Kennedy Space Center Smart Sensors

presented by Rebecca Oostdyk

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Outline

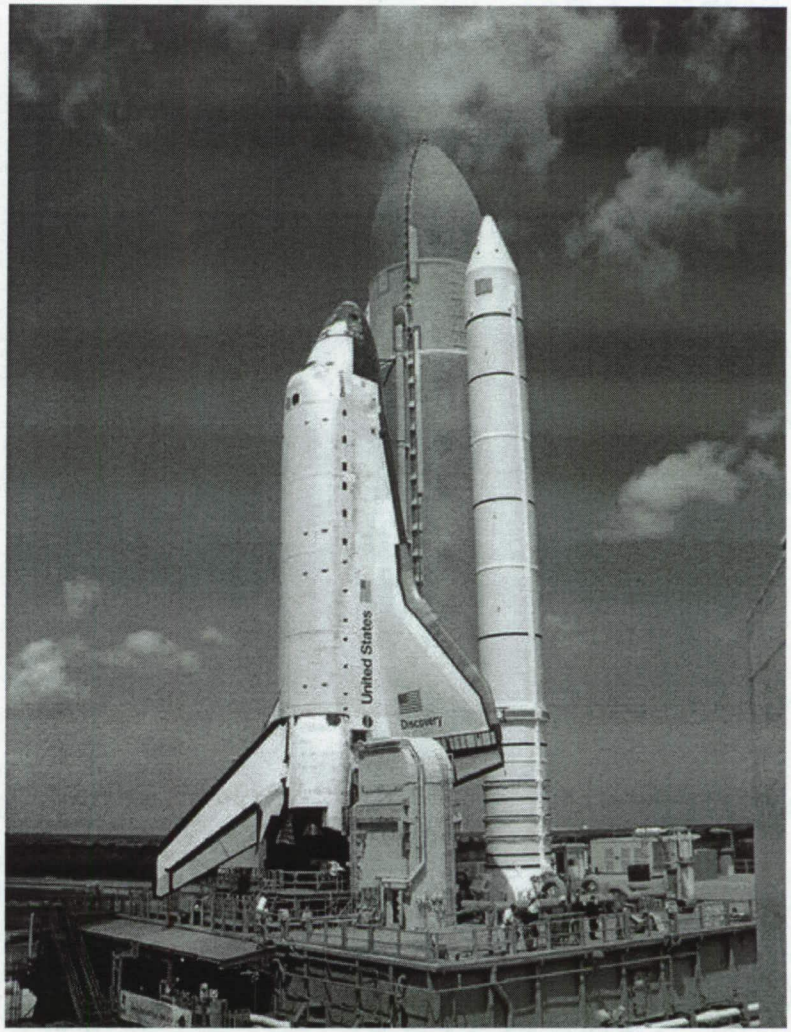
- *Problems with the current KSC instrumentation systems*
- *Smart Sensors*
  - *What they are*
  - *How IEEE 1451 relates*
  - *How they can help*
- *KSC's Smart Sensors*
  - *Architecture*
  - *Features and contributions to the state-of-the-art*
- *Future Research*

Introduction

- *At KSC, both ground and flight systems are instrumented with sensors to monitor critical processes*
- *Sensor failure, and the need to regularly calibrate sensors, can cost KSC significant amounts of money*

Case Study: Engine Cutoff Sensor

- *STS-114 Return to Flight*
- *1 of 4 engine cutoff (ECO) sensors indicated the tank was full when it was empty*
- *The launch was scrubbed resulting in an estimated $616,000 loss*



Source: foxnews.com

Case Study: Calibration Cycles

- *Ground support sensors must be removed on a regular basis for calibration (average every 6 months)*
- *Since KSC has 3000+ transducers in their Ground Support Equipment system, the cost of calibration is sizeable.*
- *By extending the calibration cycle, technicians would not be required to spend as much time maintaining the sensors*

A "Bright" Idea – Smart Sensors

- *Some of the challenges that KSC faces may best be solved with smart sensors*
- *What is a smart sensor?*
  - *Embedded with a Transducer Electronic Data Sheet (TEDS) as defined by IEEE 1451*
  - *Perform signal processing and data verification*
  - *Able to communicate with other sensors*
  - *Configurable*
  - *Able to report data and health information to higher level systems*

IEEE 1451 Family of Standards

- *IEEE 1451.1 Network Capable Application Processor (NCAP) Information Model*
  - *Network-level, object-oriented model for 1451 devices*
- *IEEE 1451.2 Transducer to Microprocessor Communication Protocols and TEDS Formats*
  - *Specification for TEDS*
  - *Digital interface for accessing TEDS, reading sensors and setting actuators*

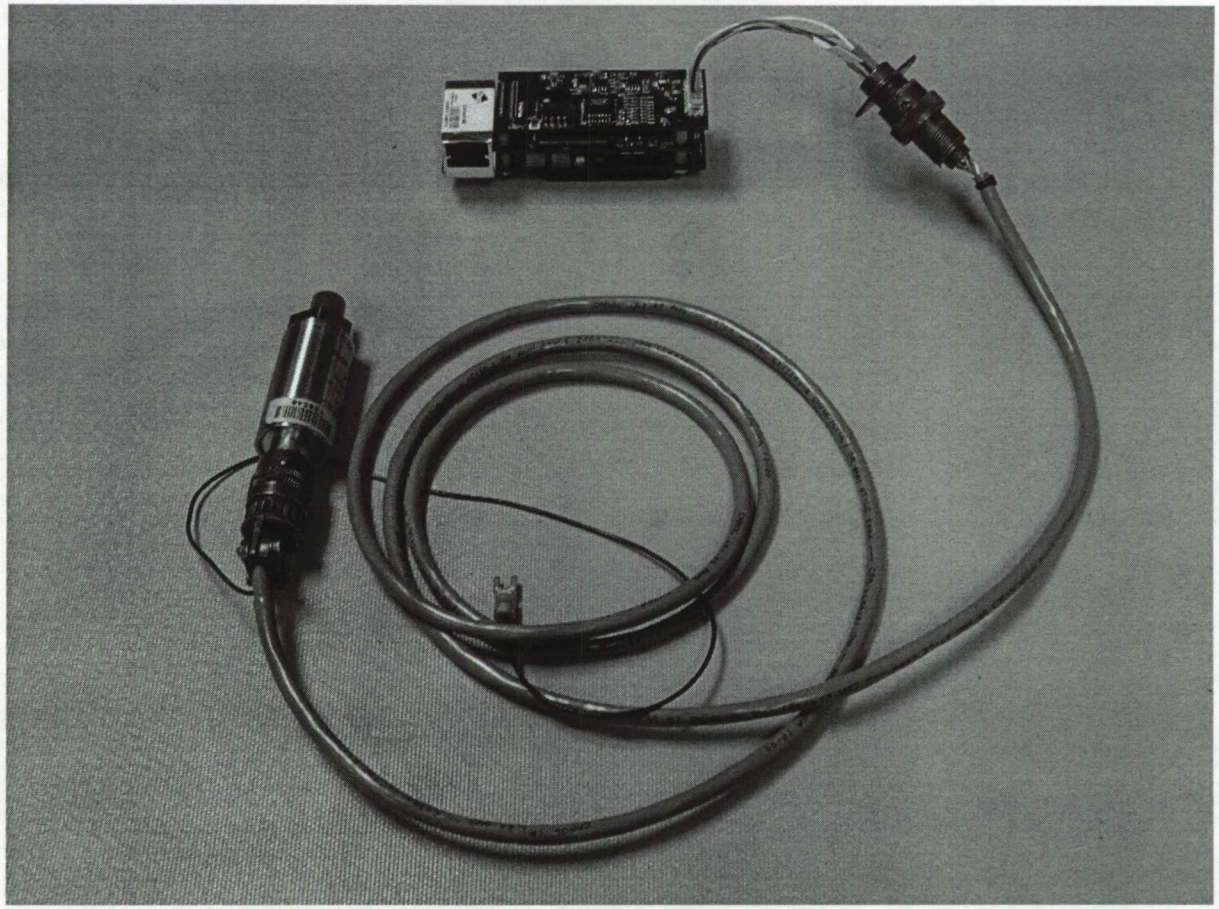
IEEE 1451 Standards (cont.)

- *IEEE 1451.3 Digital Communication and TEDS Formats for Distributed Multidrop Systems*
  - *Specification for NCAPs with multiple sensors and actuators*
- *IEEE 1451.4 Mixed-Mode Communication Protocols and TEDS Formats*
  - *Support for legacy sensors*
  - *Combining analog and digital communication buses*

Why Smart Sensors Make Sense

- *Convert analog signals into digital for more reliable communication*
- *Provide data verification*
- *Give health information*
- *Capable of self-diagnosis and self-healing*
- *Configurable via a network*
- *Can extend calibration cycles*

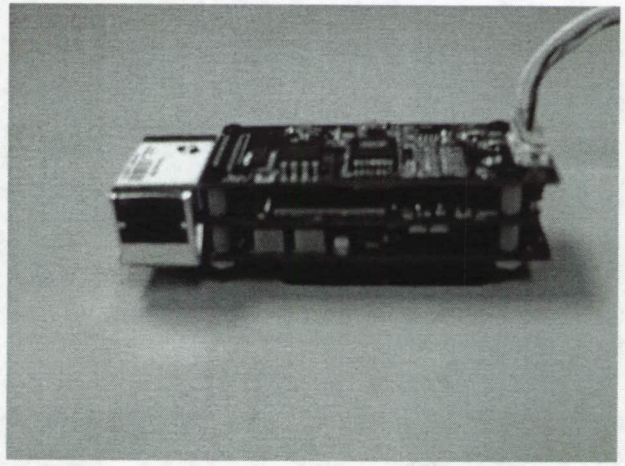
The KSC Smart Sensor

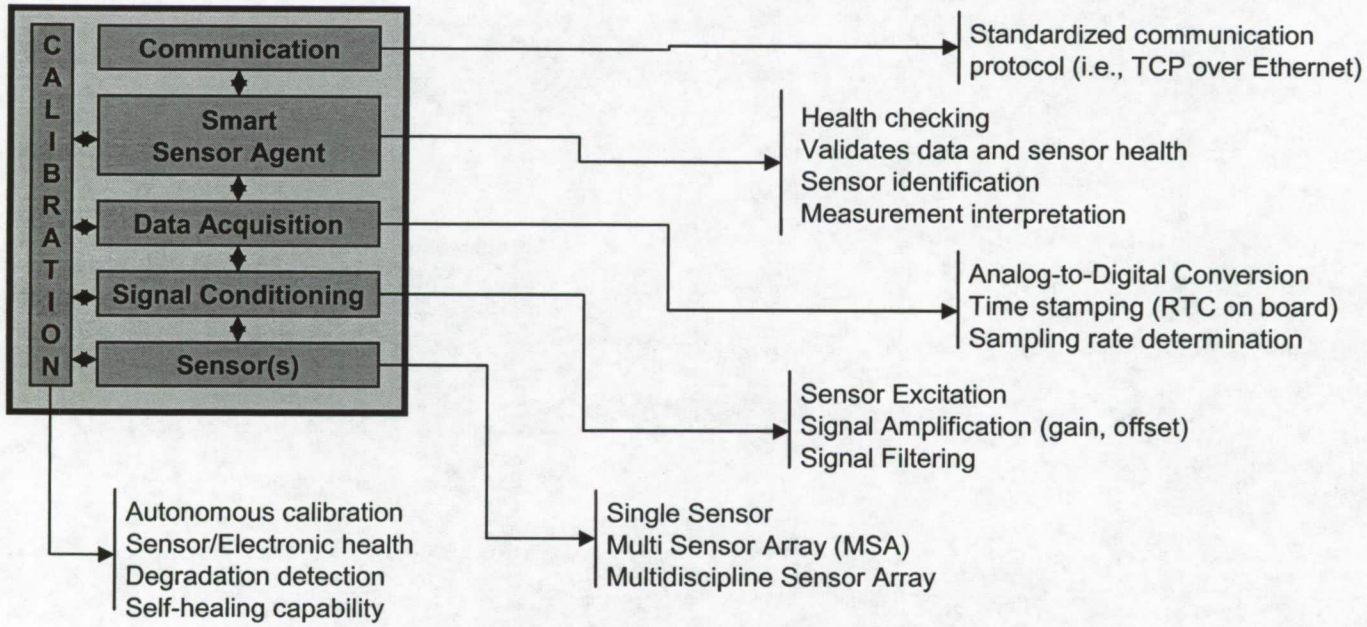


A.K.A. The Smart Networked Element (SNE)

Smart Sensor Architecture

- *Modular architecture*
  - *Analog and signal conditioning*
  - *Digital*
  - *Power and communication*



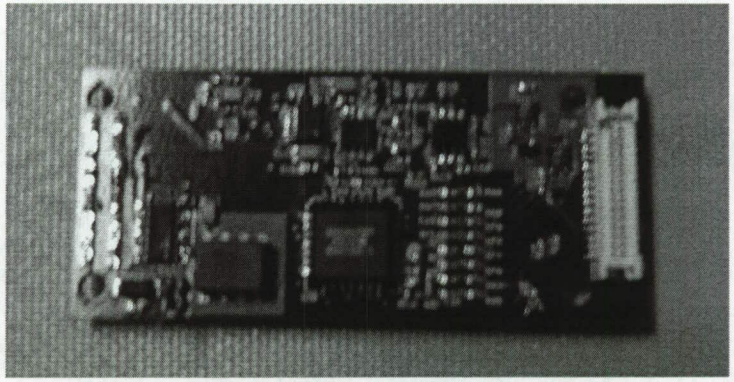


KSC Smart Sensor Hardware Features

- *Power and Communication Module*
  - *Power over Ethernet*
    - *Data and power on one cable*
    - *No external power source or battery required*
  - *Real Time Clock with battery backup*
  - *Standard RJ-45 connection*
- *Digital Module*
  - *TI 200MHz Floating-point Digital Signal Processor (DSP)*
  - *512 KB external RAM*

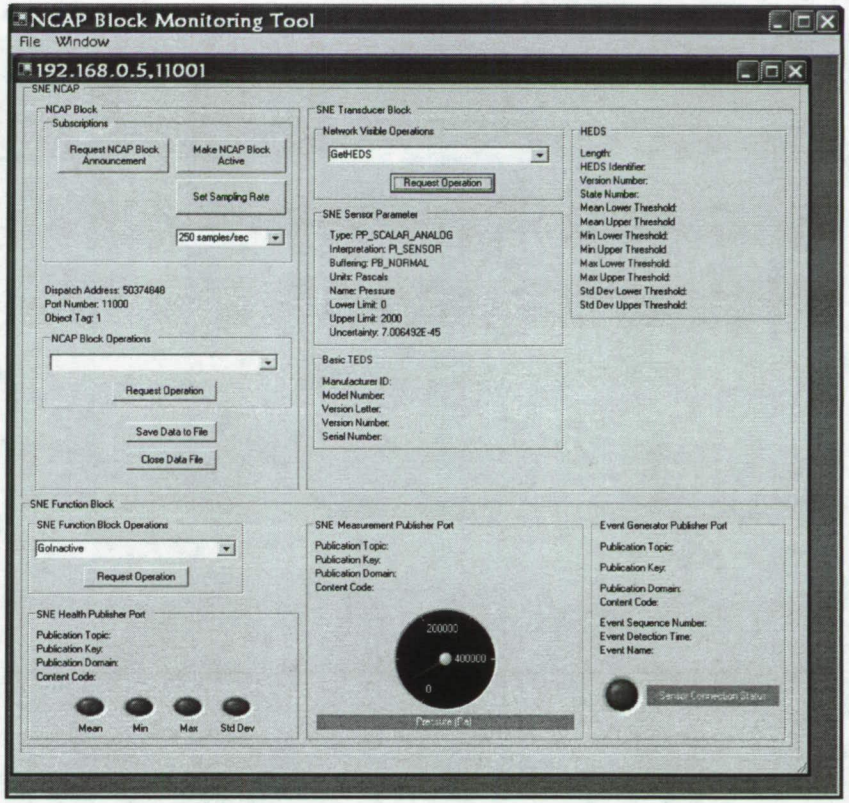
Hardware Features (cont.)

- *Analog Module*
  - *Redundant multiplexers, signal conditioning stages, and analog-to-digital converters (ADCs)*
  - *Digital-to-analog converter (DAC) for feedback*
  - *Ability to connect up to eight individual sensors*
    - *Redundant*
    - *Multidiscipline*



KSC Smart Sensor Software Features

- *IEEE 1451.1 "light" implementation of the network-level object model*
- *Customizable sampling rate, message contents, and health parameters via a graphical user interface*

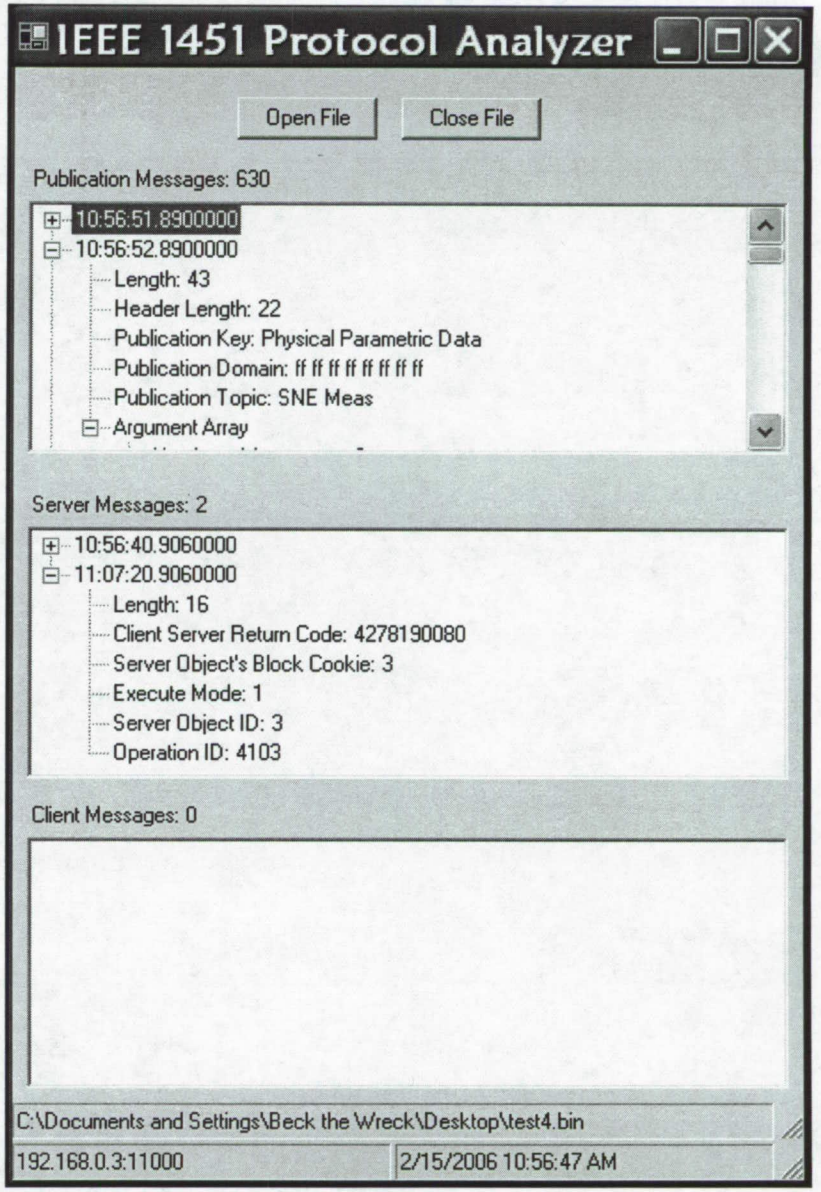


Software Features (cont.)

- *Algorithms for monitoring the health of the sensor*
  - *Voltage reference/current excitation monitoring*
  - *Trending*
  - *Threshold detection*
  - *Sensor connection status*

Contributions to Intelligent Sensing

- *Ethernet-based, PoE compliant network sensors*
- *Perform data verification and health monitoring*
- *Implementation of a communication protocol between IEEE 1451 devices over Ethernet*
- *IEEE 1451.1 Protocol Analyzer*
- *User-defined TEDS – the Health Electronic Data Sheet (HEDS)*



Future Research

- *IEEE 1588 Precision Time Protocol (PTP)*
  - *Time synchronization with sub-μs accuracy*
- *Addition of a control module for closed-loop feedback control*
- *Firmware to exploit multi-sensor array capability*
- *Real-time downloading of algorithms to the smart sensor*

Q&A

An expert knows all the answers – if you ask the right questions.

Author Unknown