it can hurt us. You cannot account for things like being a great leader or having an attitude problem.

Mark Brazinski: Converting to computer you must have had some growing pains. In my experience programmers rarely get the entire full product done on the first try, there is always an iterative process. Did you ever get “it wrong”?

Billy Beane: You can never say you “got it wrong”, it just may not always be as right. What you said is correct, it took a couple tries to get an algorithm that really fit what we wanted. Everything is process driven through the data collection. Even when it doesn’t work as right in the beginning, we continue the research and continue to work with it until we do. we try to find what we don’t account for and make fix that in the next iteration.

One case that was always interesting that took us a few tries was how to evaluate a relief pitcher. There was so much volatility, and no matter how many times the process got adjusted, nothing could stop that volatility year over year. A reliever only maybe pitches 50-60 innings a year. We came to realize that simply isn’t a big enough sample size to find meaningful data. We also could never account for something like age year over year.

Mark Brazinski: I have a question for you about collective bargaining and wearable sensors. I have talked with other league officials and they felt they could not implement any wearable technologies without collective bargaining. My other interviewees felt that most players associations would be resistant to include these things. What is your view both as a former player and current GM?

Billy Beane: That's an interesting question, and I have never been asked something like that before. The union exists to protect its members and to pursue things that are in its member's best interests. It is hard for me to comment on exactly what they would want when looking to negotiate in these new contracts.
Something that is important in any system, both wearable's for the players and our algorithms for selection, you never really know what will happen with data and processes until after you get the data. I can understand how a union could be weary of wearables because of the uncertainty of what could come. It could be completely outside of their member's interests.

Mark Brazinski: In my master's studies in sensors I believe that sensors could affect player selection, skill development, officiating, player safety and fan experience. I want to ask you about fan experience. I believe that by adding sensors fans could continually follow individual players on the field. Then clubs could track which fans are subscribing to which players, to help in their marketing plans for season ticket holders.
Billy Beane: Its very similar to before with the union. You never really know what this data for the fan experience could really do until you start collecting it and using it in real life. I think your plan is something that could work for soccer, basketball or football, but in baseball there is not much to follow. Any fan at the game or on TV following the ball will get everything they need. There is some limitations based on the game itself.
As for marketing, I take my job in marketing very seriously. I believe my role in marketing is to put together the best team I can for the fans.
Mark Brazinski: My work deals with contact sports. One project I have is looking to see if we can make metrics for offensive lineman and force outputs for evaluation. What challenges did you face using new metrics in sports that you could pass on to me?
Billy Beane: There is always resistance whenever something changes in any well-established business. The major thing you have is a background. There is a huge demand for big data in sports, but very few people who can do it. Having a former athlete who can process the data and understand what it is like to be a player really helps. It helps when you have that credibility with the people on the data collection end, and those who implement it (coaching).

Mark Brazinski: Thanks for your time, I will be at the game on May 9th when you crush the Nationals.

Billy Beane: I am always glad to help students. Good luck with the rest of your project.

Juliene Simpson

April 9 2014

Juliene Simpson is the athletic director at Saint Elizabeth's College in Morristown, NJ. Saint Elizabeth's College is an all-women's liberal arts school that is classified as a division III athletic program according to the National Collegiate Athletic Association. Division III is the lowest level of college athletics, it is the most underfunded and unlike division I, they cannot give out athletic scholarships.

Mark Brazinski: Thanks for taking the time to take my call. Before I begin, I was just hoping you could give me some of your background as a player, coach and administrator.

Juliene Simpson: Sure, I played in high school, I won 2 national championships in college, I was a 4 time all American in college as well. I played on 11 international teams including the 1976 USA Olympic team where I was a co-captain an won a silver medal. I coached for 25 years in the division I level. I also coached junior college, NAIA (alterative league to NCAA) and division II. I was an associate athletic director (AD) for 3 years and currently I have been an athletic director for the last 5 years.

MB: Wow that is quite the resume. Spectacular really. I am studying sensors in sports, and I feel that it could have an effect on 5 main areas. The first of the five is fan experience. Giving the fans the ability to follow their favorite players in real time. What sort of implications could this have for the division III level?

JS: I don't really know if there would be any real interest in something like that for the division III level. Even the top division III teams may not be interested in something like that at all.

There has been a big movement in division III to really focus on academics. Unlike division I and division II there are no athletic scholarships, and our athletic departments do not have the kind of funding that those bigger schools would have. One thing that makes division III awesome as well is that there is a huge diversity in programs. Some conferences and schools have football, some do not. Some conferences are incredibly strong at every sport and some conferences cannot compete. The schools are the same. Schools like University of Mount Union and the University of Wisconsin-

Whitewater could even compete with the biggest division I football programs. Those schools are comprised of division I transfers. So there may be some schools that would want this fan experience in sensors, but not many.

MB: The next facet that sensors could make a difference in a game is within the officiating. Finding ways to input sensors either into game implements or onto things like pylons on the field could give referees immediate responses if something is out of bounds among other things. How do referee hiring work at your level? Who would end up covering these costs? Would there be use of this at division III

JS: Again there is so much diversity at this level, and it differs at the conference level. The better-funded conferences have their own full time officials that can be assigned to every single one of their games. For Saint Elizabeth's College we use different organizations that offer officiating for our games. We use our conference, the Eastern College Athletic Conference, for basketball but will hire someone from the New Jersey Association of Intercollegiate Athletics of Women for softball. We would go to different organizations for every sport. I do not see much of a need for this at the division III level because of how many different organizations we need to deal with. We also just do not have the funds for many things like this, maybe the top half percent with huge boosters that could afford that.

MB: The next facet that we're investigating is how sensors could affect player skill development. This could be anything from force production in shoulder pads to putting sensors into basketballs to study how your new freshman's arc on the ball compares to your veterans. Do you think there would be a use for something like that on the division III level?

JS: Division III has different rules for offseason work than division I and division II. You cannot coach a student athlete when they are not in season. For instance, players can only be coached for basketball from October 13th until the end of season, compared to division I, which basically works year round. Having something that can track players for their own workouts could be useful for this level. Everything is based on costs though. When it comes to division III we get many things subsidized from the NCAA. We have a game tape exchange where we take our team's games, and send it to every other school in the conference. That costs us 500 dollars. The NCAA gives the conference

250 dollars per school which then trickles down to each of us. We also get subsidized for medical software. The only real way I could see division III getting these things is if it somehow gets subsidized by the NCAA.

MB: The next area that sensors could impact is something like player selection. Having players use wearable technologies to see how your players interact among each other. It could help formulate game plans, and impact how you work with players.

JS: I cannot see much use for something like this below the division I level, maybe more in the professional level. I do not think we at Saint Elizabeth's College could use something like that. Maybe the top half percent of division III schools with high level football teams could use sensors. They may be the only ones with the boosters to do that. The level of talent at this level is so low, so it would not matter that much anyway.

MB: What about something like putting sensors into protective equipment to see if the hits sustained could cause something like a concussion. It could help with understaffed medical personnel, and could bring better real time data for the school.

JS: The biggest thing I have learned is that we live in America. Someone always wants to sue. I think many athletic directors would not adopt this willingly because of the liability that could come from a messed up sensor or if the sensors gets a bad reading. I think the only way it gets adopted is if medical professionals endorse it and it is made into legislation from the NCAA.

MB: Last question, how much does division III feel the effects of things adopted from division I level, either by choice or by legislation?

JS: We would almost never adopt anything by choice because we do not have the money. We have more allotted time to comply with rules than division I. For instance when the NCAA legislated that an arc must be placed inside the paint in basketball, the division I schools had to comply that year, division II had another year to get that done and we had 3 years to do that. This is mostly based on budgets.

Professional Offensive Lineman

April 9 2014

(Note: Interviewee's name has been redacted at the request of the interviewee)

Mark Brazinski: Thanks for taking the time to talk to me about my master's work. Before we begin could you please tell me about your background as a football player.

POL: I was an all Pacific 12 conference player, and I am currently playing for the Cleveland Browns. I was a second round draft pick to the browns. I have earned many more accolades, but I don't have the time to list them.

MB: I am working on a study of sensors in sports. I wanted to ask about your thoughts on some of the prototypes we are working on. The first one is a pair of shoulder pads that can study force and force outputs. It is most useful for understanding who could pair well with certain players for things like combo blocks. An example could be if the Browns needed a new guard next to you, they could study them at their workouts to see who could pair well for your double teams.

POL: I'm not sure how you can quantify that, and how important that really is. The problem is that in terms of the things that are valued in linemen that's so far down the list. If you can't block Geno Atkins by yourself on 3rd and 12, it doesn't matter that your combo blocks are great. A big part of double team fits is getting used to each other and knowing where he's going to be and where your fit is and you can't just work a guy out and get raw data to figure out who's more powerful, because that might not translate One other important point is that when you have a workout you are not going to have Joe Thomas (All pro player with 84 million dollar contract) to come out and do some backside combo blocks.

MB: One of the other things we are looking into are helmet sensors to see how hard players have gotten hit. This could give real time data to help diagnose those hits to see if they could have gotten a concussion. I know this would be relevant on the high school and sub high school level because most training and medical personnel are understaffed, what do you think about the uses on the professional level?

POL: I am worried that you would then risk taking guys out of practices and games just to give them preemptory X-rays based on how hard they're hit. That's something that could get bad very quickly and as a player I want to be on the field.

As players we really do not worry much about getting concussions. We do not really talk about it much in the locker room. I know there are some long-term effects, but honestly it's really a not that relevant. I think more players would be worried about missing time on the field.

MB: one of the last things we are looking at are sensors in pants. The pants would have prefabricated pads with a CPU in butt pad. That CPU would be attached via wire to each and every pad in the pants. The second a player goes down, you could pull the CPU out an immediately plug it into an iPhone or other handheld device. There could be a readout that says where they got hit, how hard they got hit, what angle they sustained the injury and could provide the most likely injury. This is meant to make a faster diagnosis for the doctors. Broken bones diagnosed and wrapped within 45 minutes of occurrence can make recovery 3-4 weeks faster. As a player do you think this would have value for you or your teammates?

POL: That is something interesting I have never thought of before. I understand that need for a fast diagnosis, but like the helmets its something I wouldn't want to be pulled off the field all of the time to test. If it were just in case someone goes down (injured so bad they need assistance to get off the field) then that makes sense. I am not sure how you'd know if a guy has a break that isn't readily known by the player. These are professional athletes, finely tuned to understand their own bodies. If it helps the doctors I think that's cool, but most players know what gets hurt when it happens because of how in tune they are with their bodies. I'm also thinking hairline fractures, but you can't tell without the X-ray and then you're basing it not off what a guy says but force readings. I think using both could be helpful, but I would question a reading if I didn't feel it.

MB: So I have a few more questions about other things sensors can read that may be useful for professional athletes. The first one is positioning on the field and how far people have moved. It can be used to ensure people like receivers only run a certain distance. It can help with recovery as well. Would that be helpful for you and your teammates?

POL: They did that for us last year. It really translated to success.

MB: Is that sarcasm?

POL: Yes, yes it was. We went 4 wins 12 losses last year, which is not good at all. We wore heart rate trackers and GPS systems all year. I felt that it didn't do anything. I think collecting most data is useful. It just is not applicable until you get that same data for games.

We hired 4 people to be our data scientists. I did not see them do anything for us at all. I think they were just paid to collect the data, but I did not see them process it. Despite collecting the data they [coaches and administration] didn't change practices. They didn't limit reps for overworked guys except for like one practice in camp in which one guy got 10 reps off of team. That guy was a 3rd year player who otherwise didn't have the years or skill to warrant getting those plays off. I just don't think they did anything with the data at all.

MB: Thanks for taking the time to talk to me. Good luck this year.

Kevin Weiberg

April 17, 2014

Kevin Weiberg is the Chief Operating Officer for the Pacific 12 conference. Henceforth known as the “Pac 12”. The Pac 12 is one of the biggest division I conferences, with one of the biggest television contracts in history. The Pac 12 conisists of schools like Stanford University, the University of California-Berkeley and the University of Utah. Weiberg is the first of series of three interviews with Pac 12 executives.

Mark Brazinski: Thanks Kevin for taking the time to talk to me about my master’s thesis. My project is in sensors in sports. There are five major use cases that I am studying: Player safety, skill development, player selection, officiating and fan experience. Before I begin, I was just hoping you could tell me about what conferences do and a little bit about your background in sports administration.

Kevin Weiberg: Not a problem, we love to help students when we can. Prior to coming to the Pac 12 I was the commissioner (highest position) at the Big XII conference (another top 5 conference in terms of revenue). After that I worked as the CEO of a start up, then I got hired by the new commissioner of the Pac 12 to help with their new television contract. The Pac 12 has its own television network, with a 3 billion dollar contract over 12 years for football broadcasts alone.

The conference works to organize its members for sporting competitions. We can negotiate media deals, we have our own referee systems, and we can make rules for things like academics, travel and funds that may be above the NCAA legislation.

MB: Awesome. I would like to get started on the use cases. I’d like to start with player safety. Player safety begins with helmet sensors among other sensors in sports equipment. What has the Pac 12 done for this in the past? What are you looking for in the future for player safety?

KW: The Pac 12 takes player safety with the highest regard. As a conference we have set aside 3.5 million dollars for research projects for head trauma.

This would include things like sensors, collision data, and things like that. The funding is to be determined. I know that when you talk with Woodie Dixon, (Pac 12 general counsel, one of the next interviews) he will have more information on that for you. When

it comes to health and safety, I can see some serious changes within the next 3 years for sensors.

This last year we got permission from the NCAA to test shoulder pad sensors for medicinal purposes. It could have some implications to see how players recover after surgery. The issue that came from this is that our vendor messed up and did not deliver on their promise to provide our sensors. The vendor was Sport Vision Inc., I believe they may be bankrupt now. Many companies will reach out directly to institutions on their own. When it comes to the individual schools, we as a conference act as a conduit for companies to meet equipment management.

MB: That is interesting. The next area that sensors could impact is in fan experience. This could mean tracking certain players for fans. It could help with marketing, and could help with fan engagement by studying the data and using certain players in promotions and what not. What is the Pac 12 looking into for something like fan experience?

KW: We are among one of the best conferences when it comes to media, so you know that we are always on top of our fan experience. Danette Leighton (the chief marketing officer and one of the next interviews) has more expertise in this than I do. I know that when it comes to fan experience Fox Sports can show peoples movements in space. They can track athletes and get data for things like kick return speeds. They currently do it all by camera. Each stadium is unique when they get set up for those cameras and that system. The biggest issue for fan experience comes from getting 70,000 fans connection to the Internet. Applications do not matter if the fans cannot even sign on to the web.

MB: The next use case for sensors deal with officiating and officiating crews. Tracking the officials and putting sensors into equipment to help the officials get better calls in real time. What has the Pac 12 done for officials to help them and their calls?

KW: The future to help these officials will be within 4 years. We have a state of the art command center that we use for real time evaluation. Prior to that, everything would be done after the fact or on someone's DVR. We had issues even finding all of the games on television at that time. For basketball we electronically grade officials after the game. We cover things like whether the official had a good call, bad call or no call at all. We

are interested in tracking the officials' movement, so we can coach them up later where they are standing to ensure they make good calls.

Sensors are being used to help with game filming. There is a company that uses sensors to help with clock management. It helps when a ball just hit the line before the whistle gets blown.

The biggest issue with football is with instant replay. The hardest thing could be putting sensors into the pylon or end zone. If anyone could figure that out that would be a huge deal.

MB: That is interesting. My last questions concern player selection and skill development. What does the Pac 12 do for those things?

KW: The Pac 12 does not put together individual teams. We would overlook those things for teams, but unless high school players wear it and send the data. At the conference level there is nothing much we can do for those.

Woodie Dixon

April 17, 2014

Woodie Dixon is the General Counsel and the Senior Vice President of Business Affairs of the Pacific 12 conference (Henceforth known as the “Pac 12”. The Pac 12 is one of the biggest division I conferences, with one of the biggest television contracts in history. The Pac 12 consists of schools like Stanford University, the University of California-Berkeley and the University of Utah. Dixon is the second of the three interviews that occurred with Pac 12 executives.

Mark Brazinski: Thanks Woodie for taking the time to talk to me about my master’s thesis. My project is in sensors in sports. There are five major use cases that I am studying: Player safety, skill development, player selection, officiating and fan experience. From my discussion with Kevin [Weiberg] I understand that your area of expertise is within safety and officiating. Can you tell me about background?

Woodie Dixon: Its great to work with students, I was a student for too long. I got my law degree from Harvard Law School, followed by getting my masters in business administration from the University of Massachusetts. I took me way too long to pay off those student loans.

MB: I would like to start talking the first use case, player safety. Kevin [Weiberg] told me that you already had done some work with sensors in pads that did not work out to well. I am also interested in what other steps the Pac 12 is taking for the betterment of player safety.

WD: The company that we were going to use did not deliver the sensors, and after the fact we learned that they were not as robust as we thought. It was supposed to be for shoulder pads. These pads would be used to compare athletes before the injury and post injury. It could tell if the players were running slower after recovery or if they at the same level prior to injury.

I know that a couple teams used some shoulder pad sensors in their own practices. I know Stanford University used some version of the sensors, as did the University of Oregon.

I know there is a company that uses some 3D technologies in shoulder pads. It has something like 5000 total data points per person.

MB: What other things are you doing for player safety? Besides your use of shoulder pads have you looked into helmet sensors?

WD: Oh yes, we have set aside a fund for 3.5 million dollars for research into head trauma. That money is set-aside for this year; we are hoping to get that money every year for continued research. There will be a committee panel review board that will review each proposal. These proposals can come from schools and third parties. If a third party were to get some funds it will have to be for a conference wide system or one for every school. Obviously the schools could get money for research for their own schools. These funds are not just for football, but for every sport that the Pac 12 competes in. It will be an interesting balancing act between practitioners, researchers and third parties.

MB: How does what the Pac 12 does reflect what is going on the national level with the NCAA?

WD: Recently the NCAA appointed a Chief Medical Officer to show that they are looking to deal with this big issue. It is hard to do something on the national level because of government legislation like HIPPA (the Health Insurance Protection and Portability Act of 1996). On the national level the NCAA would ideally like to have one huge database that could data. I am talking about things like recovery times, and injuries. So if someone at like the University of Tennessee had a certain injury, the people at Cal[ifornia-Berkeley] could compare a recently injured player to the recovery of the Tennessee player.

MB: What legal issues could you see with a system like this? What other issues about data integrity could you see with something like that?

WD: To make sure that everything complied with HIPPA, most of the personal data would have to be scrubbed so there was nothing that could show who is whom. I would also worry about data from smaller, understaffed schools. If those benchmarks were off, it could affect others using the database.

To get this database built, we would need to have some high-end studies conducted on players and their health. The main issue with anything medical is to get the clearance to do it. You would need more forms and signatures from each student athlete involved.

The NCAA is very receptive to using sensors in sports. Usually it takes 1-3 years for them to change rules, but for sensors they made an exception. We were able to start using sensors now before any legislation. The NCAA is very open to using devices for safety.

MB: That's great information, thanks. What can the Pac 12 do with officiating and officials? What value can sensors add to officiating and officials?

WD: The way we look at officials in football is changing from the traditional views of officiating. The South Eastern Conference (a top 5 collegiate conference in terms of revenue) is starting to use wireless headsets and microphones in their stadiums. The Big XII Conference (another top 5 collegiate conference in terms of revenue) is starting to use an 8th official to get a better view of everything on the field. I think that there are some great uses for tracking where the officials are moving. It could help break down their movements to teach best practices.

I think that add sensors into the ball or pylons is great idea, but so very hard to implement. Games are won based on inches, and men running out with sticks attached by chains determine games. There has to be a better system than that. You watch teams like Cal-Berkeley and the University of Oregon run high-tempo no huddle offenses (teams that run a play every 12 seconds) and the referees are 15 yards behind the ball as the offense lines up for the next play. You watch the chains (the people who mark the distance to a first down) and they are basically guessing where they should put it down. Finding a way to track where the ball should go would be great for the game. It would be hard to make because many times players will stretch their arms out after being tackled. How would something like that be calibrated to counteract that?

MB: I have one last question for you and your expertise. In my discussion with some other sources, many seem to worry about liability by having some of this data. Who holds the liability with sensor data, and what could be in store for data like this?

WD: This is the question of the day. It is a very old fashioned thought to think that by having this data on hand it could hinder them, so it is best not collect anything. It is hard to tell what will happen with that data in the future because there is no specific precedent for it.

My view on it is that sensors are hitting a point that the automobile industry hit a while ago. They asked themselves if it was in their best interest to collect data on their crashes and failures or would it be too much liability. The industry collects the data and now tailors their products to be safer and more efficient. They also know when to make a recall to protect their customers. I think that sensor data, especially head trauma could become something like that because it can create preventative measures for long term health.

MB: Thanks so much for your time. This was a great interview that added great points to my research.

Danette Leighton

April 17, 2014

Danette Leighton is the Chief Marketing Officer for the Pacific 12 conference. Henceforth known as the “Pac 12”. The Pac 12 is one of the biggest division I conferences, with one of the biggest television contracts in history. The Pac 12 conisists of schools like Stanford University, the University of California-Berkeley and the University of Utah. She is the third and final interview of Pac 12 executives for the project.

Mark Brazinski: Thanks for taking the time to talk to me about my master’s thesis project and capstone. My project is in sensors in sports. There are five major use cases that I am studying: Player safety, skill development, player selection, officiating and fan experience. From my discussion with Kevin [Weiberg] I understand that your area of expertise is in fan experience. Can we start out by giving me some context about marketing in sports?

Danette Leighton: It is my pleasure to help anyway I can. Everything is about data and what data you can gather. It’s also about where the data lives. There is no true data warehouse, and there has to be solutions to fit all the data. There is data from the merchants, player statistics, sales of tickets and individual consumers data. There is nothing that contains all of this data. One big question is who owns that data. Here at the Pac 12 we believe that the institutions own the data taken on its campus.

MB: That is very interesting. Can you tell me about how censors would work with fan experience? I could see it being used for marketing purposes to appeal to season ticket holders. I could see fans following individual players on a play-by-play basis and for help people in the stadium in their experience.

DL: When we talk about data from sensors we need to think about the path that the data will go down. That data needs to go from the sensors to a server to hold the data. That collected data needs to be scrubbed and repurposed so it can be spit back out to the fans that way.

When it comes to fan experience, it is not longer about having one cool idea and running with it. One can collect so much data that it can steer how you market things

these days. Its not just about the simple numbers, there are psychographic and behavior data that marketers need to understand. These psychographic and behavior data complements the standard user data of age, gender, and residency. The psychographic and behavior data helps you understand your fans. You can have the best data in the world, but if you do not know what delights your fans it will not matter.

MB: Can you elaborate more into the fans and what you think would get done with sensors?

DL: Yeah one of the big things we look at for marketers are what we call “behind the red ropes”, to get an inside look at what the team is up to. These are the people that want to be in “the know”, be the insider and the “big man on campus” for knowing more about the team than any other fan.

When looking at fan experience in sensors, and fan experience in general, there are many subgroups to consider. Many are split up by age. The young generations need to be connected at all times. If they cannot post to Instragram or to twitter they are not happy. Older generations may want to vote on what song gets played next at the stadium either by the DJ or by the school band. There is a constant battle for the fan experience to find a way to make going to the game more enjoyable than watching it at home.

MB: Are any teams using sensors yet? How effective is it?

DL: Currently we have one school going through a pilot program to sensors in their pads to enhance the game experience. It can provide data to the fans in real time to the games. This is part of a big project for the entire fan experience. We are increasing connectivity for the younger generations. We are using a better CRM technology and data warehouse for all of the fans as well. We are using this one school in particular because it was one of the few that fulfilled the strict parameters we needed for this project.

MB: When trying to implement technological changes, what issues have you met with before? When you look at adoption where would you say is the biggest issue in the standard adoption graph?

DL: Everything is about the people. I have seen some of the best technologies fall by the wayside and some lesser ones get fully adopted. When I say it is about the people,

it means that there needs to be processes in place to help them adopt and accept this technology. 99% of what we call “shiny metal objects” that can help the game just sit there and do nothing. There were no processes in place to get these things adopted. The reason the people are the ones we worry about adopting technology is because there are so many different groups that would need to be taught how to use it. These groups would include people like the merchants who sell t-shirts, vendors who sell drinks and ushers who bring people to their seats. Every single one of these groups would need to be on boarded.

MB: Thanks for taking the time to answer my questions. This has been tremendous for my research.

DL: It was no problem, and I was glad to help. Good luck with the rest of your project.

Schutt Helmet Salesman

One of our interviewers ran into a Schutt salesman in the locker room at California Memorial Stadium in Berkeley, California. The following was a short interview discussing the helmet market.

Mark Brazinski: Hey, I have a few questions for my graduate capstone project. I just wanted to ask you a couple of questions. First, what is your market share across all levels of football?

Schutt Helmet Salesman: We are just under 55% of the total market. It varies based on league and level of play.

MB: Where is the greatest fluctuation in market share?

SHS: Riddell (Schutts main competitor) paid to be the official helmet sponsor of NFL. That being said, we have a 36% share in the NFL market which is significant. That number is impressive because every Schutt helmet worn on the field was bought by the player when they had the option to get a free Riddell helmet.

MB: I know Riddell makes a helmet sensor, do you guys do as well.

SHS: I believe we may be working on one, but there are none currently available.

Sandy Barbour

Sandy Barbour is the athletic director at the University of California-Berkeley ("Cal"). Cal is a division I school, meaning it competes at the highest collegiate level. Division I programs can provide full athletic scholarships and aid to its athletes.

Mark Brazinski: I want to thank you for taking the time to talk to me. I am doing a project for my master's thesis on sensors in sports. I believe there are five use cases for sensors: skill development, safety, fan experience, player selection and officiating. I know we have a limited time, so I would like to begin with safety. What have you and Cal done for player safety with helmet sensors? What is your view on liability from collecting that data?

Sandy Barbour: I think some cases overlap, like when we put GPS sensors into practice equipment. I know that that Pac 12 is very interested in sensors. The Pac 12 can use its influence to change some rules and regulations to make games safer for student athletes. These rule changes could be something like changing the amount of days a team could wear shoulder pads during training camp, hours between practices and on field rules.

I have no concerns when it comes to data collection/research when it comes to equipment or practices. We have a constant dialogue with legal counsel all of the time; we are not worried about lawsuits from this work. As you probably learned in your research, there is a large sum of money for research from the conference. We have people on each committee, as far as I am concerned that money belongs to us. We need to do things that are based in science, not just what seemed to work in the past. This also includes what will happen with sensors.

As far as Cal is concerned we have put an emphasis on better equipping our coaches and staff with medical background. By placing AED's in our stadium and gym we saved 2 faculty members lives.

MB: The next area I would like to discuss is fan experience at games. I am interested in how you are going to connect the fans, what implications you think the sensors could have to engage the fans from everything from voting on songs to following real time stats from the chips themselves?

SB: We will need to incorporate stronger wifi into the stadium to connect all of the fans. I think there is a value to show fans stats beyond yards and completions. I think we are a data starved society. We want it all, and our fans would like as much as we can produce. There are many uses for cameras as well for new angles and views.
We have a deal for something between 4-5 million dollars with AT&T to add connectivity in our stadium. We need to give our fans the ability to get on Facebook and Twitter to make them happy. Fan participation is of the utmost importance.
We look forward to allowing our fans to order merchandise and food right from their seat in the stadium.
MB: The last area I would like to talk to you about is skill development. What implications could you see for skill development with sensors? I also wonder how sensor data would be used in daily workouts.
SB: The challenge for this level is how to use the limited amount of hours in a day effectively. There is video review, weights, practice, and school. How will you use it all? It is also an interesting comparison on how it can be used. Is it all after the fact or will it be used on the field.
Some of our smaller teams have really utilized our GPS technologies well. Teams like men and women's soccer and field hockey have used the data to work on their practice intensity. It can help show that they just had a hard day to make the next one a little lighter. It can also be used to show which players may need an extra push in practice. Again, there are few hours in the day, so the amount of crunching of the data is very limited.

Appendix 2: About Us

Lord Mark Brazinski was fifed his land from Wesleyan Manor in Cumbria, UK in 2010. Originally hailing from Basking Ridge, NJ, Brazinski was an academic all-Pacific 12 Conference offensive lineman for UC Berkeley, a semi-finalist for the William V Campbell Award (often considered the “academic Heisman”) while completing his majors in business administration and media studies in 3 years time. He finished his eligibility while pursuing his master’s in information management systems. Brazinski’s role in the Spintel project included product design, UX design, qualitative research, and business models. He is an avid fan of burritos, bowling, and weight lifting.

A web guru and entrepreneur, Peter Nguyen is a blogosphere celebrity who has extensive experience in developing web 2.0 platforms, motion graphic effects, film production, and print media. From the age of nine, when he first started programming, Peter has dreamt of making a difference in the world through these mediums. Nguyen has traveled to Gansu and Vietnam to develop web technology to help build the nonprofit sector. He is a true global citizen with a heart for service and a passion for creating compelling media. Peter’s focus at Spintel is to create a robust architectural and technical framework for studying sensors in sports. This involves prototyping, ui /ux design, database architecture, web integration, and feature implementation.

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