# A Wireless Chemical Detection and Environmental Monitor

A development supported by TSWG

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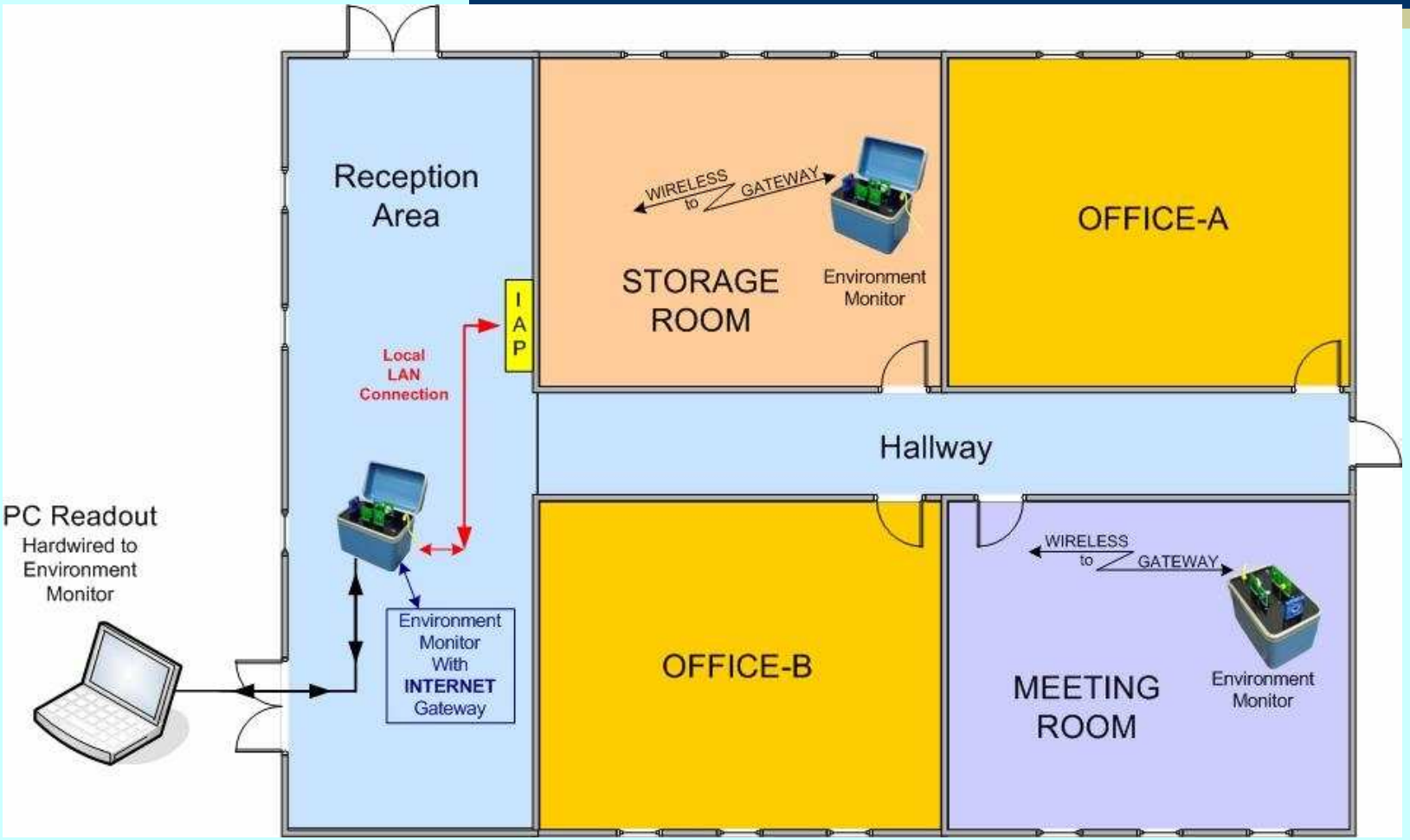
*www.eesensors.com*

Building Protection Working Group Meeting (DHS)
Washington DC, May 2006

# Goals

- Develop a chemical detector/gas monitor to be used with all common, non-remote gas sensor technologies
- Permit interchangeable gas sensor heads with automatic configuration
- Have both wired (Internet/Ethernet) and Wireless (point/point and Mesh) communication
- Read out in standard format and engineering units.
- Have multiple power options

# Monitor Placement in Buildings

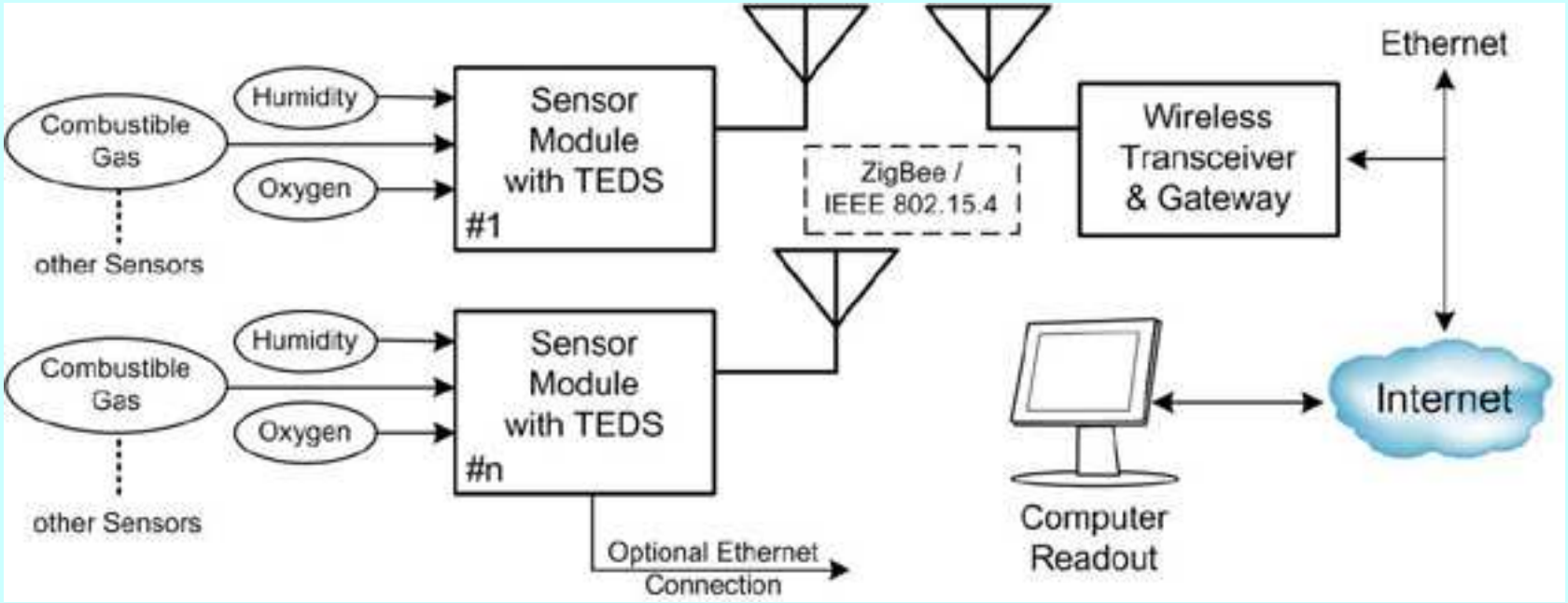


# List of Gas Sensor Technologies
(different gases require different technologies)

- Semiconductor – resistive*
- Semiconductor – voltage*
- Amperometric*
- Catalytic*
- Infrared*
- Photo-ionization
- Fluorescent
- Surface acoustic wave (SAW) & vibrating beam
- Capacitive* and other

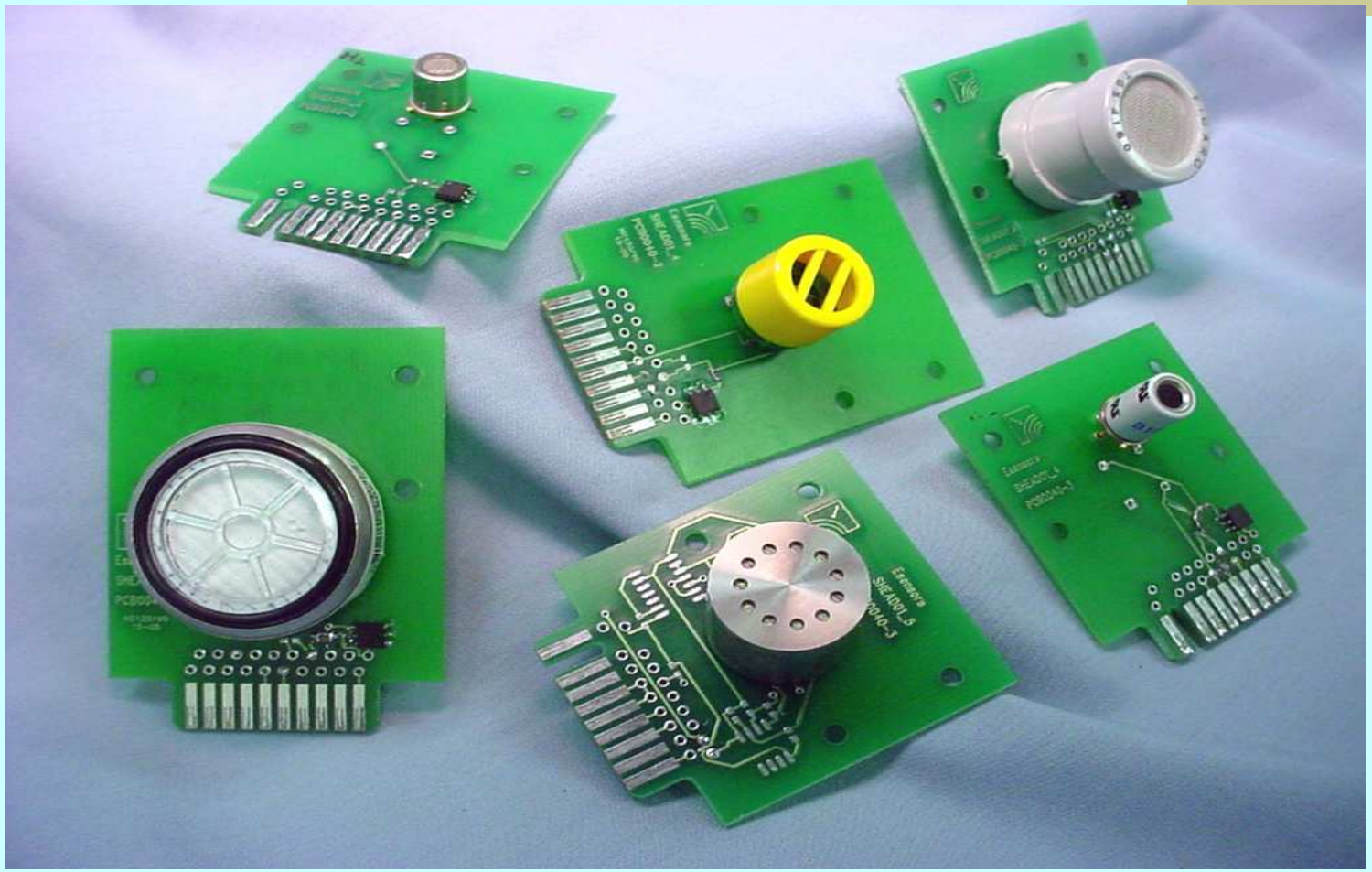
* Tested

# System Block Diagram



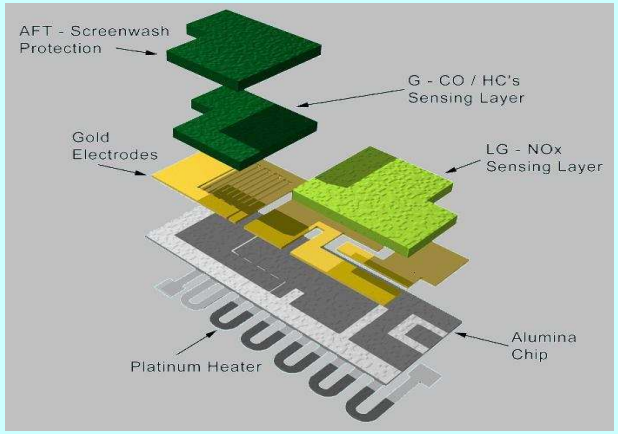

Circuit Details in Backup Slides

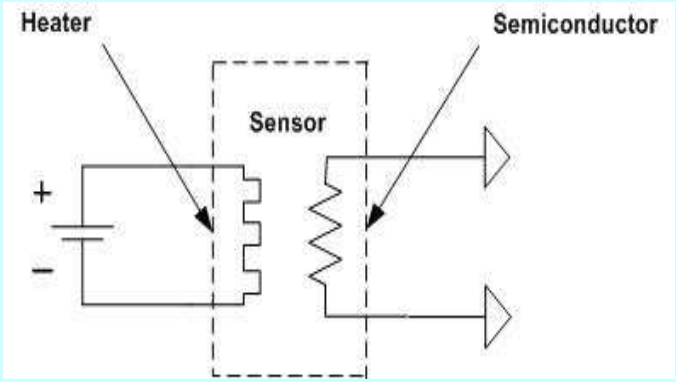
# Photo of Sensor Pods



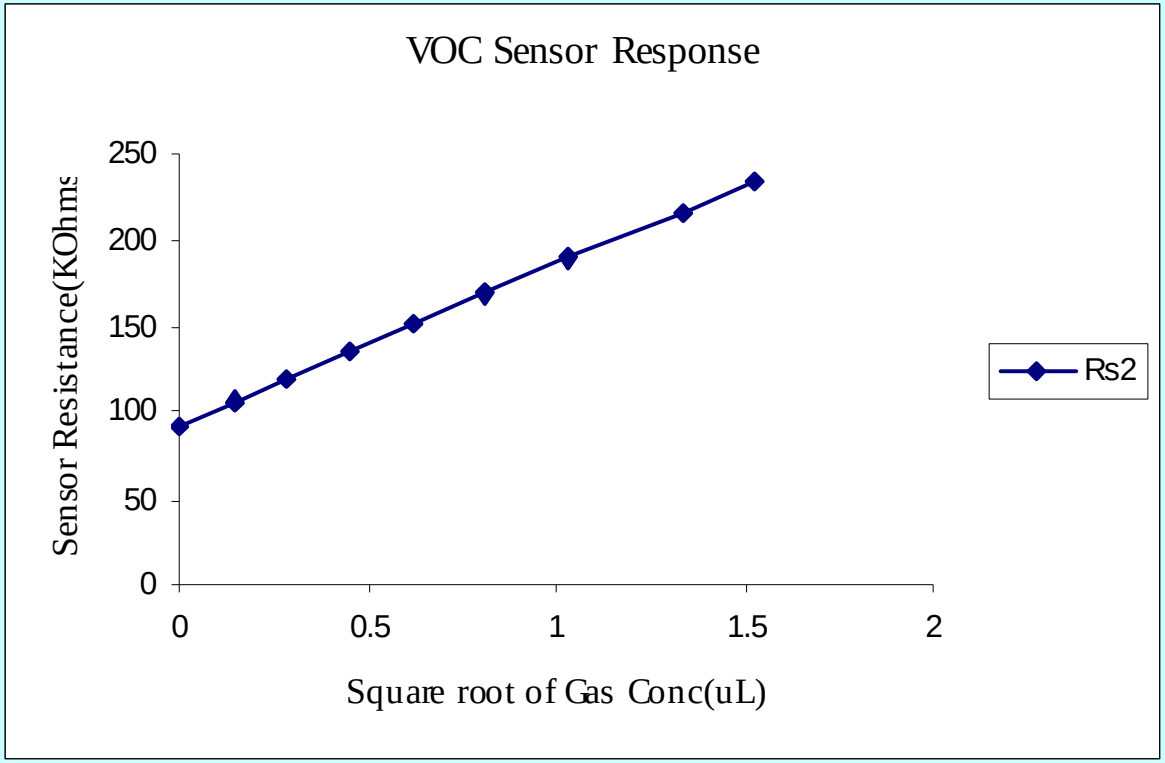
# Sensor Technology Example
## (Metal Oxide Sensor for Volatile Organic Compounds)

- Based on Tin Oxide ($SnO_2$) or similar metal oxide semiconductors
- Surface reaction with ambient gases when hot (350-500 $^oC$)
- Heater (e.g. 4 v @ 100 mA) heats substrate
- Adsorbed gas reduces grain-boundary potential barrier and thus increases conductivity (decreases resistance)
- Delta-R is a function (approx. log or square root) of gas conc. (ppm)



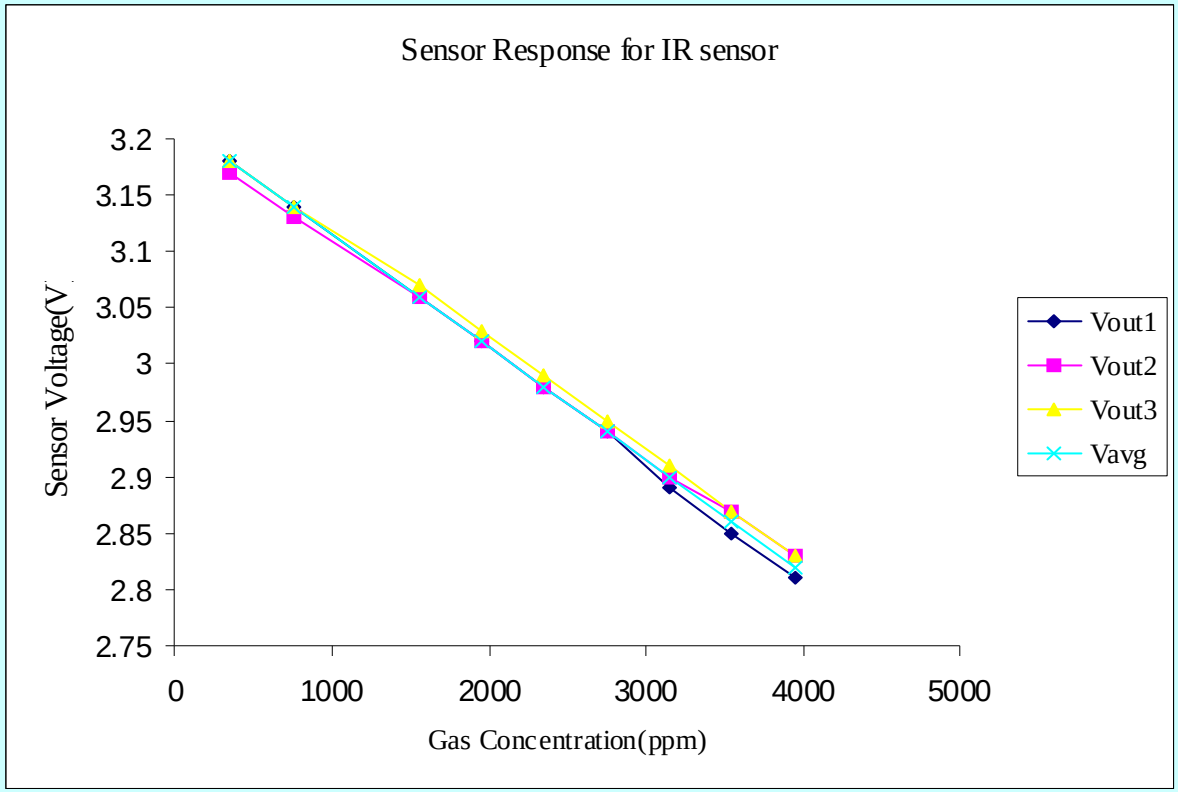



# Response of a VOC sensor (MOS) to Acetone Vapor

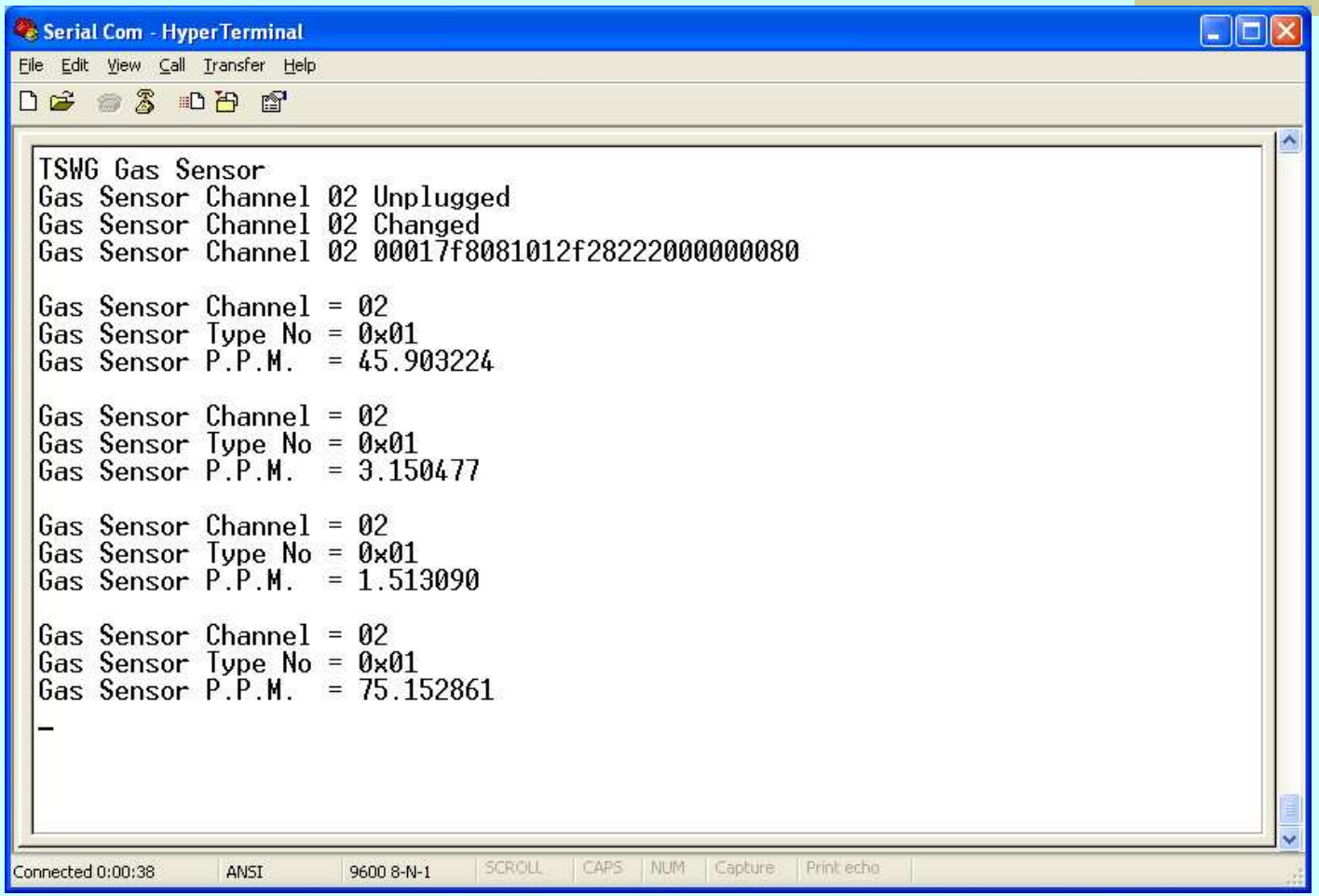



Measured at analog test point

# Response of a IR sensor to Carbon Dioxide Gas

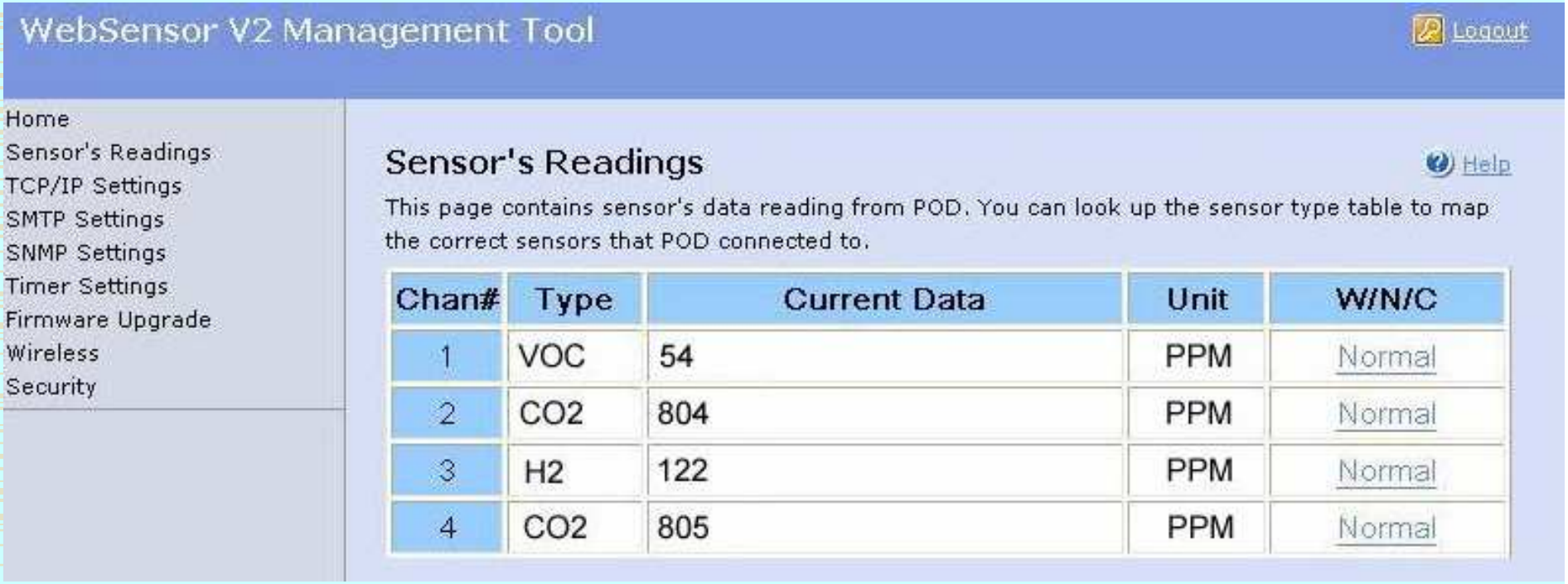


# Sensor Pod Diagnostic Screen (VOC data with plug&play)



# Response in Engineering Units

Data not encrypted (password optional)



# List of Gas Sensors

***HVAC/Environmental***

- Carbon dioxide
- Humidity /Temperature
- Smoke
- Air Flow

***Industrial gases***

- VOC (e.g. acetone, benzene)
- Combustible gases (e.g. methane)
- Carbon monoxide
- Oxygen
- Sulfur dioxide
- NOx (Nitric oxide, Nitrogen dioxide)
- Hydrogen chloride
- Hydrogen sulfide
- Hydrogen

***Decontamination gases***

- Hydrogen Peroxide Vapor
- Chlorine dioxide/chlorine
- Methyl bromide
- Ozone
- Ethylene dioxide

***Toxic gas sensors***

- Hydrogen cyanide
- Arsine
- Phosphine
- Phosgene

# Communication Options

- Internet via Ethernet

  TCP/IP protocol similar to websensor

- Wireless (RF) Point-to-point

  433 MHz  (Chipcon)

- Full-feature wireless network (IEEE 802.15.4/Zigbee)

  Scheduled transmissions for power reduction, node-to-node hopping, collision recovery, error handling

# Data Readout from local wireless receiver

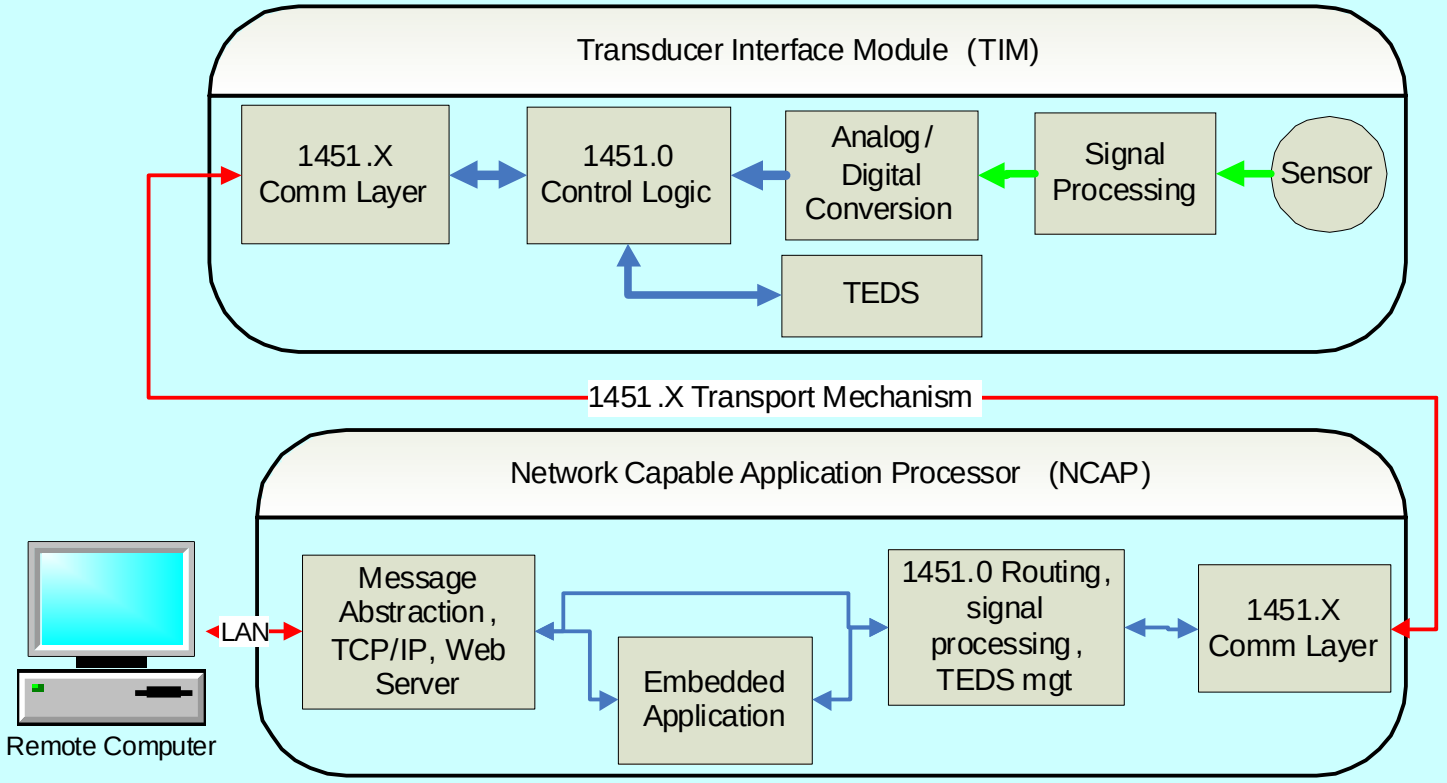
# Power Supply Options

- Power over Ethernet (POE)
- External wall-mounted supply (9 to 20 volt)
- Internal rechargeable battery (9.2 volts) -- Up/down charger source is POE or external supply
- Alternative external battery (9 volt nominal) --Will work from 6 to 20 volts

# Description of IEEE 1451 Smart Transducer Standard

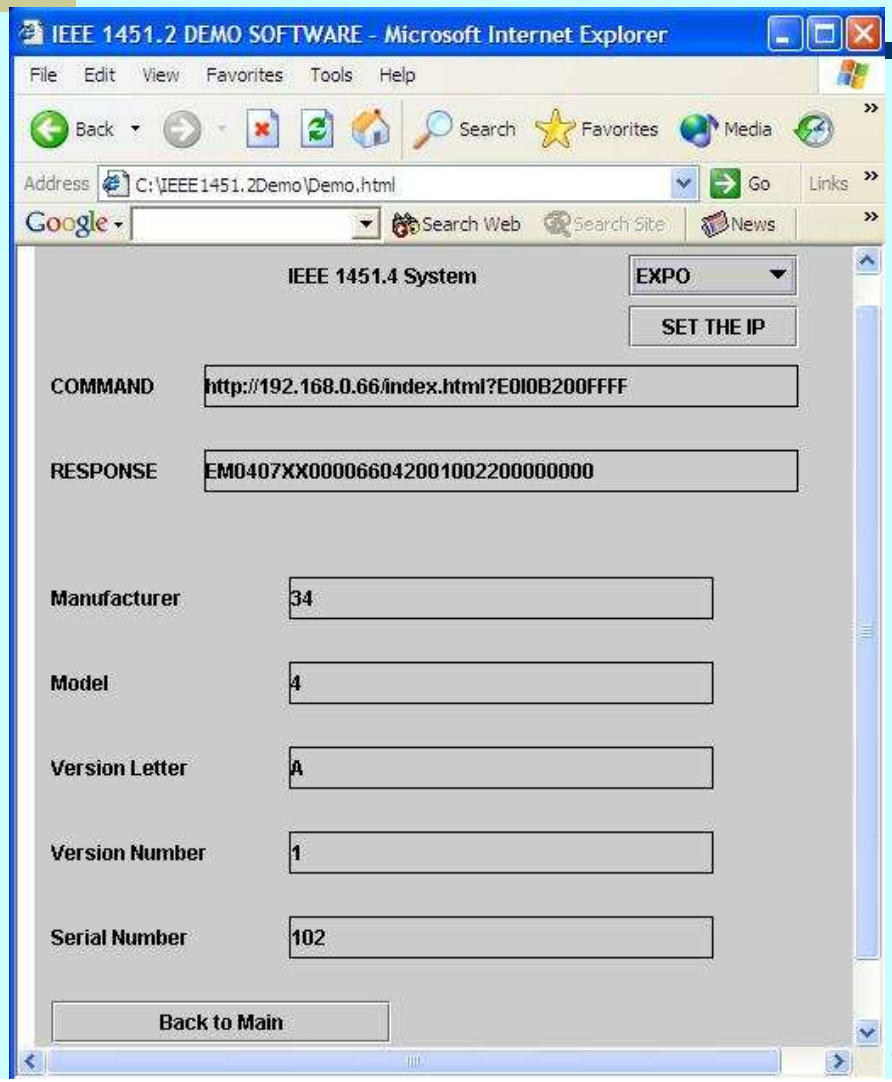
- A Universal Plug and Play Standard for Digital Sensors
- Supported by National Institute of Standards and Technology (NIST)
- Being considered for adoption by DHS, DOD, DOE, OGC and NASA.

# IEEE 1451 Smart Transducer Concept




IEEE 1451

# Basic Dot 4 TEDS




Basic TEDS (8 bytes)

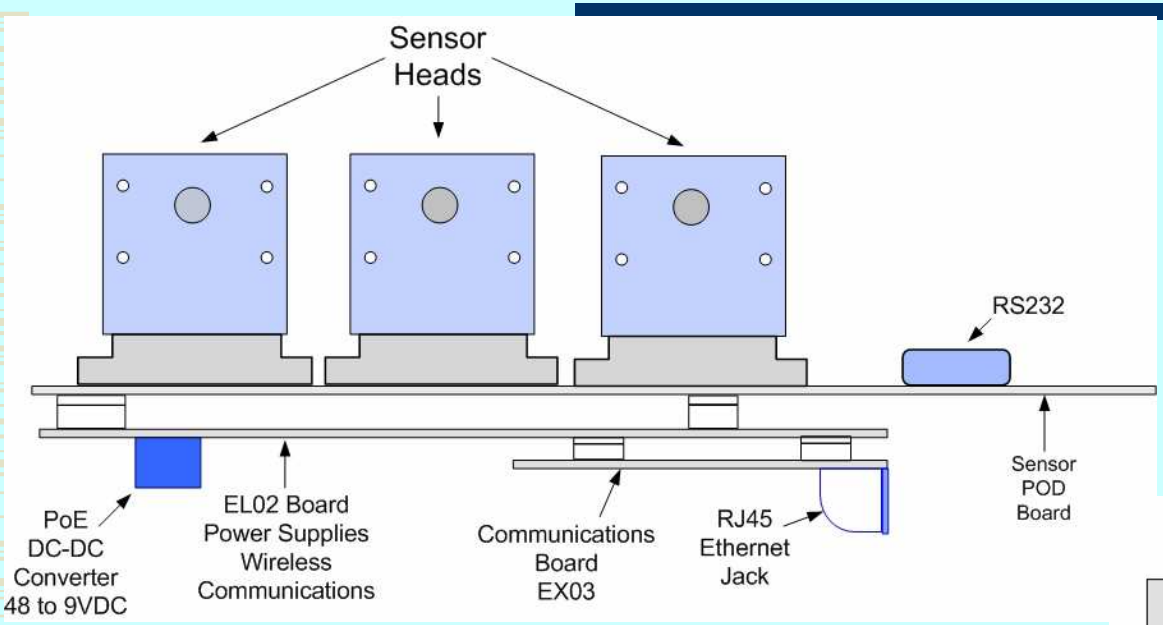
- Manufacturer ID (14 bits)
- Model Number (15 bits)
- Version Letter (5 bits, A-Z)
- Version Number (6 bits)
- Serial Number (24 bits)

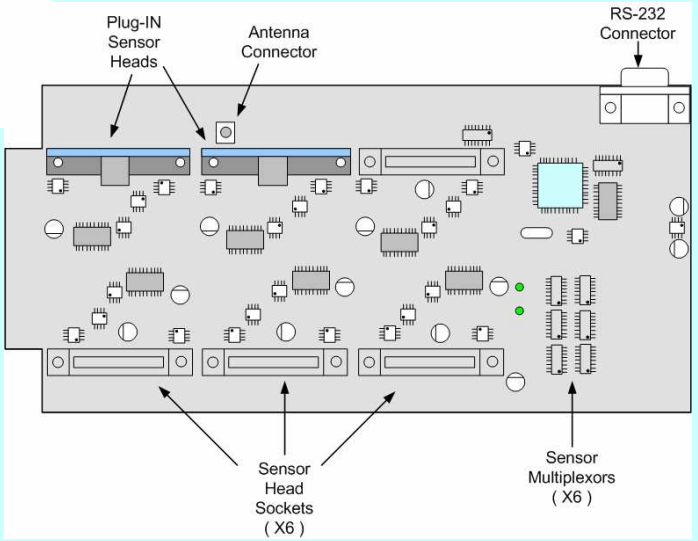
# IEE 1451.0 (Dot 0) Format

- TEDS [Memory block with defined format]
  - MetaTEDS
  - Meta-ID TEDS
  - Channel TEDS
  - Channel-ID TEDS
  - Calibration TEDS
  - Xdr-name TEDS
  - Phy TEDS
- Data Transmission [specific octet format]
  - TEDS/Status requests
  - Triggering and configuration
  - Sensor read commands and data return
  - Actuator write commands and data sending

IEEE 1451

# Sensor Pod Board Organization



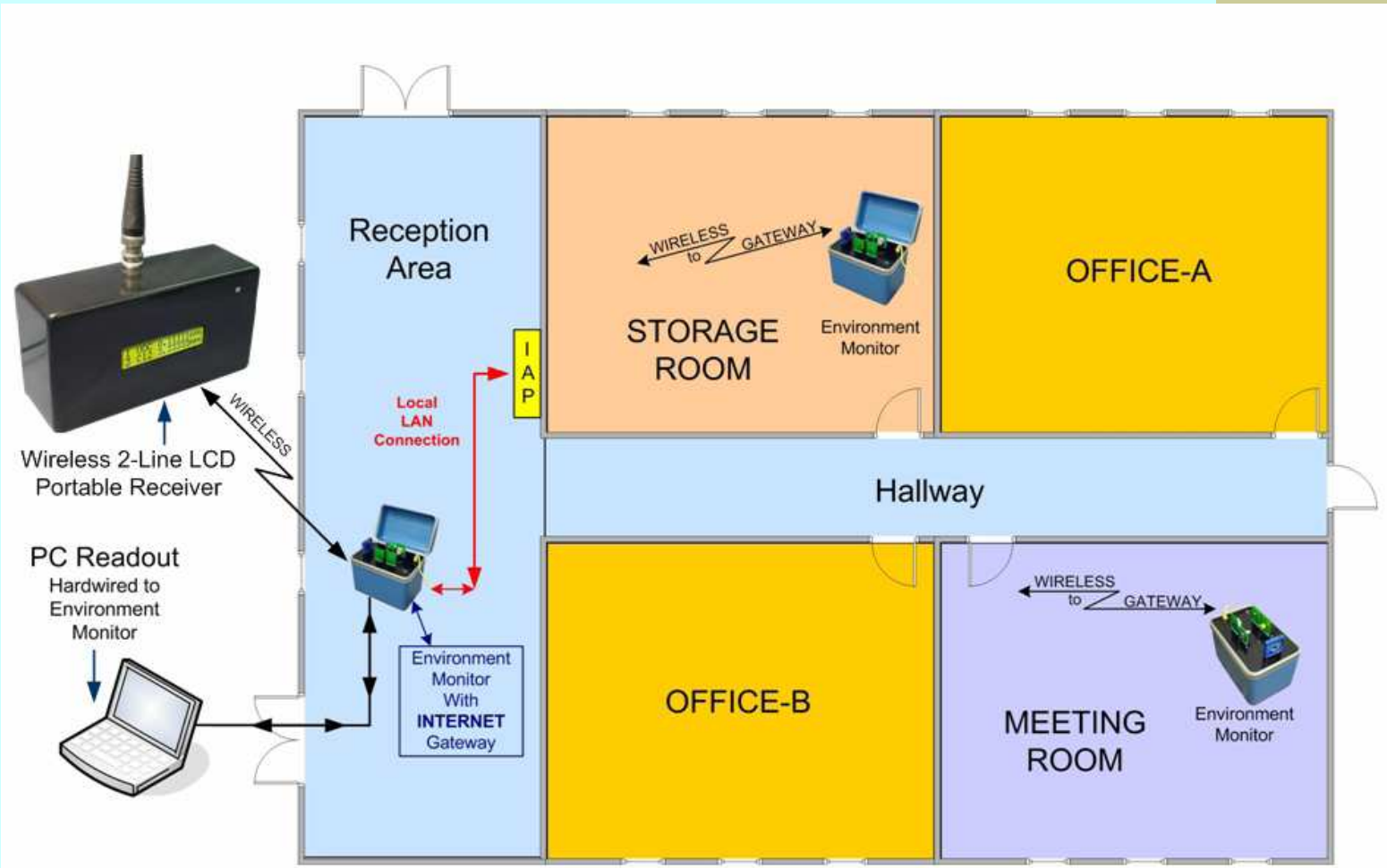

Sensor heads interchangeable (configured for specific task)

# Monitor Photo

## -- 6-pod version for Decontamination applications--


Soon: 4-pod version
For environmental monitoring

# Monitor Placement in Buildings
(with three optional readouts)



# Production Price Considerations

- Production cost $2000
- OEM price (Prod cost x 1.75) $3500
- List price (OEM price x 1.60) $5600
- Breakdown
  - Control board (EX03) 4%
  - Supply/communication board (EL01) 20%
  - Sensor board (POD01) – 6 position 32%
  - Sensor heads (6), typical selection* 28%
  - Functional (gas response) testing 16%

Note: These prices are for tested but uncalibrated sensors.

*The price of the sensor elements varies considerably. Common gases (e.g. CO) are less expensive, and toxic gases are more.

# Summary

- Design goals for monitor have been met
  - Adapts to sensor pods of various technologies
  - Implements plug and play
  - Readout in standard engineering units
  - Internet/Ethernet and Wireless (Chipcon/Zigbee) communication
  - Uses IEEE 1451 smart transducer standard
  - Multiple battery and power supply options
- Expect to start 6-pod version production this summer
- Other versions (e.g. 4-pod) expected soon

A development supported by TSWG

# Backup Slides

Esensors Inc

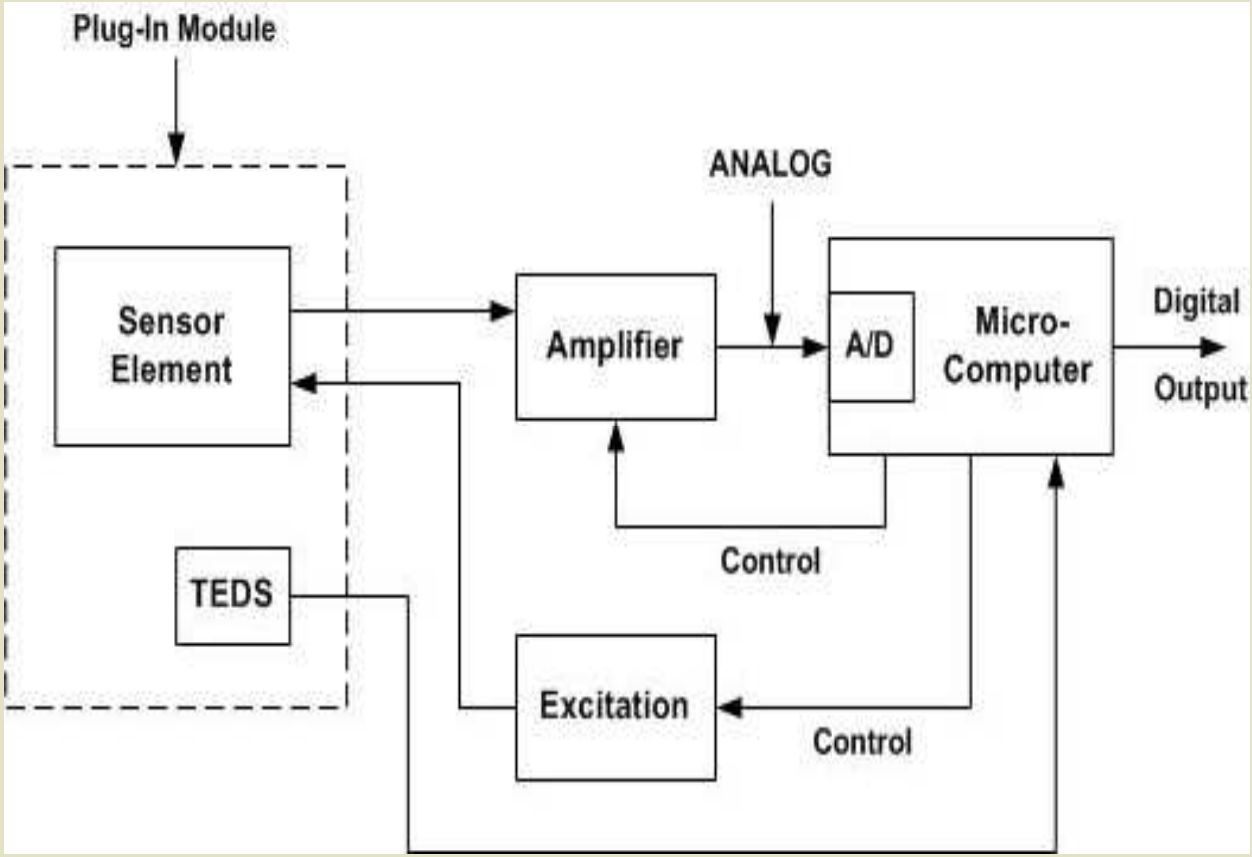
A Wireless Chemical Detection and Environmental Monitor

Darold Wobschall

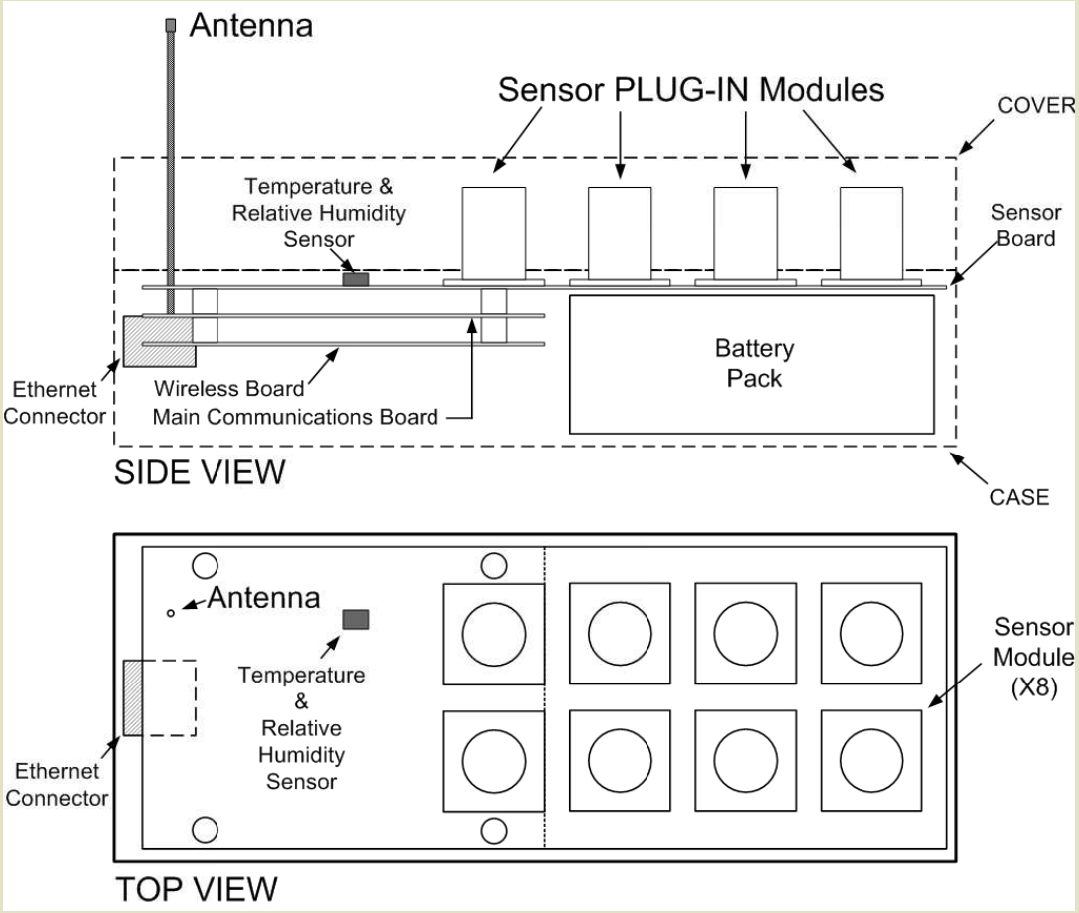
# TSWG Project Goals
(from proposal)

- Primary: Measure concentration of gases in buildings being de-contaminated
- Secondary: Measure air quality in commercial buildings
- Sensor pod/module with 6 interchangeable sensor heads (out of a list of 20), including mixed sensor types
- Auto configuration (self-organizing or plug & play), both for sensor interchange and modular interchange/additions
- Wireless (Chipcon, Zigbee) and Internet/Ethernet communication
- Battery operation with multiple options (POE, non-rechargeable, line) – 40 hours (longer with infrequent readings)

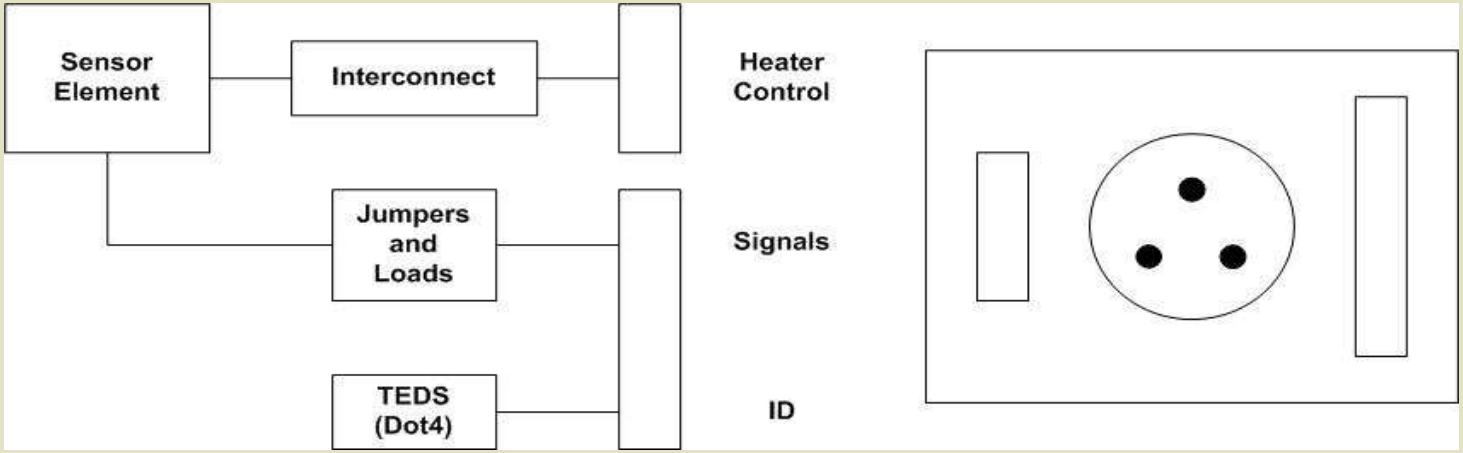
# Block Diagram of Plug-in Sensor Module



# Sensor Pod Board Organization



# Sensor Head Block Diagram



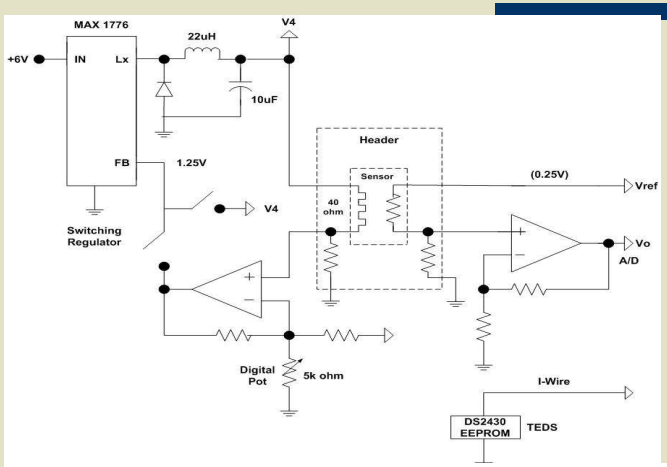

* Technologies Accommodated

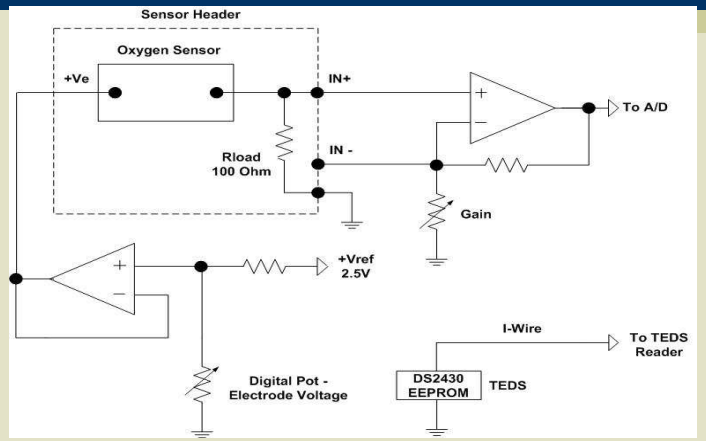
**Semiconductor with Heater (e.g. CO) – 3 Types**

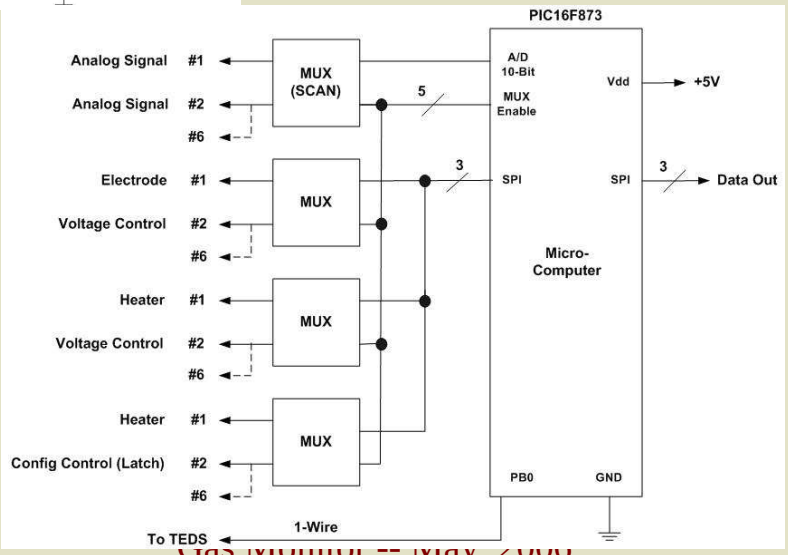
**Amperometric (e.g. $O_2$) – 2 Types**

**Catalytic (e.g. Methane) – 2 Types**

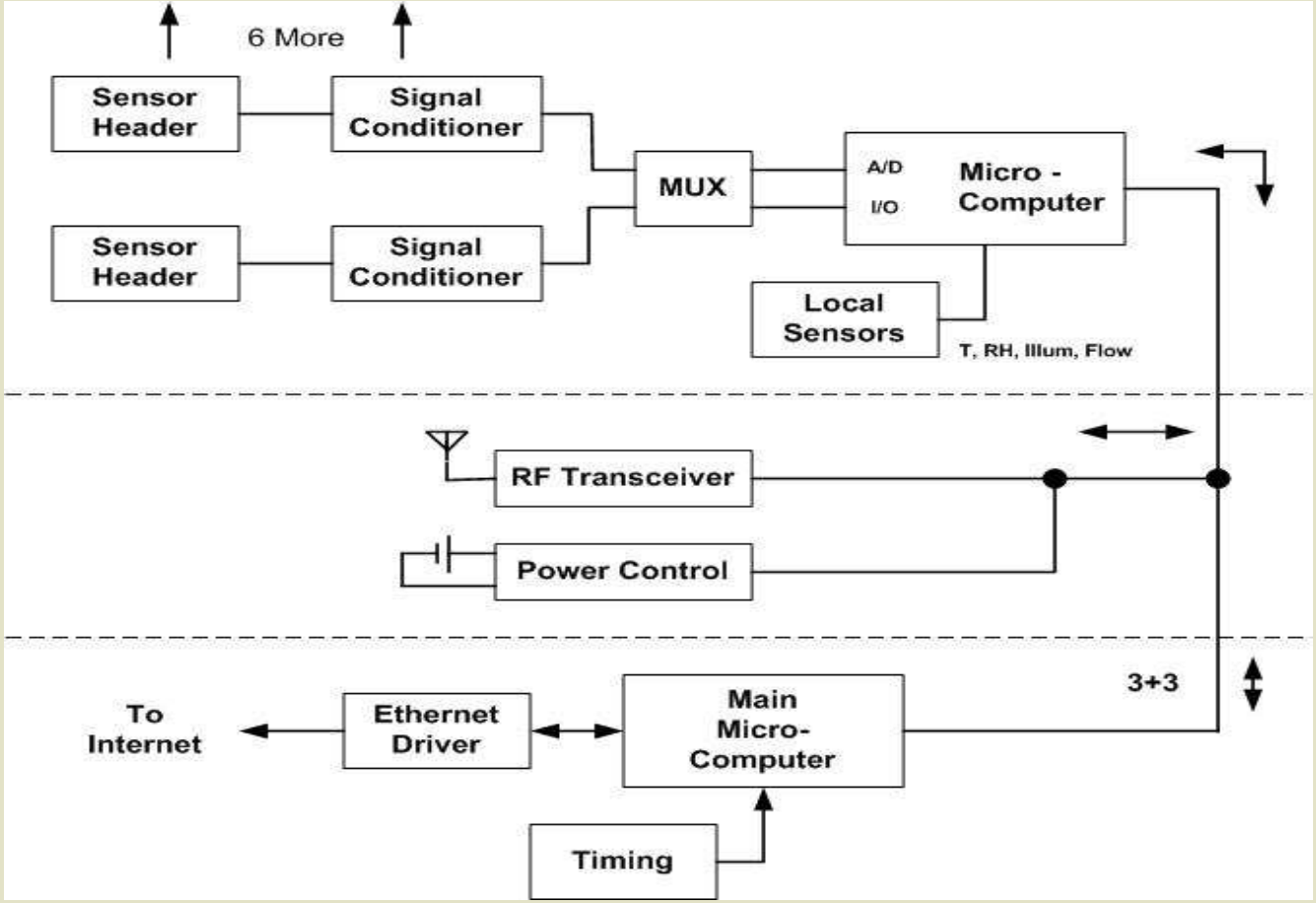
# Sensor Signal Conditioners



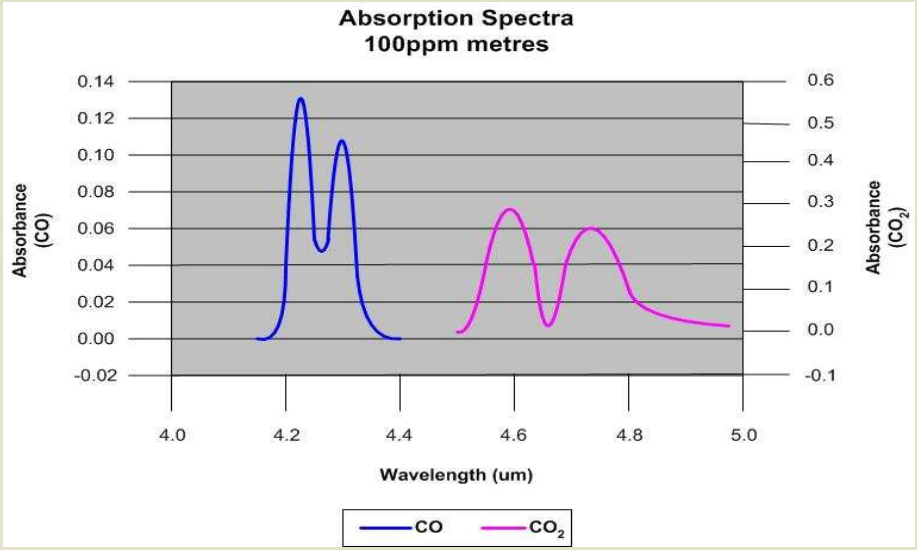
# Sensor Pod Block Diagram



# Infrared Absorption Sensor Technology

- Some gases absorb light at particular IR wavelengths
- $I/Io = e^{-Ax,}$ where I/Io is light absorbed during transmission,

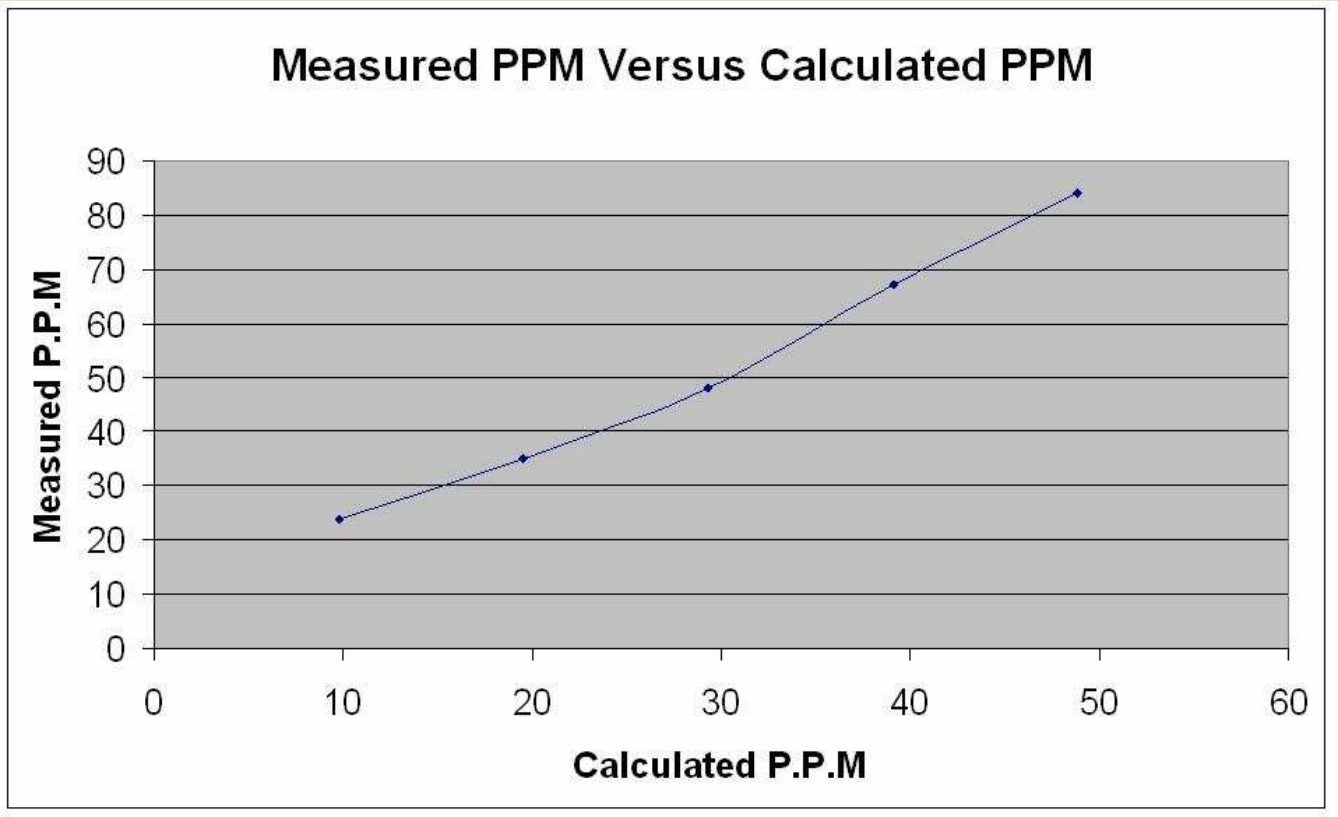
  x is path length and A is absorption coef. at specific wavelength
- Transmission filters select specific wavelength bands
- A is proportional to gas concentration
- IR sensors reproducible but not sensitive (need high conc or long paths)



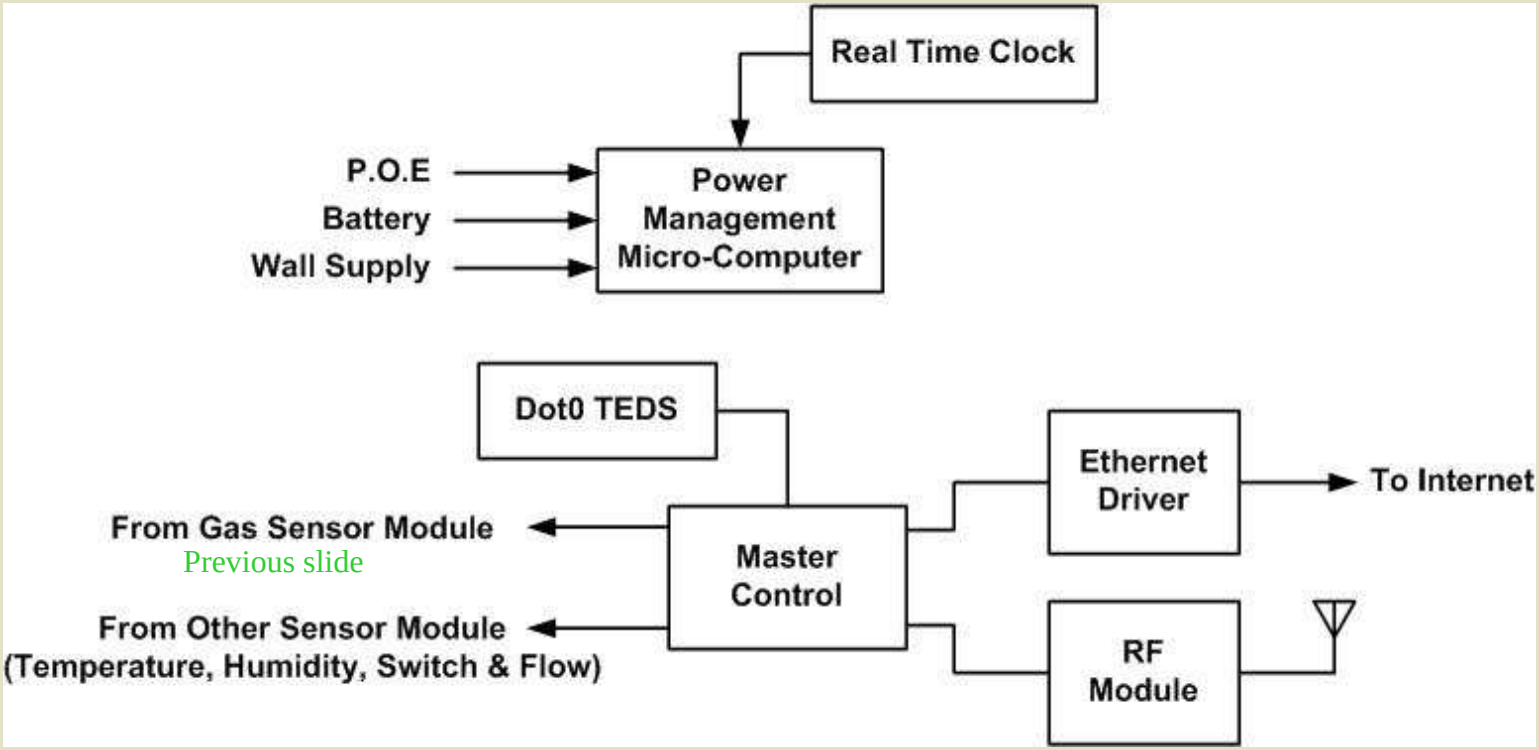
# Testing of
# - Gas Sensors -

- Need known concentrations of target gas for quantitative testing.
- Puffs of related non-toxic gases are suitable for qualitative testing (nearly all gas sensors have cross-sensitivities).
- Most tests of signal conditioner electronics and communications are done initially with simulated test signals.
- Quantitative testing are being done at the Univ. at Buffalo where proper equipment (e.g. fume hoods) is available.
- While some gases are very toxic, the tests will be done with highly diluted gases to minimize hazard to personnel.
- Our sensors will be calibrated, one at a time, against laboratory style monitors for specific gases (e.g. chlorine).
- The goal is to verify that the sensors are functioning properly in the range they operate. Certifiably accurate calibrations will not be made.

# Response of VOC Sensor to Ethanol
## (using manufacturer's calibration)



# Monitor Block Diagram



# Master/Internet board (EX03)

- Master microcomputer board controls scanning, schedules communication and handles Internet/website functions.
- Similar to websensor EX01/EX02 boards but with considerably more memory and speed. EX04 under development.
- Hardware design finished and tested.
- Internet/Ethernet and inter-board communications working well
- POE included

# Zigbee Wireless Status

- Three manufacturers of hardware (IEEE 802.15.4)
- We chose Motorola/Freescale (and have eval. unit)
- Compiler with Zigbee software being used (no need to join Zigbee alliance.
- We have constructed and tested Zigbee prototypes
- But full mesh net software still not yet available and IEEE 1451 protocol not yet available for Zigbee

# Monitor RF Transceiver (Point-to-point version)

- Based on Chipcon CC1000 transceiver IC
- Transmitter/receiver bands programmable
- Data send in bursts (433 MHz)
- FM Manchester encoding
- All transmissions have address/ID information
- Sync and CRC characters added
- Range of 30-100 meters
- Received messages retransmitted (repeated) along with local data

# RF Transceiver
## (Zigbee option)

- 2.4 GHz, spread spectrum
- Mesh network protocol
- Data transfer from node (monitor) to node
- Timed transmission option
- IEEE 1451.5 profile not yet available
- Simplified version tested

# Gateway Specifications

- Gateway is any monitor connected to Internet (via Ethernet) – it has dual function.
- All wireless messages are retransmitted to Internet without sorting or checking for duplication.
- Local readout is PC (laptop) connected via Ethernet to Gateway/monitor.

# IEEE 1451 Update

- IEEE 1451.4 TEDS is used for sensor ID and calibration
- Currently a version of SNAP format is used for wireless data transfer.
- HTTP is used for Internet data transfer (not yet IEEE 1451.0 or Dot 0 format)
- IEE 1451.5 (Dot 5) and Dot 0 are finished and in the process of being approved.
- Dot0 provides API (Application Programming Interface) and TEDS (Transducer Electronic Data Sheet).
- No Dot0/Dot5 compilers yet available (graduate student working on this)

# Transducer Electronic Data Sheet (Dot 4 TEDS)

- UUID (Universal **Unique** Identifier)

  Supplied by EEPROM (DS2433) manufacturer (6 bytes)
- Basic TEDS (8 bytes)
  - Model Number (15 bits)
  - Version Letter (5 bits, A-Z)
  - Version Number (6 bits)
  - Manufacturer ID (14 bits)
  - Serial Number (6 bits)
- Manufacturer's TEDS

  Sensor type and calibration parameters (16 bytes)

# Dot 4 to Dot 0 Format Conversion

- Monitor is TIM, except gateway function is NCAP
- No standard method of Dot 0 to Dot 4 conversion
- UUID (10 bytes) least significant bits are Dot4 UUID (6 bytes, chan 1)
- Dot 0 channel # is (gas) sensor number
- No calibration TEDS (this model) since linearization and calibration done in TIM and not NCAP
- Dot 4 basic TEDS transferred to Dot 0 Channel-ID TEDS

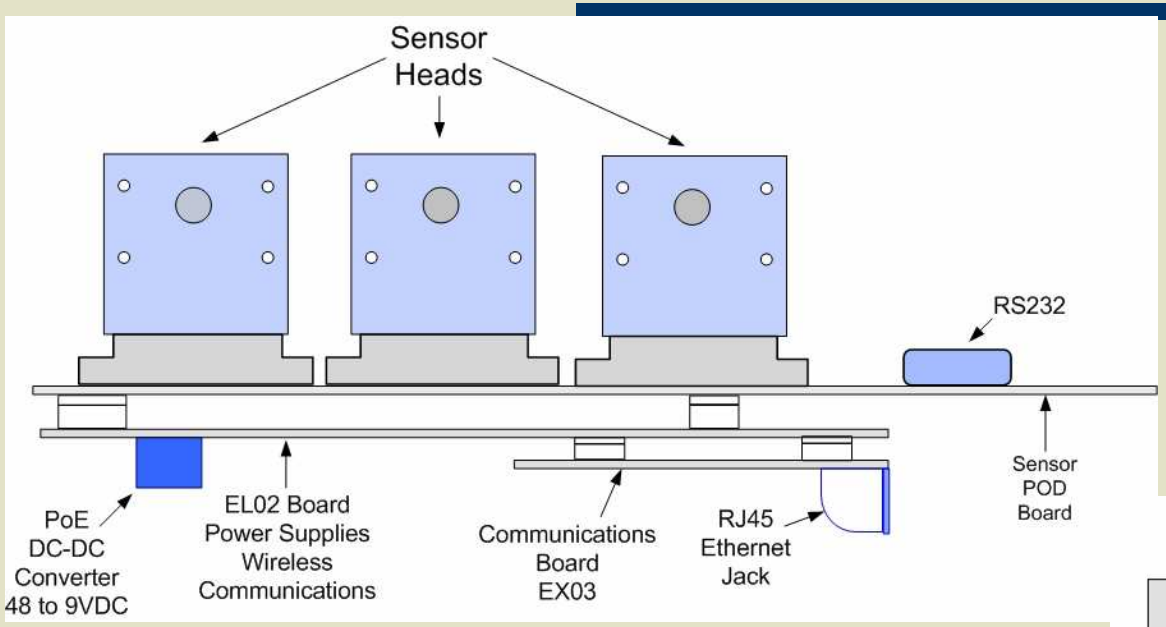
# Gas Sensor Test Chamber

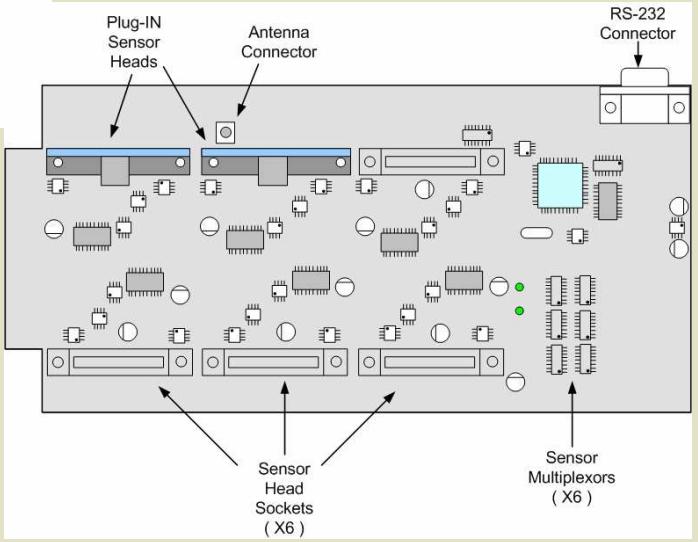
- Known volumes of gas or solvent are injected into chamber in small increments
- Fan vaporizes and distributes
- Data (analog or digital) collected and plotted.

# Battery Features

- Internal rechargeable battery is 9.2 volts (eight 1.2 v nickel metal hydride cells, -- C size)
- Charger source is POE or external supply
- Charger has been tested (moderate charge rate of 0.3 amps for overnight charge)
- External wall-mounted supply ( nominal 12 volts, with 9 to 20 volt range – charger is step up/down)
- External non- Internal rechargeable battery, nominally 9 volt (6 to 20 volts) is alternative source

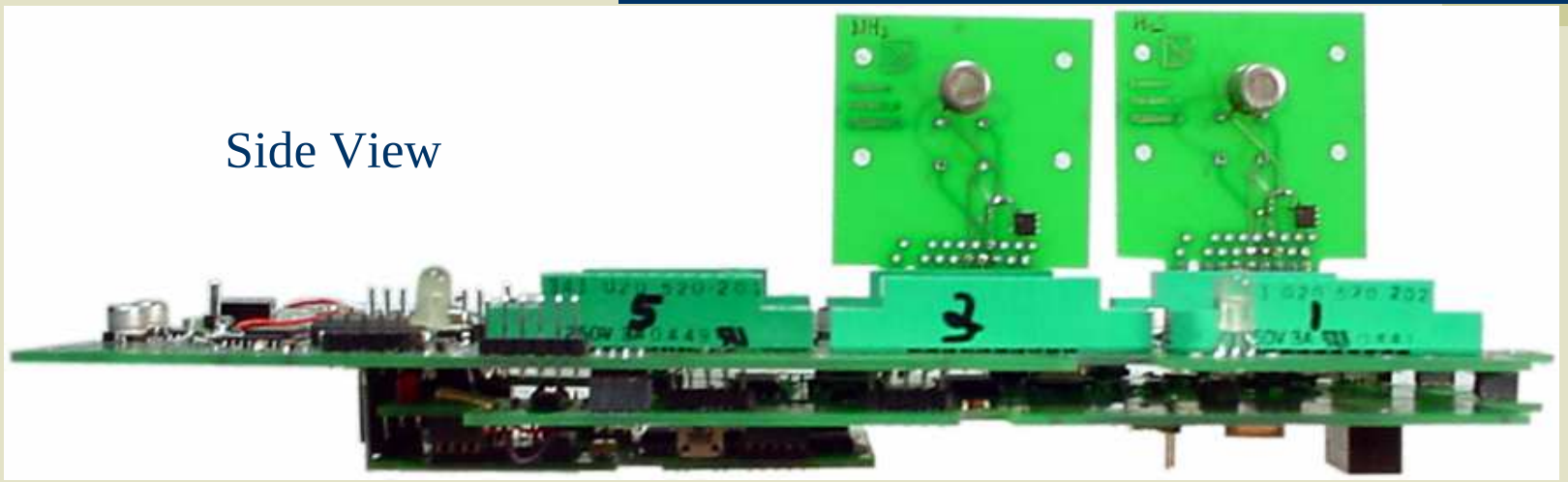
# Sensor Pod Board Organization



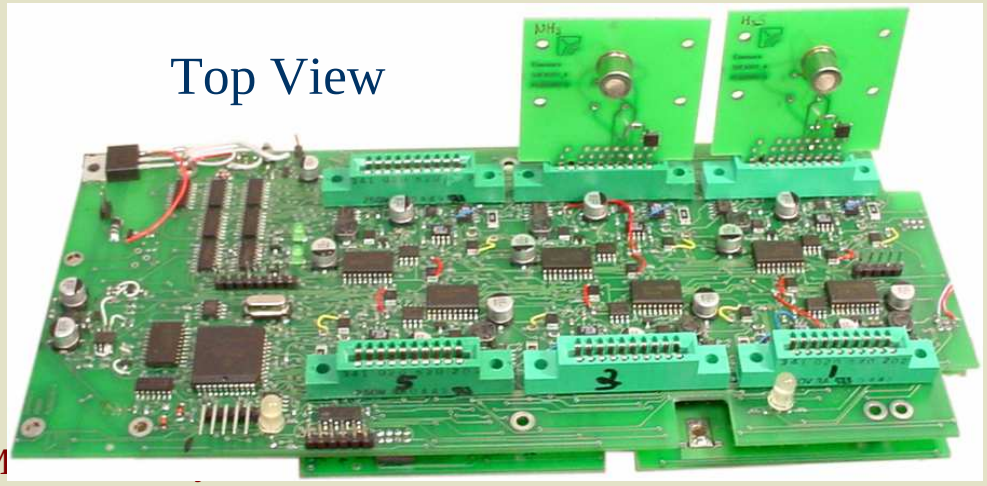



# Board Interconnection

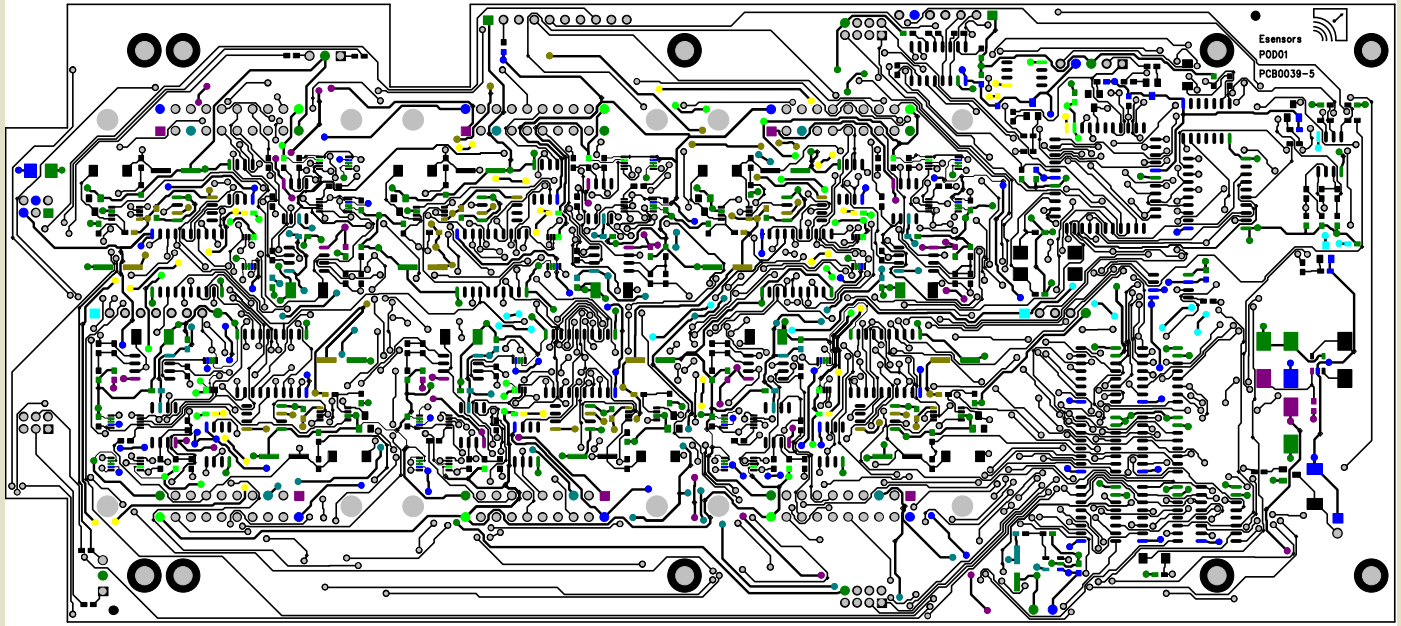
Side View



Top View



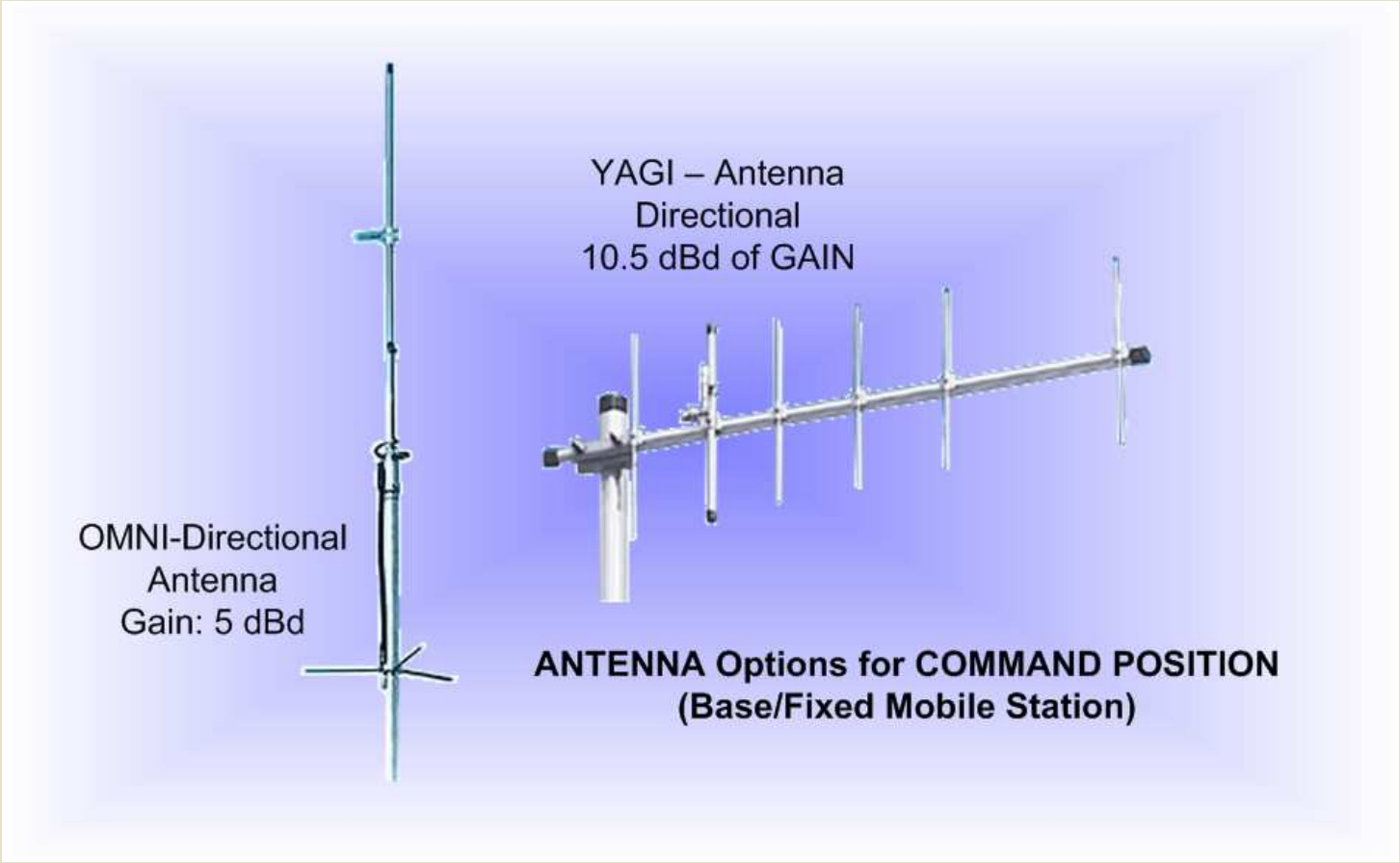
# Photo of Pod board
## (POD01, without components)




TOP SIDE ARTWORK (LAYER 1)

PCB0039-5 REV 1

# Antenna Considerations



# Case Considerations

- Need space for
  * 3 boards under panel
  * Internal rechargeable battery (8 Ni metal hydride) at bottom of case
- Need room above panel sensor heads with hood, air circulation and fan
- Room on cover for non-rechargeable batteries (6 C cells)


# Production Price Considerations

- Production cost $2000
- OEM price (Prod cost x 1.75) $3500
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- Breakdown
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# References


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- D. Wobschall, "A Minimal Dot4 NCAP with a Compatible Sensor Bus," Sicon/05 (Houston, Jan 2005).
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