October, 2009

Next Generation Wireless
Sensing Applications, Moving Forward

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Freescale Technical Sales Manager

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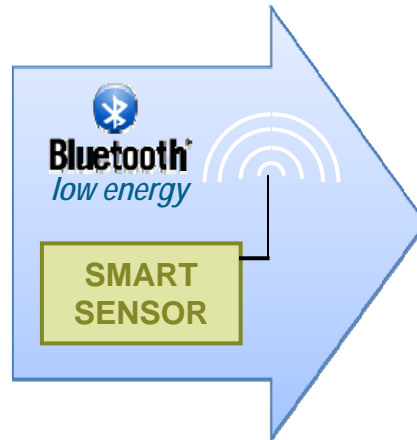*semiconductor*

Motion Sensing at the Forefront

Slick UI

Reduced camera-shake

3D Motion Point-to-control

Freefall disk protection

In-device Sensors

Body Area Sensor Network
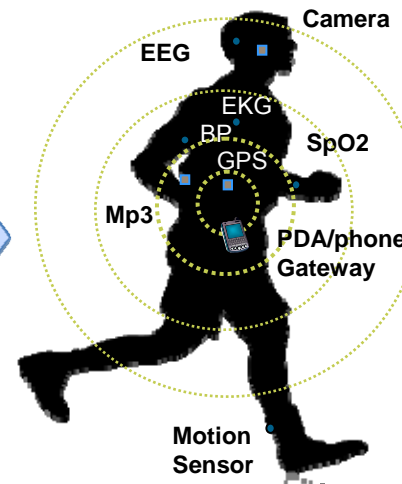
Sensor Enabled Sports Equipment

Bluetooth *low energy*

SMART SENSOR

Camera

EEG

EKG

BP

SpO2

GPS

Mp3

PDA/phone Gateway

Motion Sensor

Wireless Sensor Node

INNOVATION

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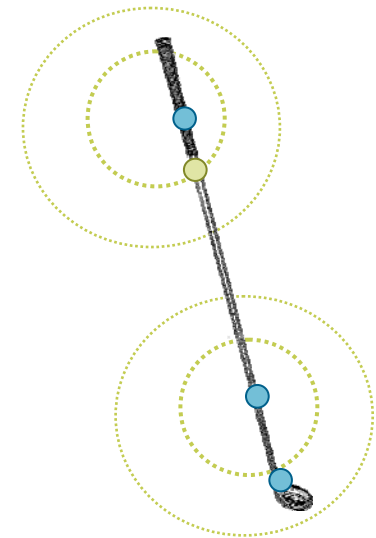
Wireless Sensing – Application Domains

Sports Training

Fitness

Healthcare

Wireless Sensor Node

Immersive Gaming

Industrial
(personal activity monitoring: process and safety)

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Sensors Provide….Context Awareness

Motion, reaction
Posture, gait, cadence
Biometrics
Emotion

Personal (Body)

Equipment and objects

Ambient (Surrounding environment)

Position
Motion, velocity, trajectory
Impact, power
Entertainment

Location, Altitude
Temperature, humidity
Light and Sound
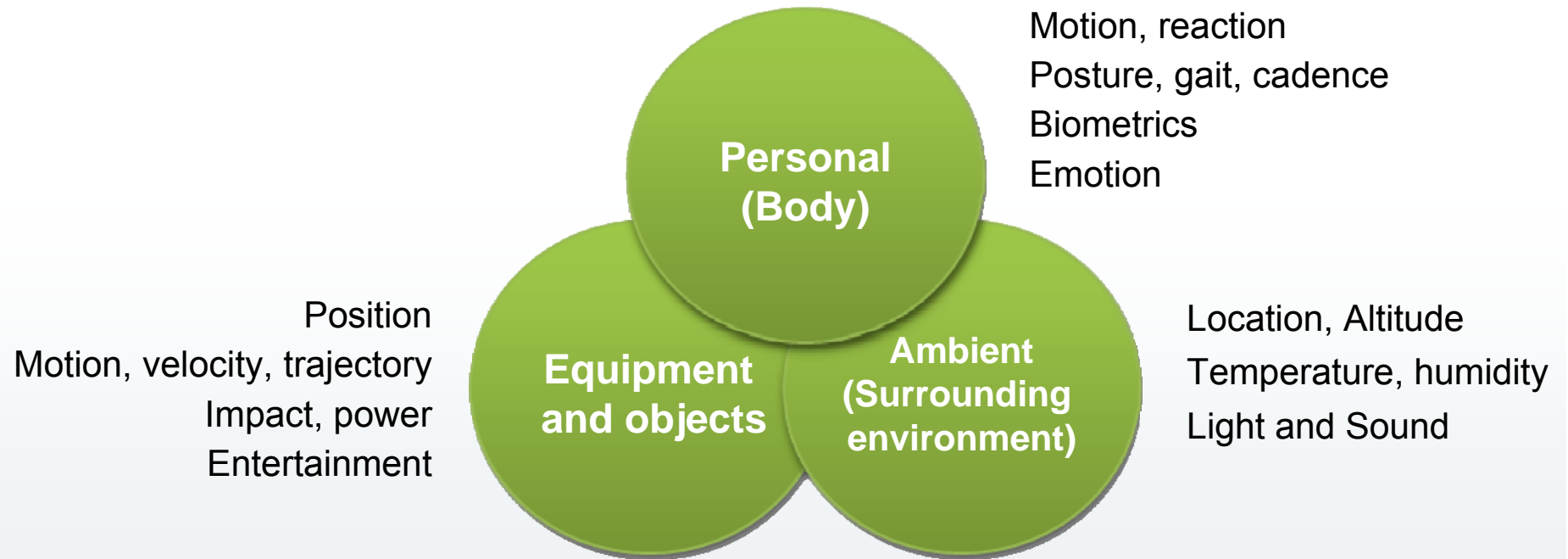
- **Knowledge about the body's movement and bio-status**
- **Our interaction with tools, equipment and objects**
- **Knowledge about, and interaction with the surrounding environment**

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Wireless sensing – Some Use Cases

Body Sensor Network

- Immersive gaming
- Real time animation
- Motion and fall detection
- Medical rehabilitation
- Industrial

Accessories

- Sports training
- Fitness monitoring
- Health
- Standard wireless interface to multiple accessories

Bluetooth low energy

Intelligent Objects, Tags

- **Object Tagging**
  - *I've dropped it!*
  - *I left it behind!*
  - *Where is it?*
- **Everyday objects with intelligence**
  - MEMS motion tracking
  - Touch sensor

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System Implementation: "Truly Mobile"

Interaction/Context

Motion
Reaction
Emotion
Posture
Biometrics

Personal

Trajectory
Impact
Velocity
Power
Feedback
Entertainment

Equipment + objects

Location
Altitude
Temperature
Humidity
Light
Sound

Ambient

Bluetooth *low energy*

ZigBee™

Personal Gateway

WLAN

Cellular data

Internet Services

Virtual Fitness Coach

Fitness Tracker

Technique Coaching

Weight-loss Manager

Group Statistics

Virtual Sports

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User Expectations Drive the Technical Challenges

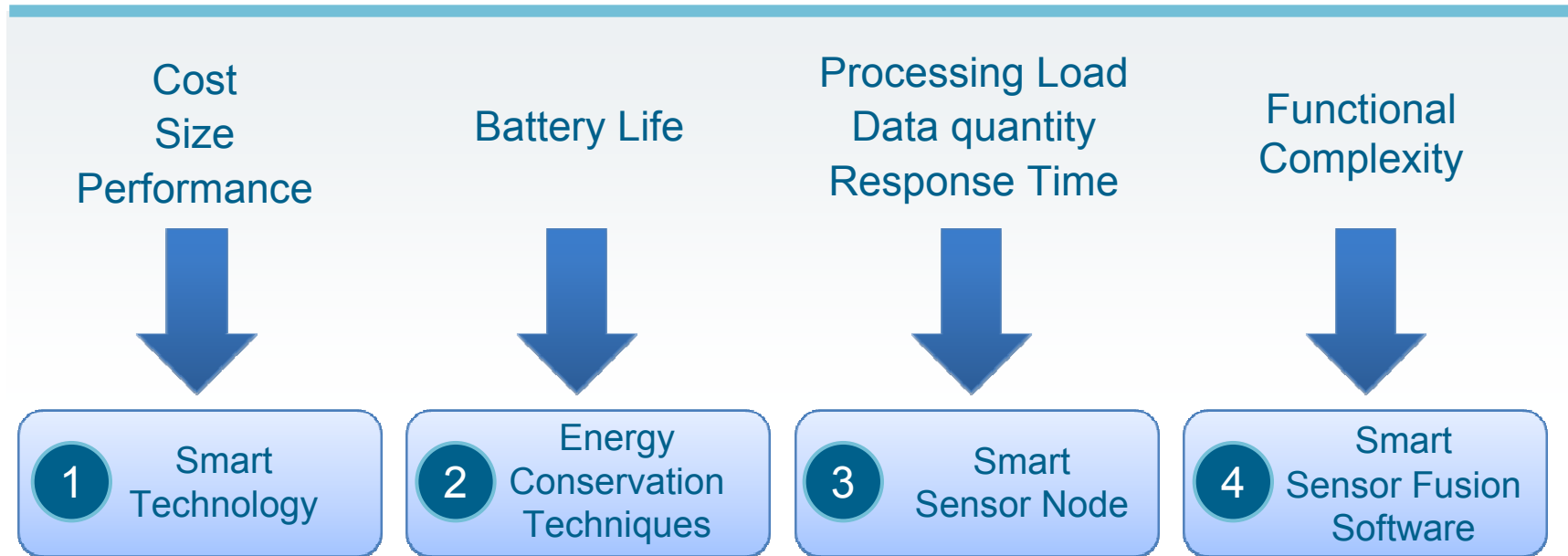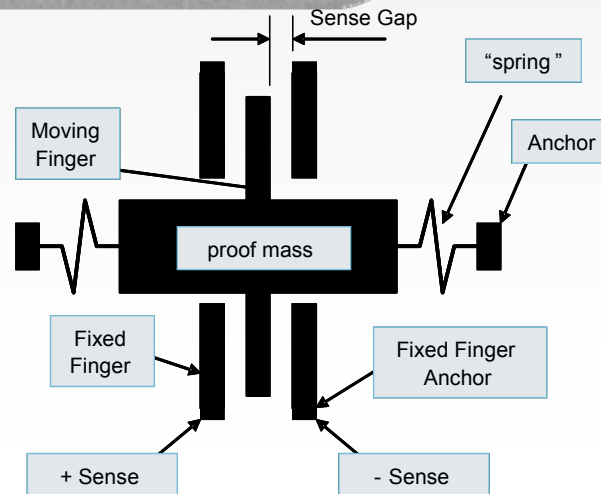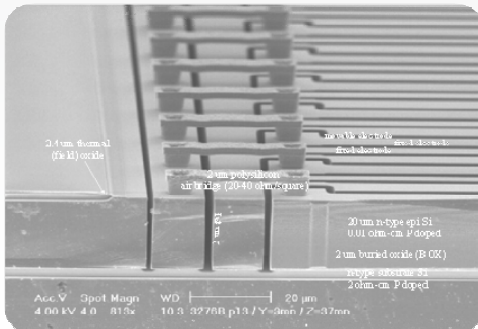|	
Mass appeal	*Low cost*
Ease of Use	*Intuitive, Immediate, Low maintenance (battery)*
Experience	*Immersive, Fast response, Accurate*
Look & Feel	*Small, Flexible, Non-intrusive, Cool*

Cost
Size
Performance

Battery Life

Processing Load
Data quantity
Response Time

Functional
Complexity

1 Smart Technology

2 Energy Conservation Techniques

3 Smart Sensor Node

4 Smart Sensor Fusion Software

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MEMS Technology Evolution

Inertial MEMS Evolution

Upper Fixed Polysilicon Plate

C1

Center Moveable Polysilicon Plate

C2

Bottom Subtrate Polysilicon Plate

Sense Gap

"spring"

Moving Finger

Anchor

proof mass

Fixed Finger

Fixed Finger Anchor

+ Sense

- Sense

More Functionality - Smaller Size
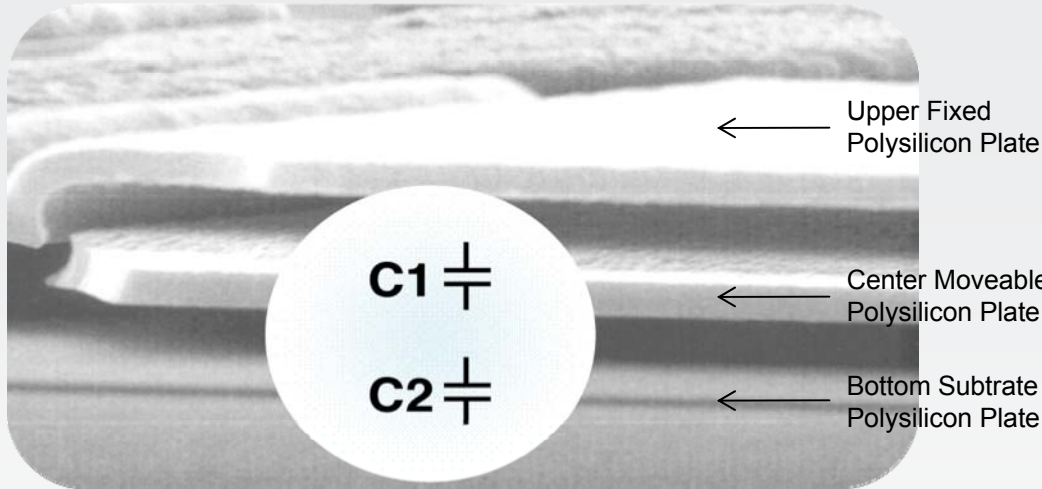
XYZ axis

XZ axis

XY axis

Z axis

X axis

1 Smart Technology

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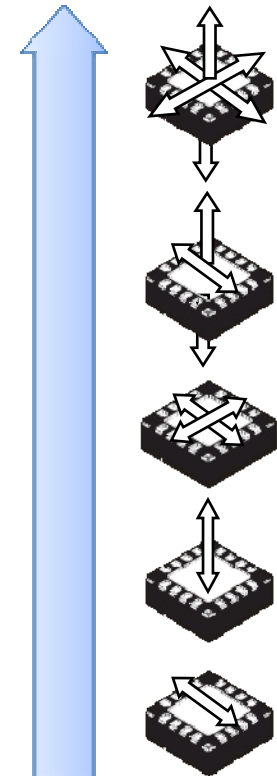
Integration and Scale

Integration – Smaller Size, Greater Functionality, Lower Power

Control ASIC

MEMS Sensing Cell

Pressure

3-accelero
3-gyroscope

Conditioning

MCU
Memory
PicoRadio

Package Substrate
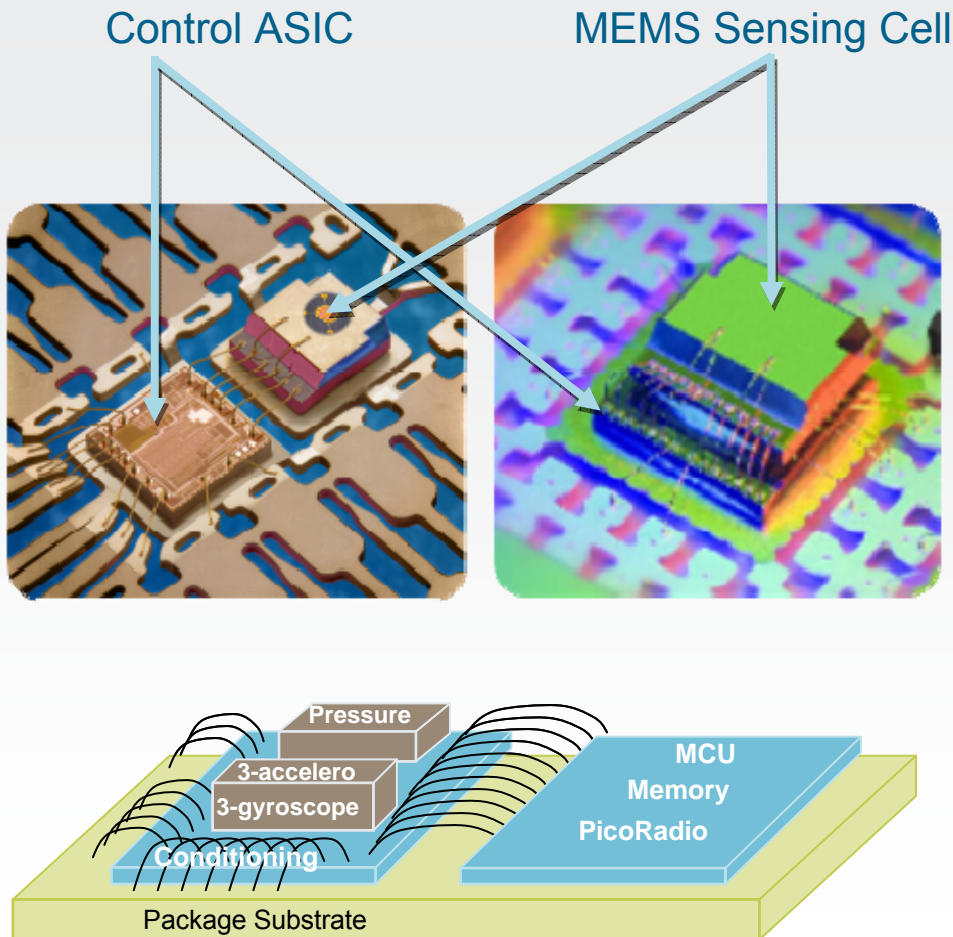
Scale Drives Down Cost

MEMS Sensors in consumer products and mobile phones
(millions)

3,000
2,500
2,000
1,500
1,000
500
0

2006 2007 2008 2009 2010 2011 2012 2013

1 Smart Technology

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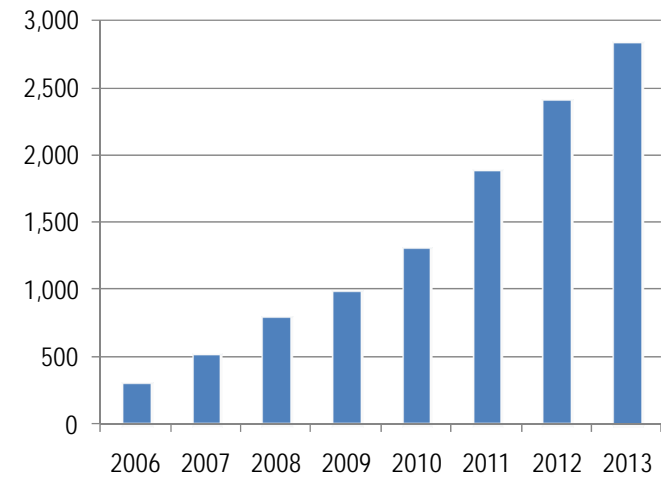
Energy Conservation Techniques

Component and System Design Techniques

Energy Harvesting

Consider at component level and system level

▶ **Sensor component:**

- Optimized circuit design
- Low power modes
- Auto transition in/out of low power modes
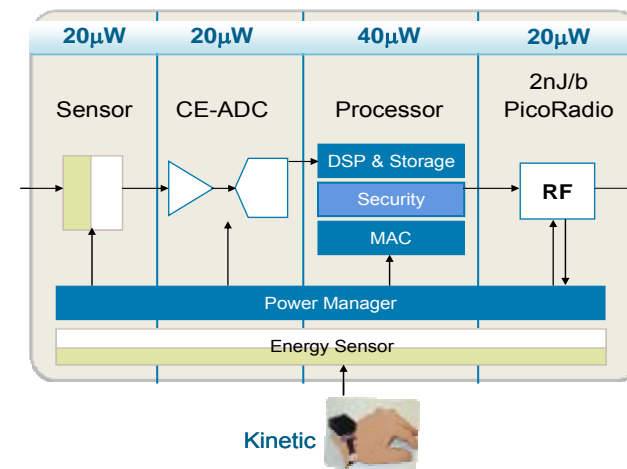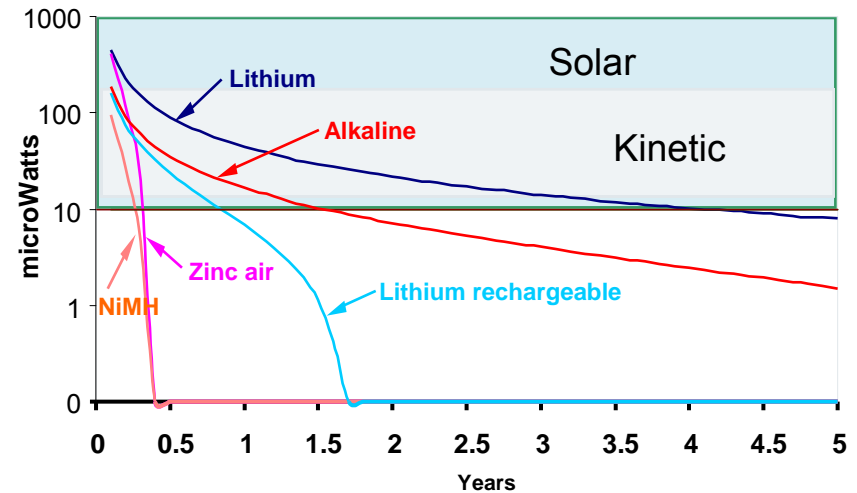- Adaptive Sampling Rate

▶ **System design:**

- System-level wakeup/sleep mechanisms
- Interrupt design
- Distributed processing
- Duty cycling

2 Energy Conservation Techniques

Continuous Power / cm^3 vs. Life Several Energy Sources

Solar
Lithium
Alkaline
Kinetic
Zinc air
NiMH
Lithium rechargeable

microWatts: 1000, 100, 10, 1, 0

Years: 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5

| 20μW | 20μW | 40μW | 20μW |

Sensor | CE-ADC | Processor | 2nJ/b PicoRadio

DSP & Storage
Security
MAC
RF

Power Manager

Energy Sensor

Kinetic

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Example: Accelerometer with Built-In Sleep Control and Gesture Detection

MMA7660FC Block Diagram
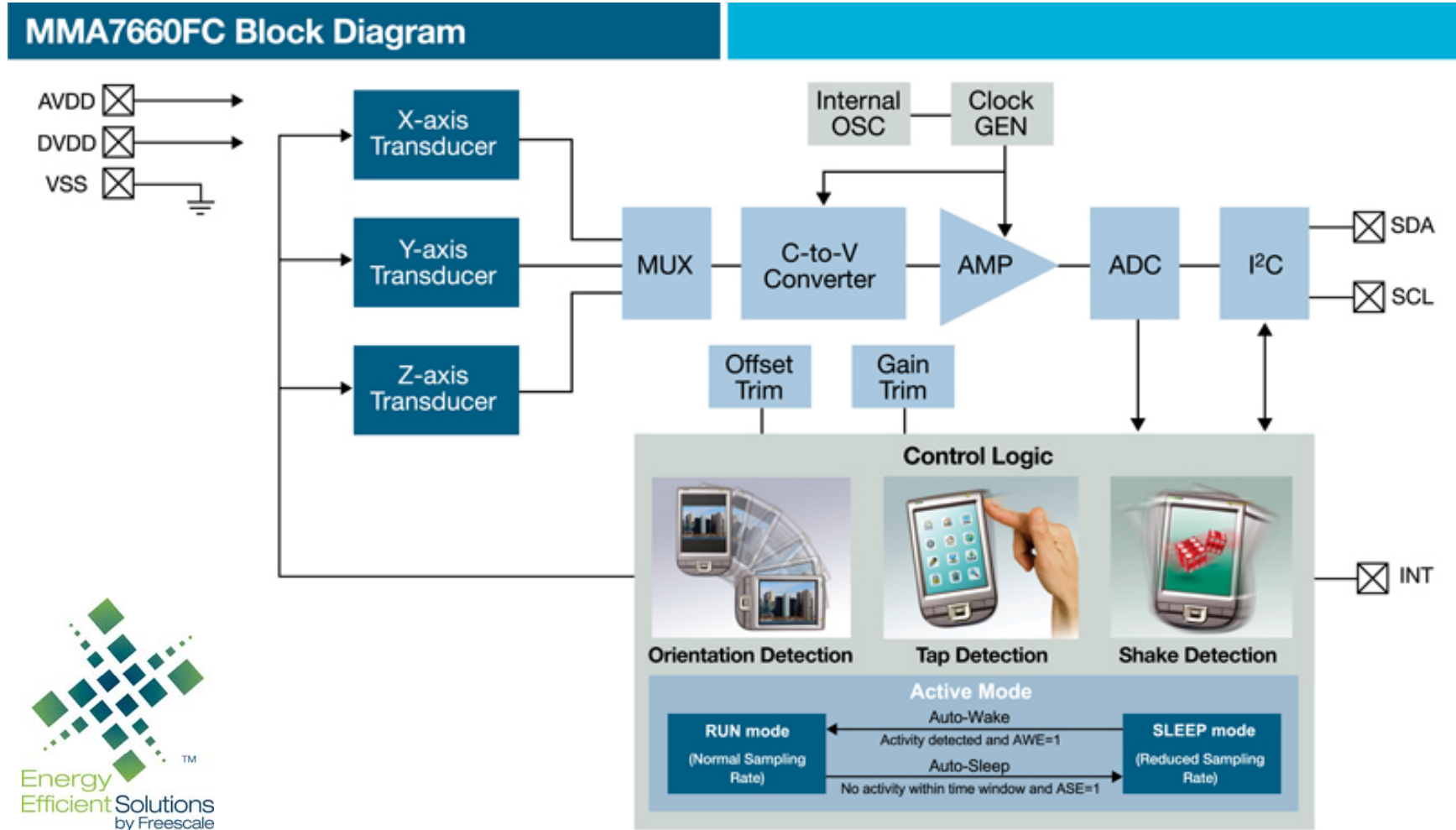
Smart Sensor Node

Smart Sensor Network
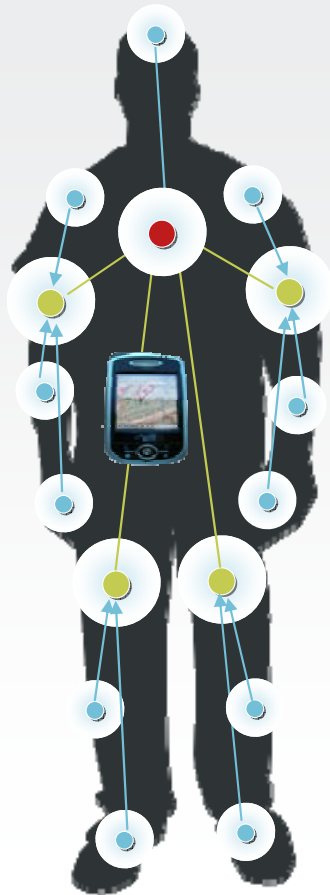
- Local processing of sensor data streams

- Distributed processing – more energy efficient

- Reduces comms traffic

- Improves response time

- Simplifies system integration

4 Smart Sensor Fusion Software

Smart Sensor Node

| Sensor | MCU + memory | RF |

| Sensor |
| Sensor |

3 Smart Sensor Node

Wireless Smart Sensor node:

- One or more sensors

- Signal conditioning, ADC

- MCU + memory

- Pico-radio

… in the same package

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Gaming - The Road to Wireless Sensing Remotes

Adding motion detection and control

Increased Memory Storage
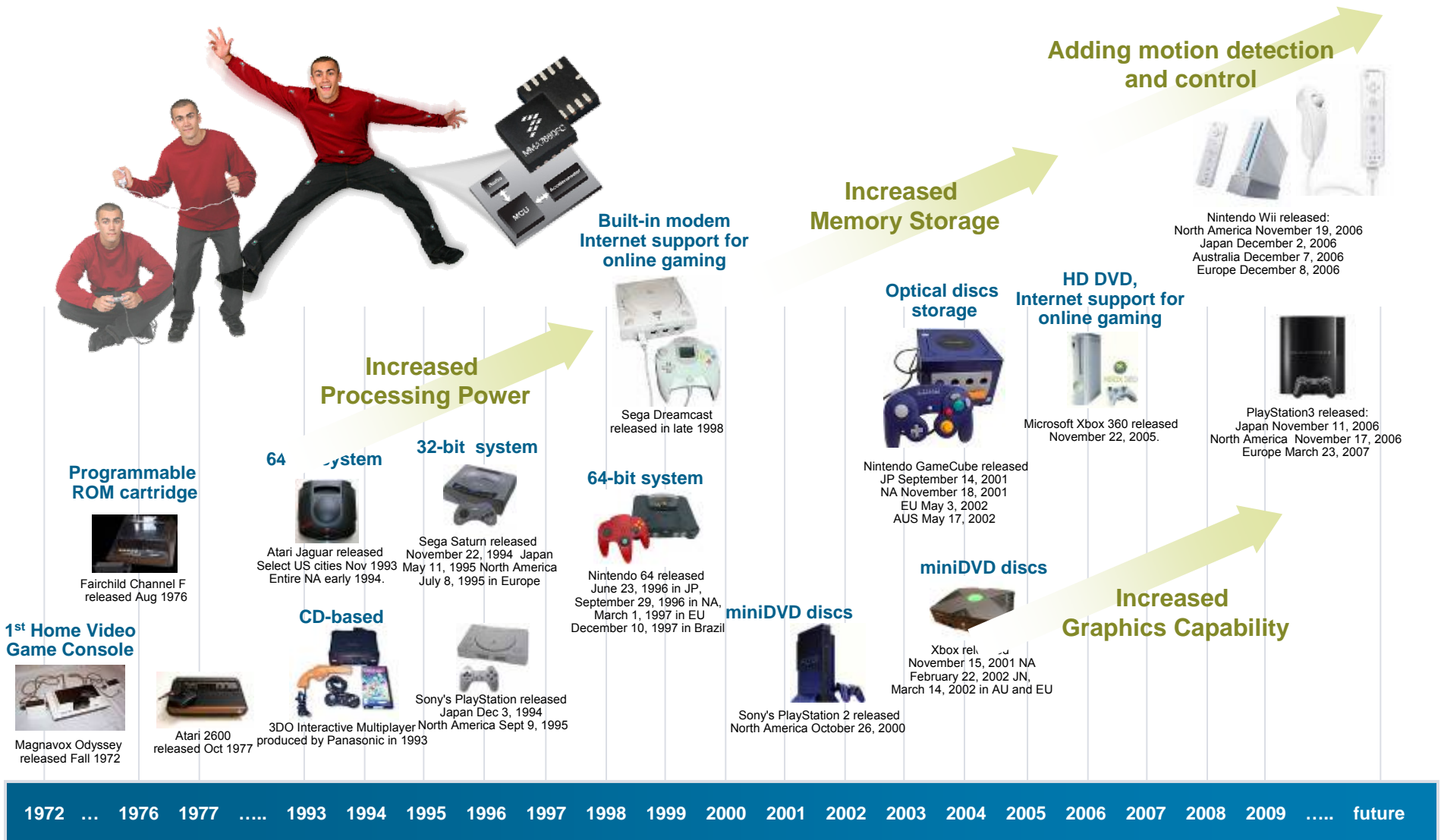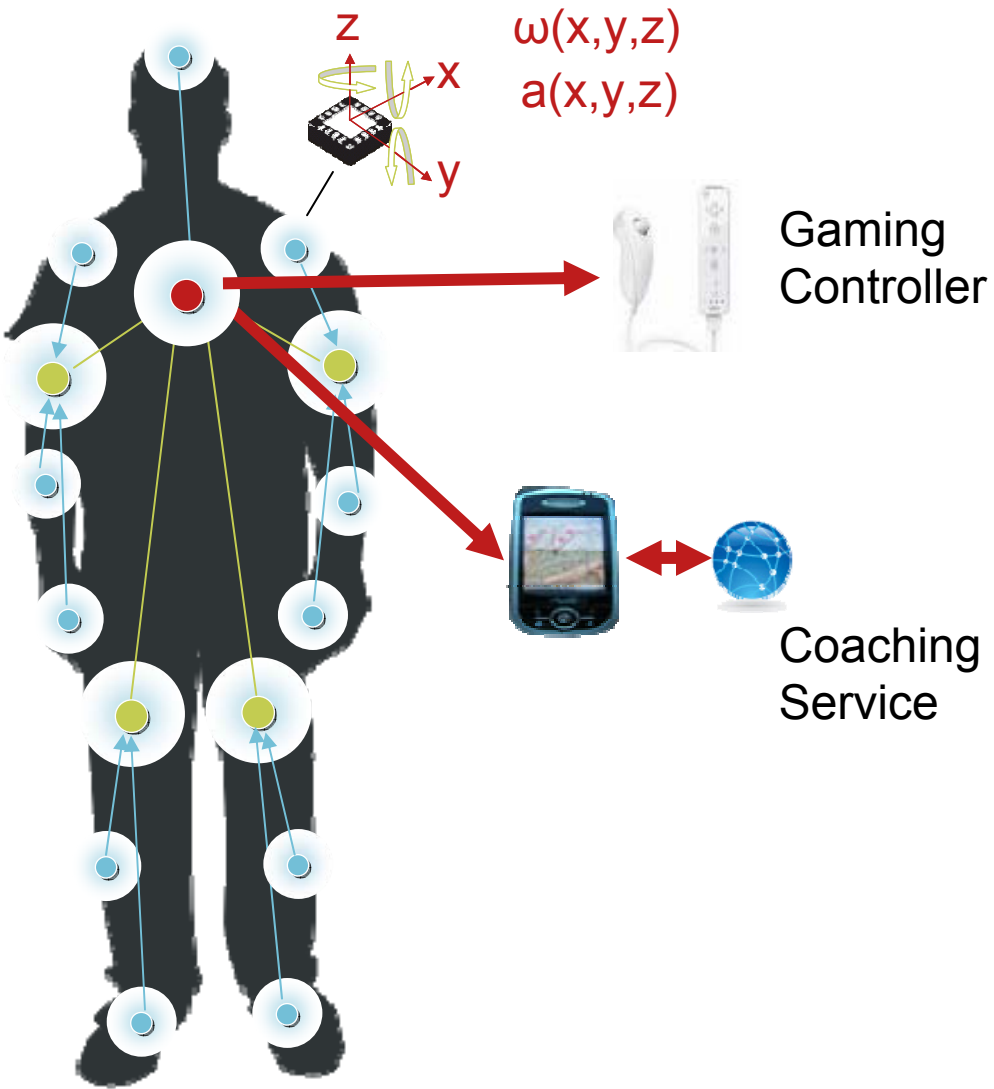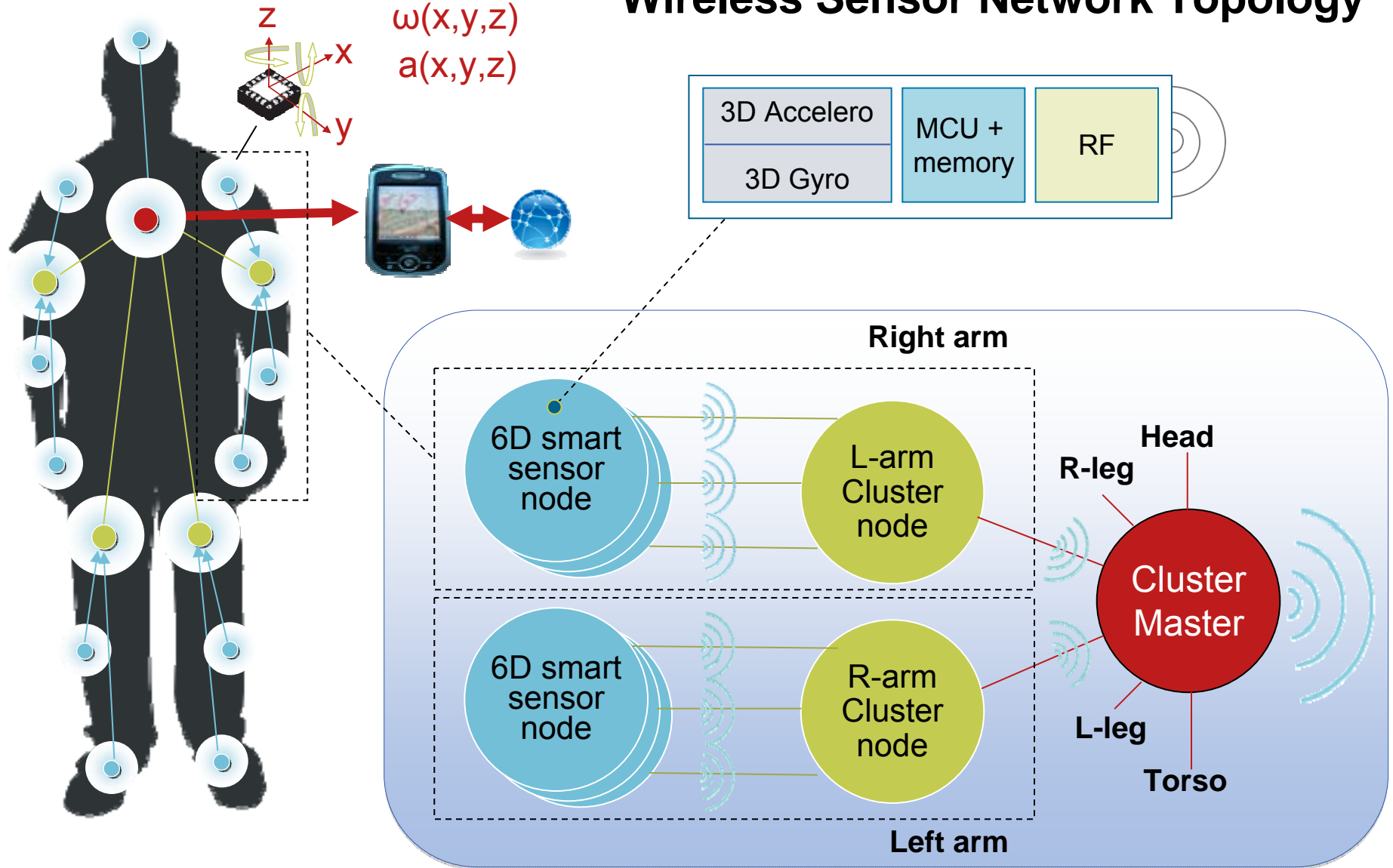
Nintendo Wii released:
North America November 19, 2006
Japan December 2, 2006
Australia December 7, 2006
Europe December 8, 2006

Built-in modem Internet support for online gaming

Optical discs storage

HD DVD, Internet support for online gaming

Microsoft Xbox 360 released
November 22, 2005.

PlayStation3 released:
Japan November 11, 2006
North America November 17, 2006
Europe March 23, 2007

Increased Processing Power

Sega Dreamcast
released in late 1998

Nintendo GameCube released
JP September 14, 2001
NA November 18, 2001
EU May 3, 2002
AUS May 17, 2002

Programmable ROM cartridge

64   ystem

32-bit system

64-bit system

Atari Jaguar released
Select US cities Nov 1993
Entire NA early 1994.

Sega Saturn released
November 22, 1994 Japan
May 11, 1995 North America
July 8, 1995 in Europe

Fairchild Channel F
released Aug 1976

Nintendo 64 released
June 23, 1996 in JP,
September 29, 1996 in NA,
March 1, 1997 in EU
December 10, 1997 in Brazil

miniDVD discs

miniDVD discs

Increased Graphics Capability

1st Home Video Game Console

CD-based

Xbox rel...
November 15, 2001 NA
February 22, 2002 JN,
March 14, 2002 in AU and EU

Sony's PlayStation released
Japan Dec 3, 1994
North America Sept 9, 1995

3DO Interactive Multiplayer
produced by Panasonic in 1993

Magnavox Odyssey
released Fall 1972

Atari 2600
released Oct 1977

Sony's PlayStation 2 released
North America October 26, 2000

| 1972 | … | 1976 | 1977 | ….. | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | ….. | future |

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Body Area Smart Sensor Network

z

$\omega(x,y,z)$

$a(x,y,z)$

x

y

Gaming
Controller

Coaching
Service

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Wireless Sensor Network Topology

$\omega(x,y,z)$
$a(x,y,z)$

z x y

| 3D Accelero | MCU + memory | RF |
| 3D Gyro | | |

Right arm

6D smart sensor node — L-arm Cluster node

6D smart sensor node — R-arm Cluster node

Left arm

Head
R-leg
Cluster Master
L-leg
Torso

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Software View of the Wireless Sensing Network
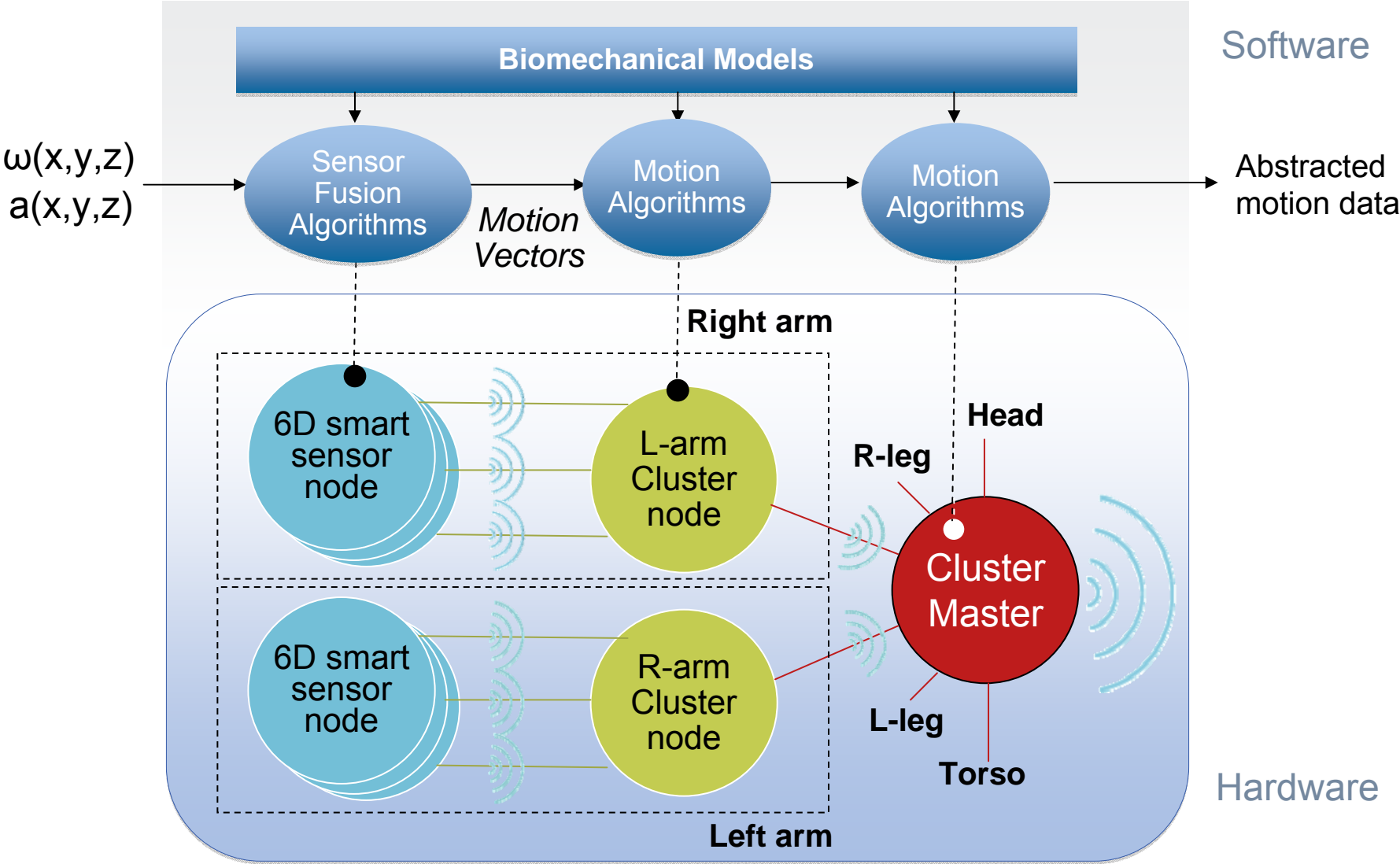
Conclusions

- Sensors are transforming the way we *interact* with our electronic devices

- Sensors will provide mobile applications and internet services with *context* awareness

- *Low-energy wireless connectivity* is enabling deployment of embedded sensors in clothing, sports and medical equipment and even everyday objects

- Cost and technical issues remain, driven by user experience and expectation, but are being addressed by
    - Advances in MEMS technology, integration and packaging
    - Smart sensor integration and distributed processing
    - Rigorous design for energy conservation
    - Energy harvesting
    - Scale of sensor deployment in consumer products

- ***Context awareness using wireless sensors provides huge scope for product innovation***

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Freescale achieved
1 billion sensor units shipped milestone
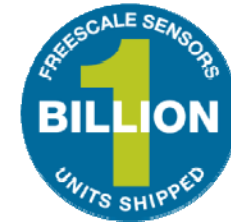
Freescale Sensor Timeline

One Billion and Counting ...

From 1980 to 2009 Freescale has designed, produced and shipped a wide world of innovative sensing solutions

1980
We manufacture our first uncompensated pressure sensor

1982
Pressure sensors are supplied for manifold absolute pressure (MAP) to significantly reduce exhaust emissions and fuel consumption

1985
Sensor products release a Temperature Compensated Pressure Sensor.

Late 1980s
Freescale* begins developing the first surface micromachined inertial sensors for the automotive airbag market

1991
Bipolar integrated pressure sensor production begins

1992 to present
Dedicated supplier to the critical care medical market through shipment of over 80 million units for the invasive blood pressure market

1996
Inertial sensors start volume production

Late 1990s
A new wingback/PDIP Package is developed for the Z-axis inertial sensor

2002
Began providing pressure sensors for respiratory medical equipment

2003
The pressure sensor portfolio expands with the tire pressure monitoring system utilizing capacitive technology to save power

Early 2000s
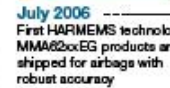Inertial sensor portfolio expands with X-, XY- and Z-axis low-g products for the consumer market

2003
Satellite accelerometers introduced for airbags provide smarter, faster response time deployment

June 2007
Spalding uses the ZSTAR Wireless Sensing Triple Axis Reference design for an intelligent basketball that tracks trajectory

May 2005
Freescale introduces its first 3-axis MMA7260Q low-g inertial sensor alleviating the need for multiple devices

July 2006
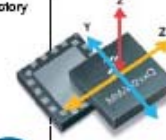First HARMEMS technology MMA62xxEG products are shipped for airbags with robust accuracy

February 2008
Motion-sensing accelerometer enables interactivity of Guitar Hero® and other popular video games

November 2008
Synerject announces its ongoing supply of Freescale pressure sensors for robust, cost-effective ECUs for two- and four-stroke engine management

December 2008
3-axis accelerometers offer reliable, cost-effective freefall detection to help protect data stored on laptop hard disks

June 2009
MPL115A first digital barometric pressure sensor with easy-to-use digital interface, small package and low power

April 2009
MMA7660 intelligent 3-axis digital accelerometer introduced for advanced mobile phone interfaces

2008
TPMS MPXY8300 highly integrated single-package low-power solution:
- Pressure sensor
- 8-bit MCU
- RF transmitter
- 2-axis X- and Z axis accelerometer

100 MILLION   200 MILLION   500 MILLION   1 BILLION

*The Semiconductor Products Sector of Motorola, Inc. became Freescale Semiconductor, Inc. in 2004.

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