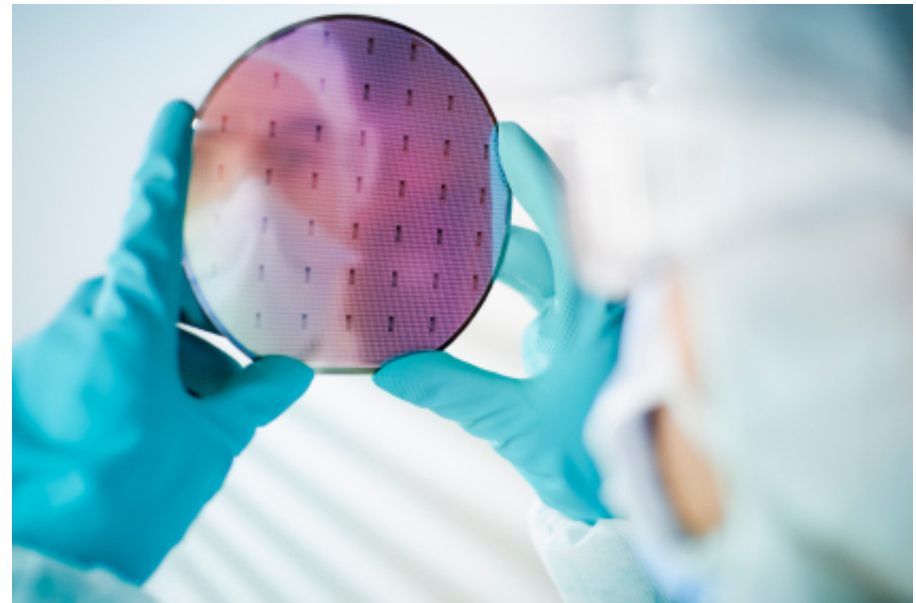


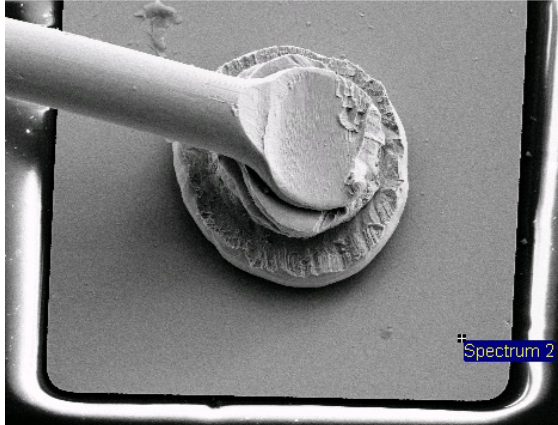


BIOMEMS 2013: The Revolutionary Change in Sports from MEMS and Sensor Enabled Products

David DiPaola, Managing Director

www.dceams.com





Who are we?

Problem Solving Based Company

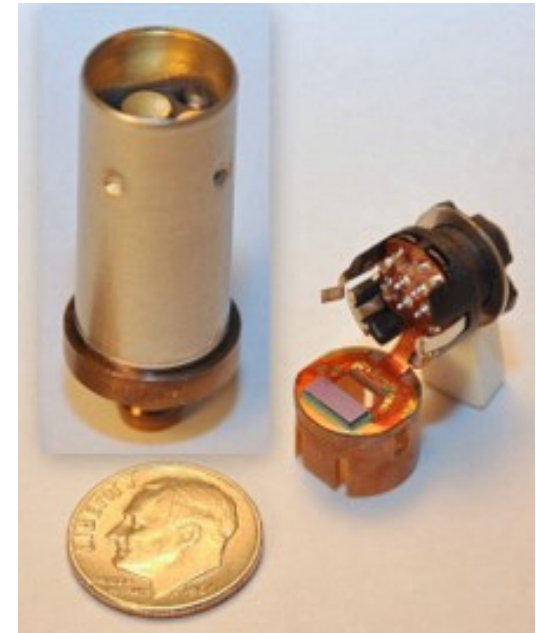
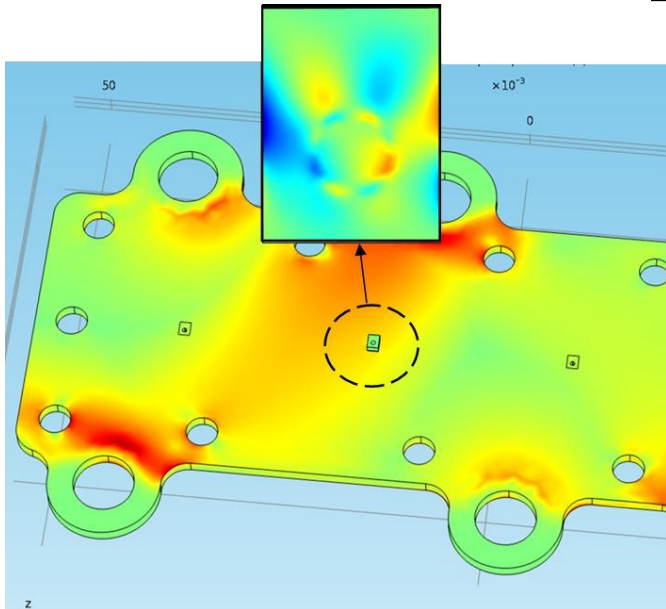
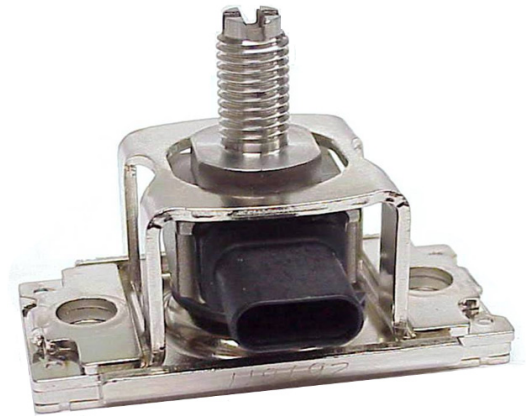
Electromechanical, Sensors & MEMS Products

Design and Process Development

Concept to Production

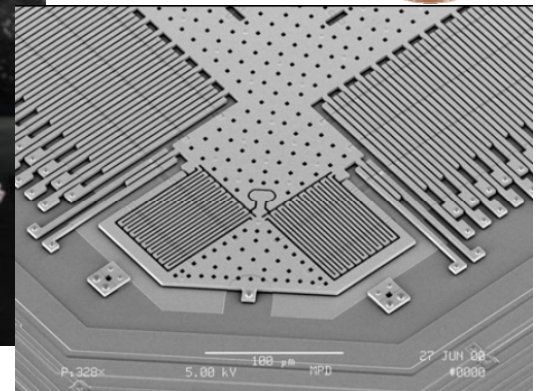
Macro to Micro

North Potomac, MD





MEMS and Sensors in Sports – More than Pedometers





The Revolutionary Change

- Enhanced learning through instant sensor feedback
- Better understanding of humans in sports and their interactions with equipment and within teams
- Resulting behavior is based on accurate, actionable data not perception or trial and error resulting in faster attained goals
- Improved safety and performance are achieved through monitoring exertion and vital signs real time
- Large, field collected databases lead to better engineering off the field to improve athletic equipment
- Access to customize training plans and tips from virtual coaches
- Enhanced user experiences and game viewing with up to the second player stats
- High accuracy in match outcomes through smart monitoring

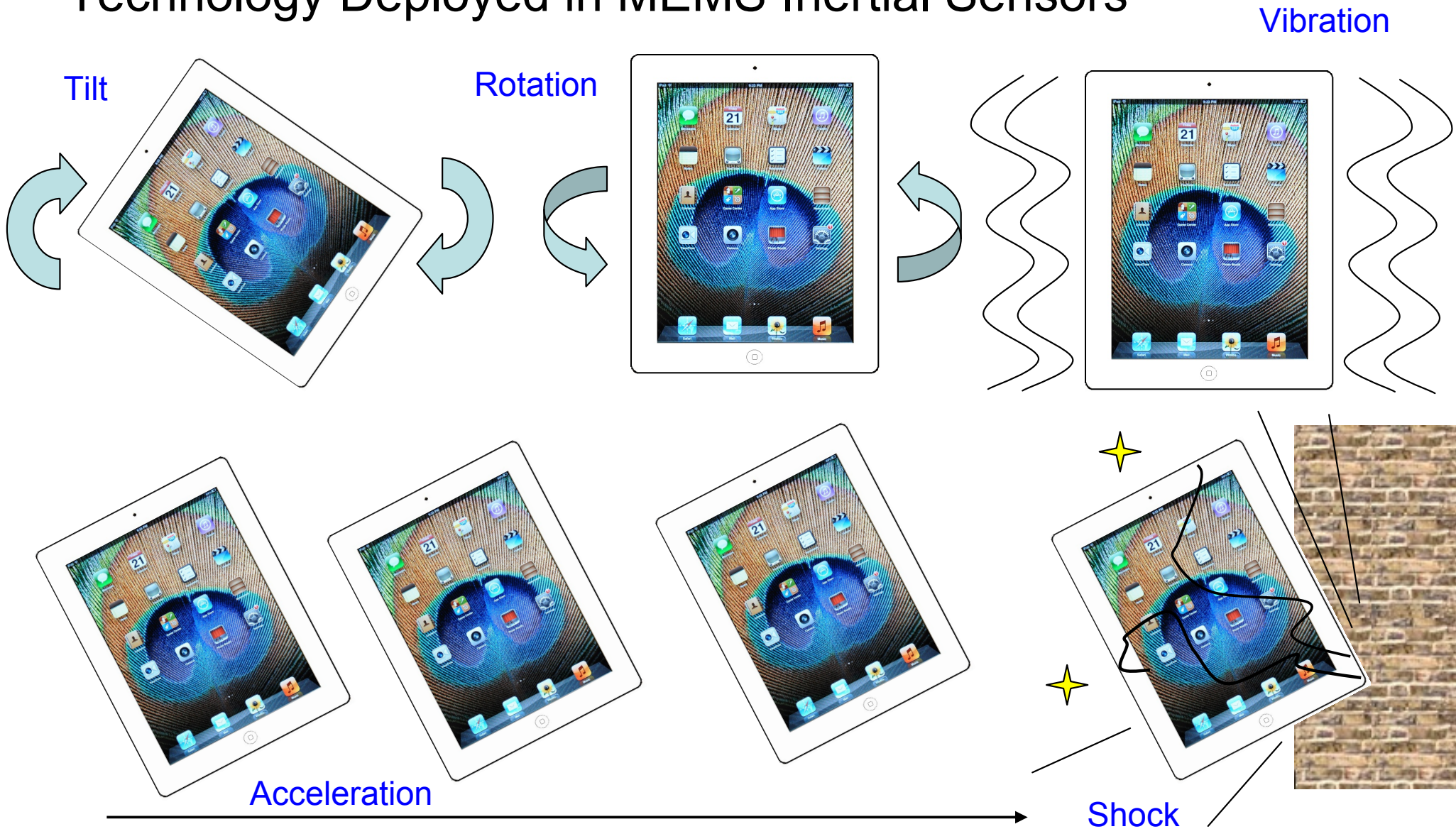


Factors Influencing for Mass Adoption

- Unobtrusive size
- Reduced sensor cost
- Accurate
- Use of smart algorithms programmed on small chips
- Reduced packaging size
- Low power consumption
- Wireless connectivity (Wi-Fi, Bluetooth, RF, more)
- Simplified interfaces for data interpretation
- Powerful mobile computing



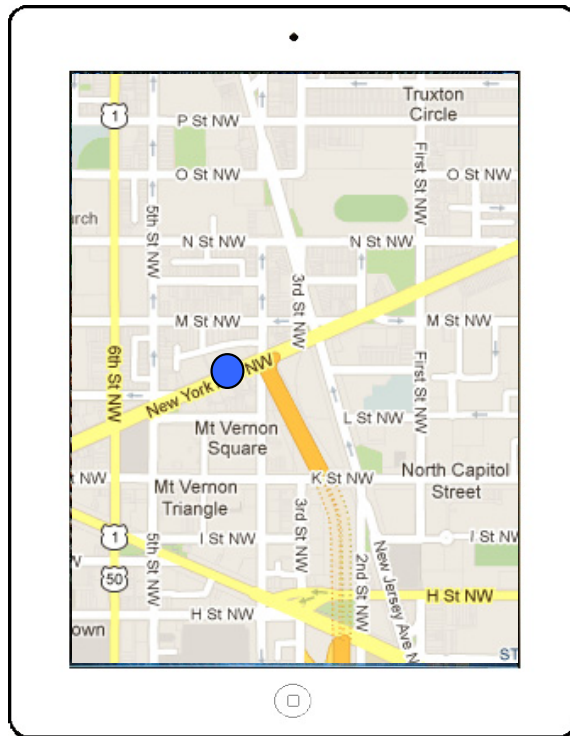
Technology Deployed in MEMS Inertial Sensors





Technology Deployed in MEMS Inertial Sensors

E-Compass



Indoor and Outdoor Navigation

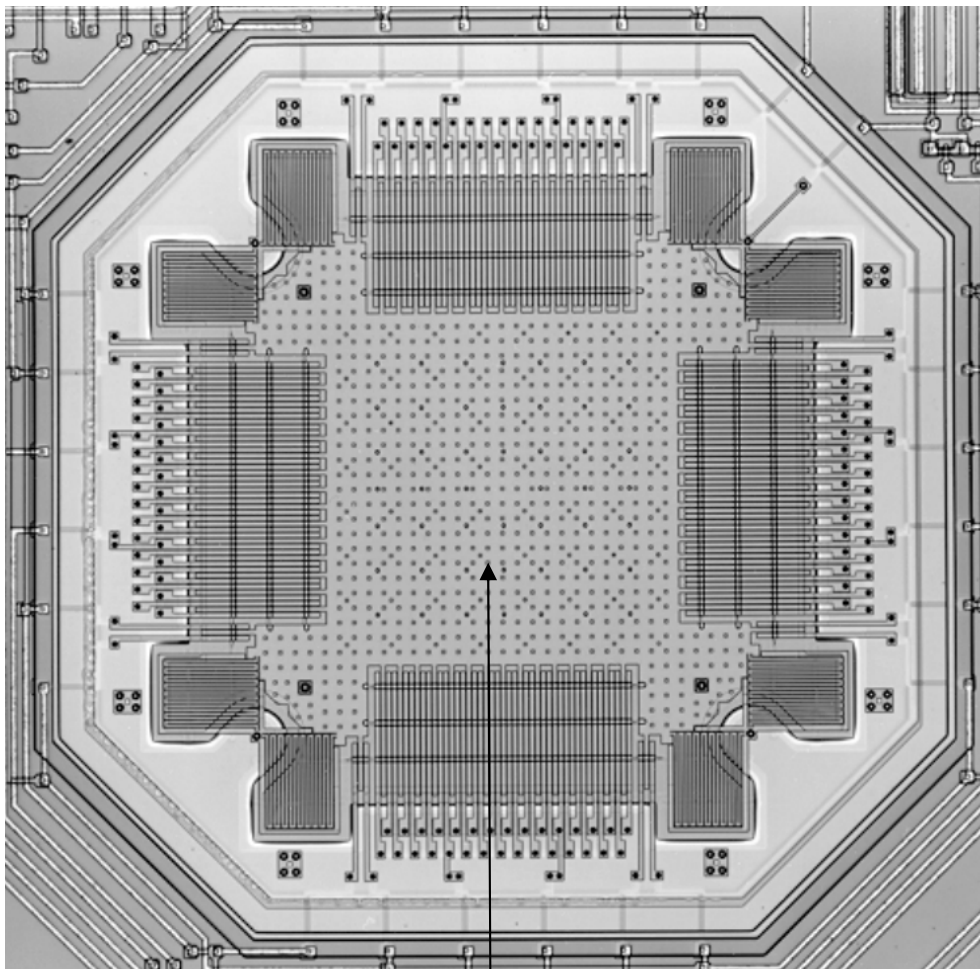
Barometer



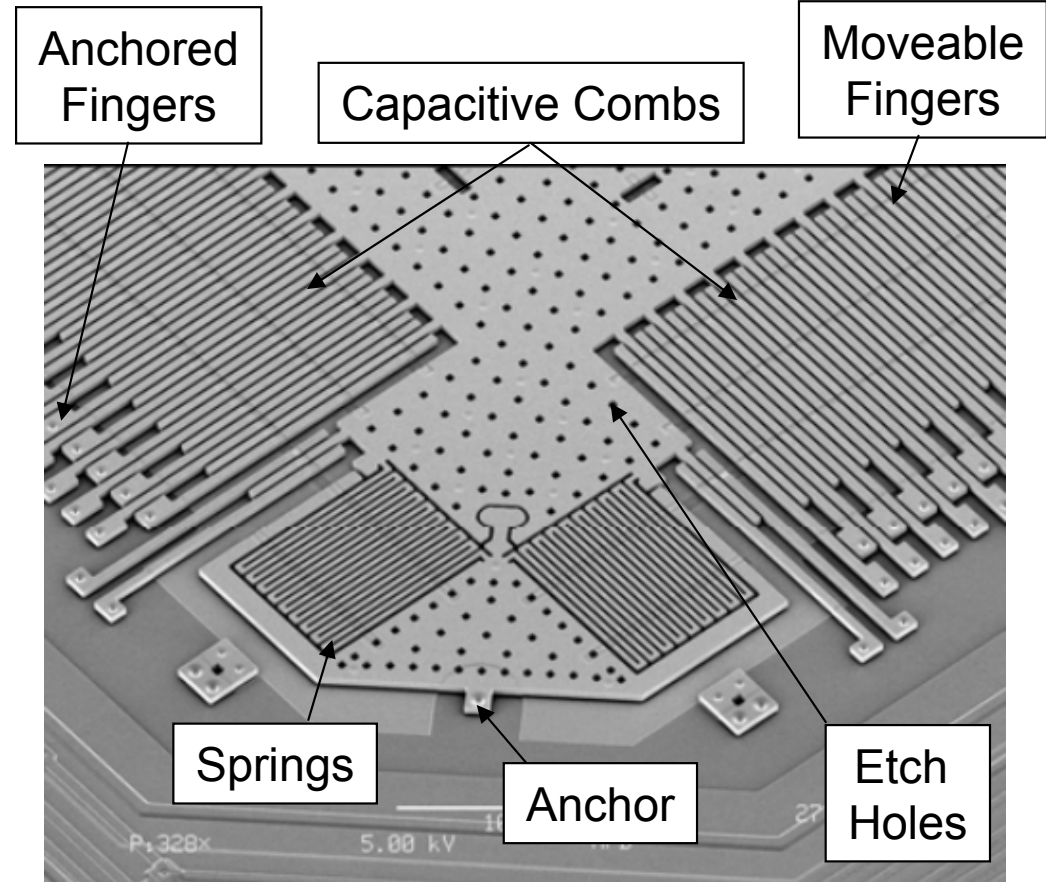
Height Measurement



2-axis MEMS Accelerometer ADXL202



Proof Mass



Images Courtesy of Analog Devices

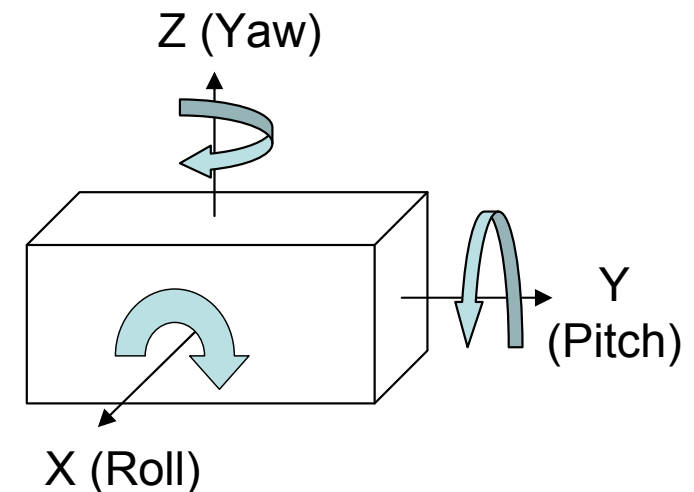


10 Degrees of Freedom in Single MEMS Package

- Tri-axis accelerometer (acceleration, tilt, shock and vibration)
- Tri-axis gyroscope (rotation of an object)
- Tri-axis magnetometer (magnetic field detection)
- Pressure sensor (atmospheric or height change)

Other Sensors Present in Sports Include:

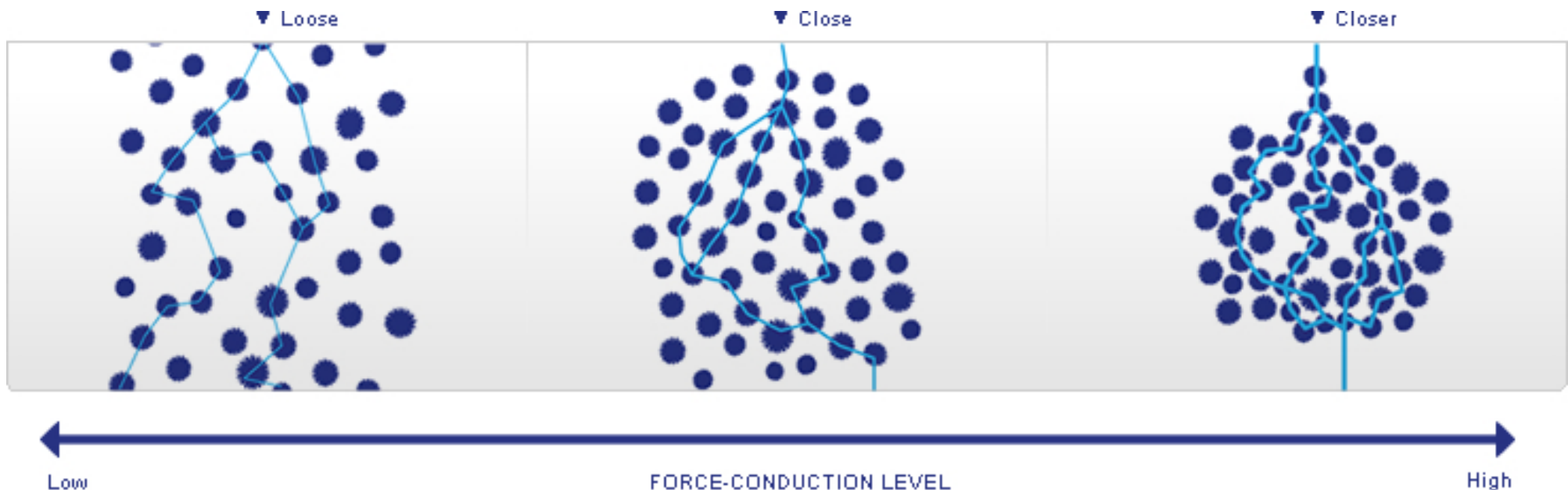
- Temperature
- Global Positioning System (GPS)
- Galvanic Skin Response (changing conductance)
- Heat flux (heat dissipation from the body)
- Heart Rate
- Force
- ECG – Electrocardiography, an interpretation of the electrical activity of the heart over a period of time across the chest (coming soon)
- Respiration (coming soon)





Quantum Tunneling Composite Pressure Sensor

- Conductive filler particles combined with an elastomeric binder
- Insulator when uncompressed and increasing conductivity when compressed
- Quantum mechanics shows that electrons can behave like waves under certain conditions and tunnel through a barrier (such as the polymer)
- Peratech uses spikes on the conductive filler particles to produce a localized increase in the electric field at the tips which effectively reduce the barrier 's width and allows conduction to occur





Fitness: BodyMedia Fit

- Obesity is estimated to cost the US \$150 Billion / year affecting 1 of 6 children and 1 of 3 adults resulting in physical wear, heart disease, cancer and diabetes - *Obesity Society*
- A class II exempt medical device that automatically tracks the calories burned during your daily activities, monitors workout intensity and quality of your sleep
 - The on-body monitoring system consists of an armband device, online Activity Manager, optional display and mobile app



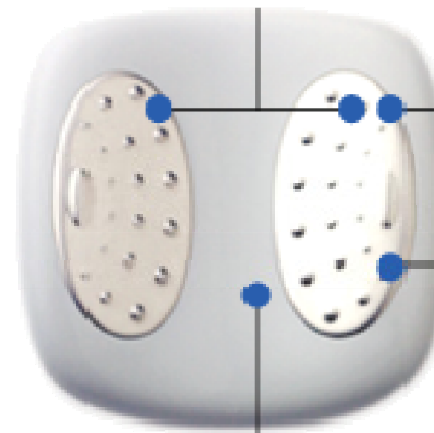


Fitness: BodyMedia Fit

- Function
 - Using sensors monitoring galvanic skin response, skin temperature, heat flux and motion/steps, the armband monitor captures over 5,000 data points per minute and uses a complex algorithm to monitor calories burned
- “Data doesn't mean squat unless you can use it.”
 - Easy to use interface lets you track progress towards goals and monitor calories in and out
- 3X improvement in weight loss reported

Galvanic Skin Response

When you sweat, your skin becomes more electrically conductive. This measurement helps to see how active you are.



Skin Temperature

Measures the surface temperature of your body.

Heat Flux

Measures the rate at which heat is dissipating from your body.

3-axis Accelerometer

Measures your motion and steps taken.

Image Courtesy of BodyMedia



Adidas MiCoach

- Modules include pacer (electrical interconnects, microprocessor), stride sensor (tri-axis accelerometer), heart rate monitor (on strap or integrated into clothing) and mobile app
- Fitness activity tracking and verbal coaching with customizable workout plans
- Major League Soccer and Adidas have announced that every player in the league will be wearing the MiCoach Elite System in the 2013 season
- Monitors players heart rate and uses tri-axis accelerometer, magnetometer, gyroscope and GPS to derive velocity, rotation, acceleration, field position and player exertion
- Sends information via RF to a base station computer that analyzes data and sends information to coaches' and viewers' iPads with updates every second



Images Courtesy of Adidas



Nike+ Sports Sensor (Hyperdunk+)

- Modules include a tri-axis accelerometer and four force sensitive resistors (i.e. Quantum Tunneling Composites) that communicate wirelessly via Bluetooth to your mobile computer and display data in user friendly application
- Tracks pressure exerted, vertical jump height, the number of steps per second and a measure of your NikeFuel
- Nike+ app lets you share and compare your stats via social media
- NikeFuel is an accumulation of all your movements, its calculated the same for everyone and is standard to compare and compete with friends
- Sensor also available for Nike Trainer (virtual coach / workout plan)





Arrow-mounted Ballistics Measurement System

- VELOCITIP Arrow uses MEMS sensor technology in arrow tip
- Includes tri-axis digital accelerometer, non-volatile memory, microcontroller and battery
- Monitors in flight and ballistics characteristics of arrow from launch to target impact including velocity, momentum, drag, trajectory, dynamic efficiency and time of flight
- Data is transferred from field point to a computer via a docking station where the data can be displayed
- Understanding of an arrow's flight enhances learning and aids in modifying human behavior and interactions with the equipment to achieve better performance





94Fifty Sports Technology – Basketball with Motion Sensor

- Basketball with MEMS tri-axis accelerometer and gyroscope to track its motion
- Advanced pattern recognition algorithms automate motion capture
- Monitors every bounce, hold, impact, speed, spin rate, wrist strength, force off the ground and shooting arc (release and entry angles) and derives characteristics such as coordination and shooter accuracy
- Generates objective and personalized diagnostics with 6000 measurements per second, communicates wirelessly to a laptop and stores information in the cloud for players and coaches
- Ball motion provides detailed information regarding the person controlling its movement and provides value feedback to improve skills rapidly when coupled with great coaching
- Spalding and 94Fifty have a distribution and product partnership



*Image Courtesy of
94Fifty Sports Technology*



Movea MotionPod - Golf Swing Analysis

- 9 degrees-of-freedom motion detection with a PCB module that is about the size of a small wristwatch
- Incorporates tri-axis accelerometer, gyroscope and magnetometer, printed circuit board, microcontroller, analog-to-digital converter, power management IC, and a Bluetooth transceiver in a fully integrated package complete with advanced software algorithms to analyze and display motion and impact data
- The miniaturized MotionPod is now an off-the-shelf component, ready to be used in a wide range of applications including fitness, gaming, and sports
- Movea SmartMotion data fusion technology uses advanced algorithms and signal processing that gather and analyze the data from the sensors and display it to the user on a smart phone, tablet or laptop
- MotionPod attaches to club just below the grip to provide full characterization of your golf swing, club head speed and impact angle, ball speed at impact, hook and slice correction



Image Courtesy of Movea





Babolat's Play & Connect Through Partnership with Movea

- MotionPod located in the handle of the racquet
- The system will analyze the ball's impact on the strings and the trajectory of the racket before and after the impact
- Metrics measured include the shots' power and spin, player swing consistency, position of the ball on the strings and type of shot (forehand, backhand, or serve)
- MotionPod also used in Decathlon NABAIJI to track swimming laps, distance, and speed all while playing music with a waterproof MP3 player



Images Courtesy of Movea and Babolat



Applied Science Laboratories Mobile Eye-XG - Eye Tracking Technology

- The Mobile Eye-XG glasses track eye movement, sound and the scene simultaneously in an unobtrusive design
- ASL's analysis software displays easy to interpret visualizations such as gaze plots, scan paths and heat maps
- Two digital high resolution cameras are used to record the scene image and the participant's eye
- Images are then integrated into a single video recording with the scene and a superimposed gaze cursor
- Data is stored on a SDHC card or sent real time wirelessly to a remote work station
- Video Demonstration

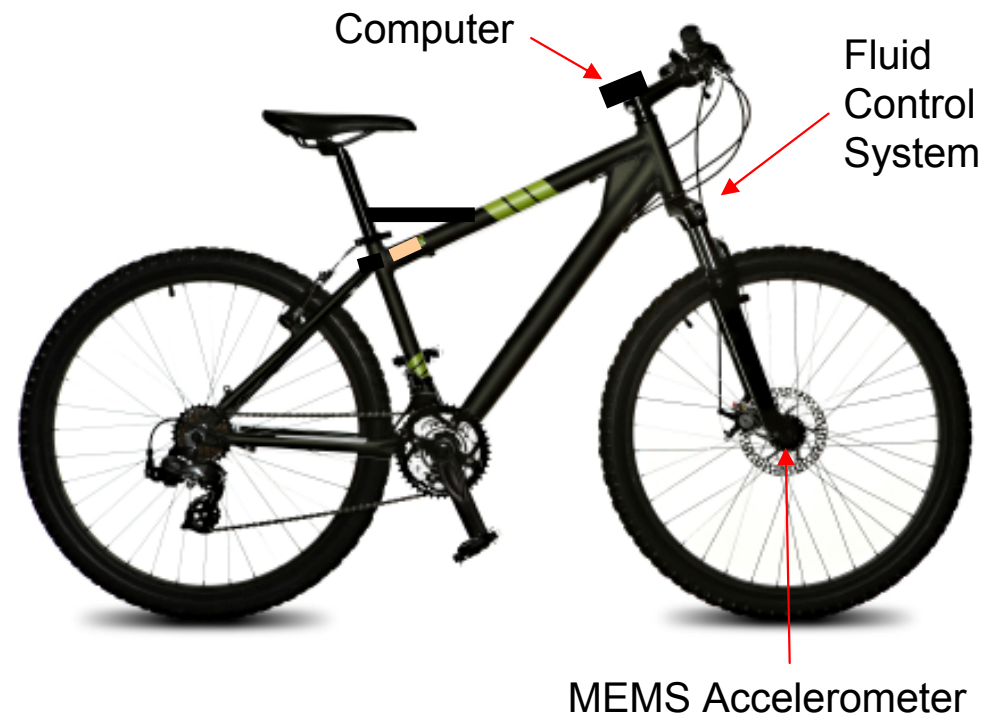
Image and Video Courtesy of Applied Science Laboratories, www.asleyetracking.com





Cannondale Simon Active Mountain Bike Suspension

- Not yet released active, programmable suspension that uses a single-axis accelerometer at the wheel hub to monitor applied forces at 2-millisecond intervals
- Sensor data is transferred over a digital network to an on-board computer that processes the terrain with sophisticated algorithms and manages the suspension fork's fluid control system to improve rider safety and control, minimize fork wear and reduce the impact loads
- The programmable settings of the controller are set using a handlebar-mounted joystick and LCD display
- Mechanical feedback devices have slower response times but accelerometers allow for real-time response to instantly adapt to changing trail conditions such as remaining fully rigid on smooth surfaces for pedaling efficiency and flex when conditions change before the rider can notice





Tekscan GripTM System - Tactile Grip Force and Pressure Measurement

- This system measures and analyzes dynamic and static pressures from grasping objects using thin, high-resolution tactile sensors mounted on a hand or glove
- Data is transferred by wire, wireless or continuously logged with sampling rates up to 850 Hz
- System provides detailed pressure profiles and forces experienced by user and presents in graphical displays
- Sensor is made up of two thin, flexible polyester sheets that have electrically conductive electrodes deposited on their inner surfaces; row pattern on first and column pattern on second
- Patented semiconductor material is printed over the rows and columns between the sheets and the sensing cell (sense1TM) is created by the row and column intersections
- Ferroelectric polymers, such as polyvinylidene fluoride (PVF₂), may be used as the proprietary semiconducting material for its piezo and pyro electric response
- http://www.youtube.com/watch?feature=player_embedded&v=q6_iZwuK3cU (video of sense element)





X2Impact Mouth Guard and Patch for Head Impact Detection

- 6 degrees of freedom motion and force detection with tri-axis accelerometer and gyroscopes to provide athletic trainers, coaches, and team physicians real time data about impacts to players heads
- Available in a mouth guard or patch worn behind the ear
- Data transmitted wirelessly (X2Net protocol) to the base station on the sidelines and recorded in Windows Azure cloud database
- Software suite analyzes and displays data, stores history, provides population exposure ranking, alerts and reports
- Software also provides a set of tools supporting athlete impact and concussion assessment in bench vs. play decisions, recovery and safe return to play protocols

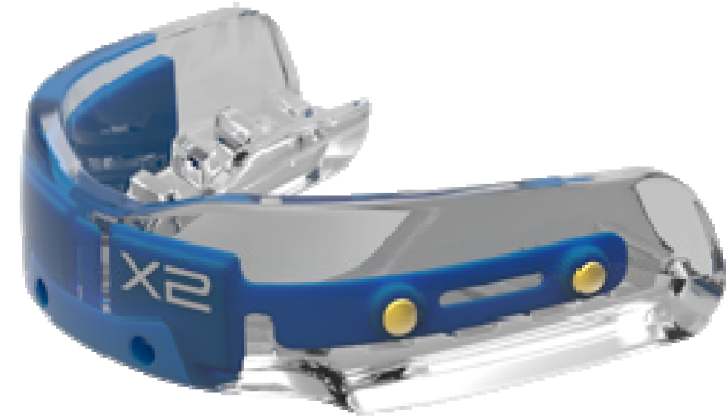


Image Courtesy of X2 Biosystems



Riddell InSite Impact Response System

- The InSite Impact Response System monitors, records and transmits the impact magnitude, direction and duration that players sustain on the field via 5 accelerometers mounted in the helmet (player unit) with close proximity to the head (no mention of gyroscope use in patent)
- Derives a single measure of head impact severity
- The data is transmitted wirelessly to an alert monitor on the side lines maintained by coaches and trainers if the impact falls outside the acceptable range
- Medical personnel can then assess the player and make appropriate play versus bench decisions
- Player Management Software is used to track equipment assignments to players and record impact exposure over time



Image Courtesy of Riddell



SMARTLIFE Technology – Smart Garment

- Body temperature, respiratory rate from chest expansion and contraction and heart electrical activity (electrocardiograms) can be detected with garment sensors integrated into sport wear
- Electro-conductive elastomeric yarn (carbon filled silicon fiber yarns) are knitted into electro conductive areas
- As the yarn is stretched and slippage occurs at the contact points of the stitches, the electro conductive area resistance will change
- Capacitive structures can be created by knitting electrode plates with conductive yarn and spacer structures using nonconductive monofilament yarn
- Discrete electrical components may also be incorporated and the electrical connections can be made with high conductivity yarn
- The sensor data is transmitted in real time via bluetooth to a remote computer for analysis and display
- Fraunhofer Institute is doing similar work; both companies are still in the development and validation stage





Cairos Technologies – Goal Line Tracking (GLT) System

- The GLT system is used to determine if a goal is scored in soccer
- Electrical current is applied to cables that are installed in the turf of the goal and penalty areas
- The magnitude of the current in each cable is different creating unique magnetic fields
- A sensor in the ball measures the magnetic field when it comes in close proximity to the wire
- The ball sends this information via a wireless signal to two receiver antennas behind the goal that transfers the encrypted data to a computer for analysis and determination of when the ball crosses the goal line
- When a goal is scored, an encrypted message is sent to the referee
- The whole process takes less than 1 second





XSENS MVN Motion Capture Suit

- MVN motion capture system has 17 motion sensors with two Xbus Masters
- The sensors are attached to the body via a suit or straps
- The motion sensor consists of a tri-axis accelerometer, gyroscope and magnetometer and it is used to track motion of a body part
- The Xbus masters are connected to each sensor with one cable and synchronize sensor sampling, provide the sensors with power and wirelessly communicate to the computer
- Sensor modules are placed on the feet, lower legs, upper legs, pelvis, shoulders, sternum, head, upper arms, fore arms and hands (Xsens MVN specifically)
- A calibration procedure is required to determine sensor to the body alignment and body dimensions
- The system runs in real time with kinematic updates every 0.008 secs
- GPS can be added for monitoring spatial position
- MVN Studio software analyzes and translates the data into avatar movements so the user can observe, record and export the movements in 3D

*Image Courtesy
of XSENS*



xsens



XSENS MVN Motion Capture Suit

- Video Presentation



Other sensors of interest

- Q Sensor by Affectiva monitors stress via skin conductance
- Measure motion characteristics, speed and intensity of bunches or kicks using accelerometers and gyroscopes
- Battle Sports Science has developed a chin strap with an integrated accelerometer to measure intensity and duration of head impacts with on-board LED indicator to allow coaches and trainers to take immediate action
- Sensor Sports is using Doppler radar to measure the speed of swings, balls and projectiles in an affordable package
- Syride has developed Sys-Evo, a lightweight triangular device using a nine-axis MEMS sensor (accelerometer, gyroscope, and compass with user entered data) that attaches onto a surfboard to provide the surfer feedback on wave height, speed, ride time, distance paddled, water temperature, calories burned and more
- Ionic Polymer Metallic Composites (IPMCs) – Lightweight and flexible polymers that produce a voltage across surfaces when compressed due to its ionic properties. Researchers are using this material to produce wearable sensors that can be used to measure impact forces without impeding performance of the athlete (an example of an IPMC is Nafine with Sulfonic acid groups on a tetrafluoroethylene backbone)



Conclusions

- There is great diversity in MEMS and sensors used in sports today but we have really just scratched the surface on their potential applications
- Sports sensors are changing the way we learn, our overall understanding of humans and equipment in the game and our resulting behavior
- Individuals are seeing 3X gains in weight loss and sports are becoming safer for not only professional athletes but our youth
- Sensors and MEMS will also enhance the fan's experience by adding new dimensions to the game, becoming interactive and ensuring correct outcomes
- When properly deployed, sensors and MEMS are poised to revolutionize exercise and sports



Questions?