National Aeronautics and
Space Administration

John F. Kennedy Space Center

SPACEPORT
ENGINEERING AND
TECHNOLOGY

Sensor Applications at NASA Kennedy Space Center (KSC)

Spaceport Engineering & Technology (SE&T) Directorate

Instrumentation Branch

Advanced Sensors Group

Jose M. Perotti and Anthony Eckhoff

Requirements

- Variety of Measurement Types:
  - Pressure, Temperature, Flow, Load/Strain, Liquid Level, Leak and Flame Detection

- Sources of Requirements
  - Various Programs - Space Shuttle, Space Station, Expendable Vehicles, Future Vehicles
  - Combination of military standards, technical and program requirements.

- Requirement Types:
  - ***Performance:*** Error band, response time, etc.
  - ***Environmental:*** Vibration, temperature, EMC/EMI, corrosive environments, explosive environments, etc.
  - ***Materials Compatibility:*** Liquid hydrogen and oxygen, hypergolic fluids, etc.
  - ***Customer Interfacing:*** Connector, output type and level, sample rate, mechanical constraints, power, etc.

Requirements (continued)

SPACEPORT
ENGINEERING AND
TECHNOLOGY

- Space Shuttle Requirement Document Examples:
  - **Flight and Ground System Specification** (NSTS 07700 Volume X)
  - **Ground Support Equipment General Design Requirements** (JSC SW-E-002)
  - **Guide for Design Engineering of GSE and Facilities for Use at KSC** (KSC DE-512-SM).
  - **Shuttle Launch Processing System (LPS) requirements.**
  - **Shuttle Launch Commit Criteria (LCC) Document requirements.**
  - **Specification Electromagnetic Interference Characteristics, Requirements for Equipment.** (MIL-STD-461 and SL-E-0002)

- KSC Transducer Specifications Documents (79Kxxxxx) combine requirements to outline performance, environmental, materials compatibility, and users interface needs.

Applications - Cryogenics

**SPACEPORT
ENGINEERING AND
TECHNOLOGY**

- Instrumentation is required to support the storage and delivery of cryogenic commodities necessary for vehicle launches.
  - LH_2 (-422 °F), LO_2 (-297 °F), LN_2 (-320 °F)

- Temperature and pressure account for the majority of transducers needs. Flow measurement and control is also required.
  - ***Temperature Sensors*** (probes and signal conditioners)
    - Platinum RTDs (presently 1400 Ω R_0, α = 0.0003925, preferable 1000 Ω R_0, α = 0.0003925).
    - Silicon Diode technology (excellent for LH_2, poor for LO_2 ranges)
  - ***Liquid Oxygen Flow Meter***
    - Vortex Shedding technology (preferable due to the low profile of meter).
    - Coriolis technology (excellent performance, size is too large for present applications).

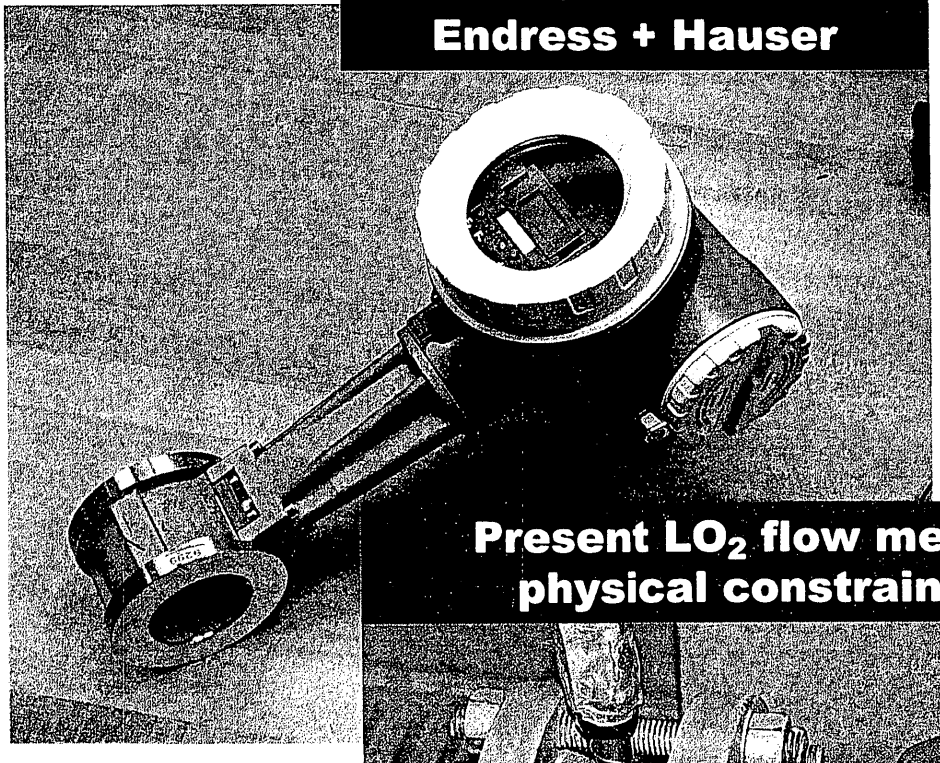
National Aeronautics and Space Administration

John F. Kennedy Space Center

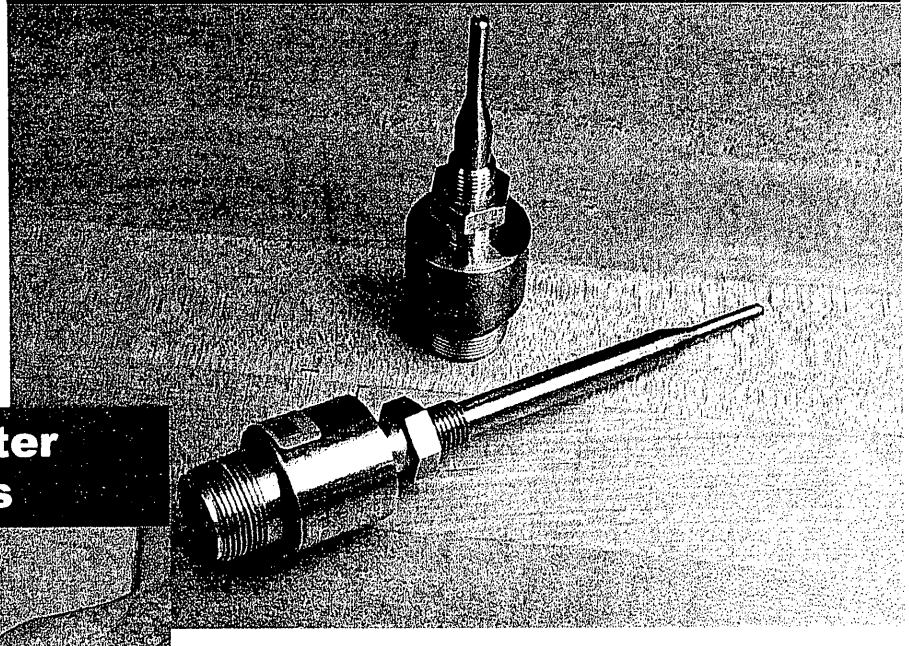
Applications – Cryogenics (continued)

SPACEPORT ENGINEERING AND TECHNOLOGY

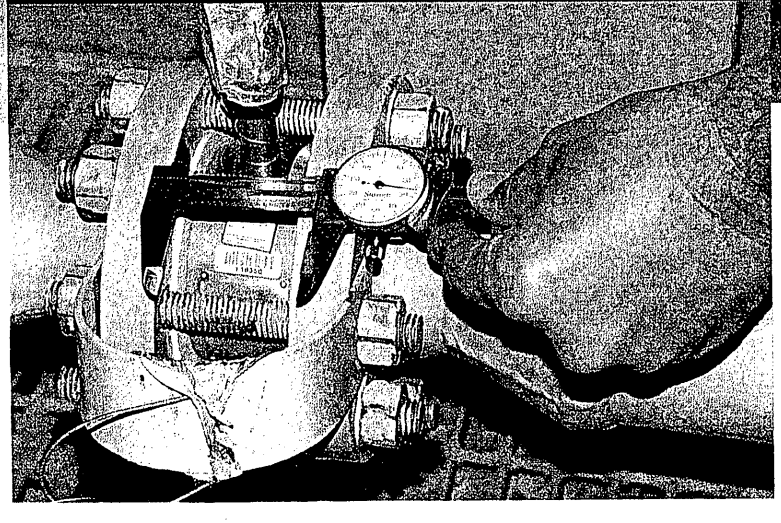
Vortex Shedding Flow meter from Endress + Hauser



Cryogenic temperature probes from Scientific Instruments (SI)



Present LO_2 flow meter physical constrains



Applications - Hypergol

- Flow measurements are required to support loading of hypergol commodities for vehicle propulsion/maneuvering systems.
  - Used for Orbital Maneuvering System (OMS) and Reaction Control System (RCS) to steer the Orbiter in space
  - Accurate loading necessary for every mission
    - too much = wasted weight = less payload; too little = mission failure
  - Mono-Methyl-Hydrazine (MMH) and Nitrogen Tetroxide (N_2O_4)

- Turbine Flow Meters Currently Used
  - less accurate, mechanical damage due to bearing over spin, safety issue (entrapped volume).

Applications - Hypergol (continued)

- Coriolis Flow Meters Being Implemented
  - Provides a mass flow measurement (accounts for bi-phase flow), measures reverse flow accurately, and overall high accuracy - 0.2% of FS (KSC qualified as a 1% device over all conditions)

- To Be Utilized as Modified COTS
  - KSC-modified to meet unique requirements
    - connectors and seals to be compatible with hypergol media

- Presently installed at launch Pad A (LC-39A)
  - Has successfully supported several hypergol flows successfully.

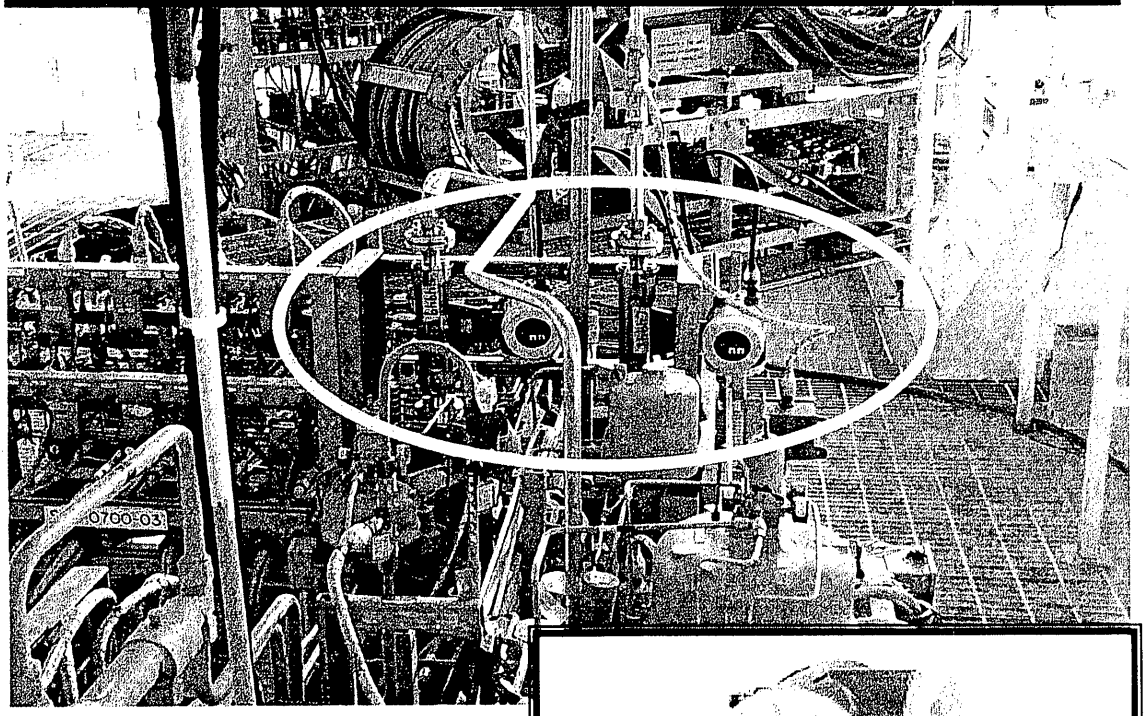
National Aeronautics and Space Administration

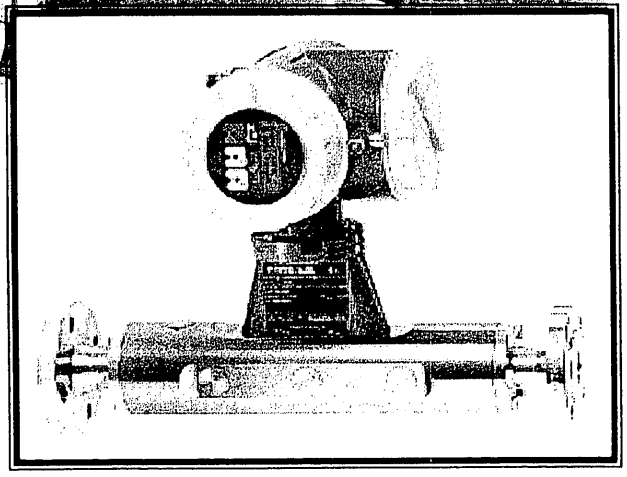
John F. Kennedy Space Center

Applications - Hypergol (continued)

SPACEPORT ENGINEERING AND TECHNOLOGY

New Flow Meters Installed at LC-39A Fixed Structure Hypergol Servicing Area





Endress+Hauser Coriolis Flow Meter

Orbiter Tire and Strut Pressure Monitor

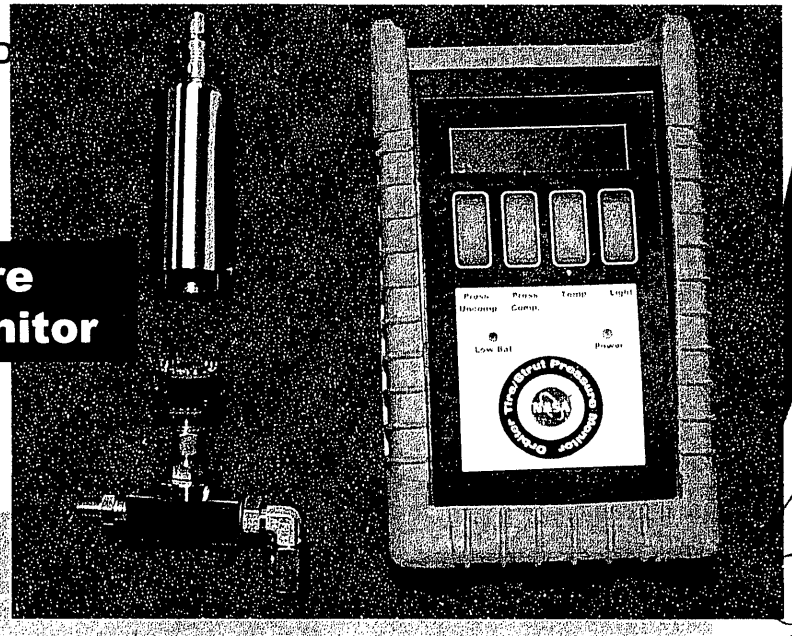
- Shuttle Operations Requirements
  - 450 psia static working pressure and able to detecting 0.1-psia changes
  - minimize amount of high pressure volume of the existing system
- COTS Pressure and Temperature Sensors Selected
  - Pressure sensor capable of 0.03 PSIA accuracy
  - Temperature compensation and correction required for 20 ^{o}F to 120 ^{o}F operating range
- Custom Sensor Housing Designed
  - Allows attachment directly to the tire or strut
  - Stainless steel enclosure containing pressure and temperature sensors, with electronics for precision excitation and amplification.
- User interface
  - Hand-held device powered by 12-VAC or 9-VDC batteries
  - Contains electronics supply voltage, low pass filtering and analog-to-digital conversion. Includes system firmware capable of maintaining the required accuracy throughout the temperature range

National Aeronautics and Space Administration

Applications – Special Tools (continued)

John F. Kennedy Space Center

SPACEPORT ENGINEERING AND TECHNOLOGY



Orbiter Tire Pressure Monitor

Orbiter touch-down at KSC landing Site

Orbiter tires post-flight inspection by astronaut

Applications – Special Tools (continued)

ET Centering and Alignment System

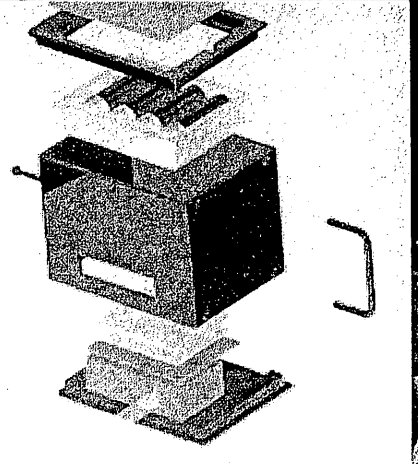
- Shuttle Operations Requirements
  - Accurate alignment/centering of External Tank (ET) with respect to Solid Rocket Boosters (SRB) during component mating
  - Automated distance measurement accurate to 0.01" between ET and SRB
  - Laser-generated line to align ET and SRB to the same centerline.
- Current ET CAS
  - Acoustic sensors (distance) and a laser crosshair (alignment)
  - Acoustic sensors require frequent calibration and are suspect at temperature extremes
  - Long cables (power and data) connecting to a central display
- New ET Centering and Alignment System
  - COTS laser sensors with capable accuracy
  - Consists of two wireless sensing systems and User Interface Console
  - Measurements are temperature compensated for temperature range (20 °F to 120 °F)
  - Provides greater accuracy with no calibration. The wireless functionality allows the engineer to relocate out of the way of the operation.

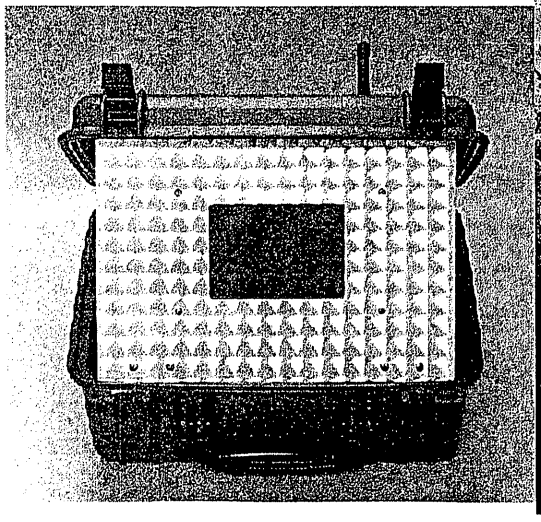
Applications – Special Tools (continued)

SPACEPORT
ENGINEERING AND
TECHNOLOGY

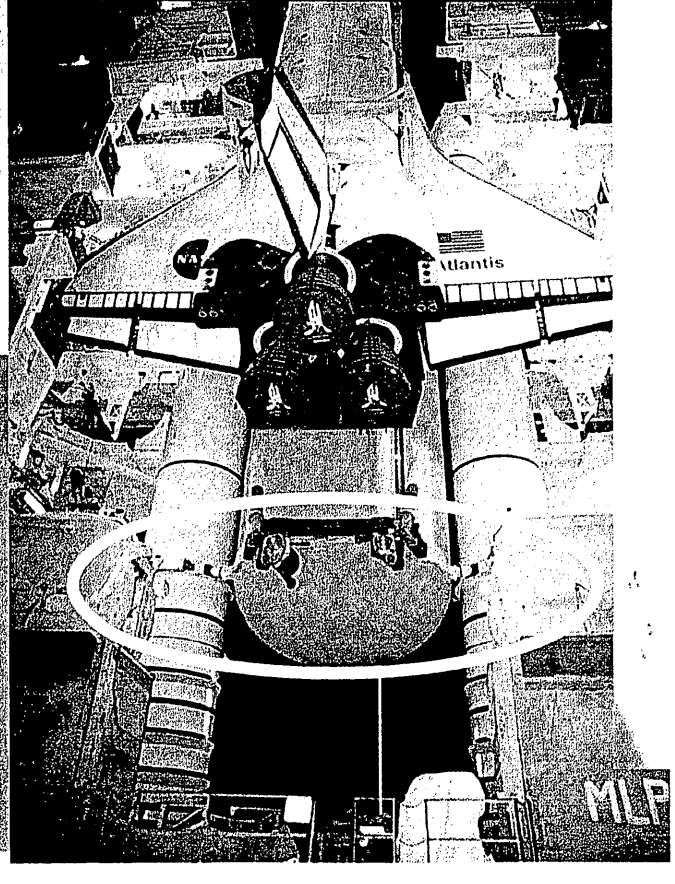
ET Centering and Alignment System

ET Centering and Alignment System

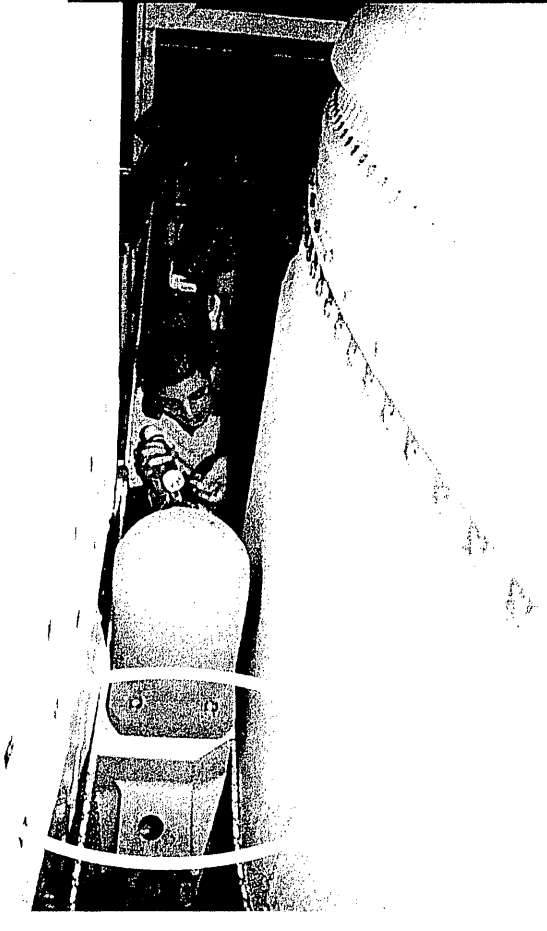




Aft SRB/ET Attachment system



Forward SRB/ET Attachment point



Summary

- Selection and Qualification of Commercial-Off-The-Shelf (COTS) transducers is desired whenever possible.

- In reality, qualified transducers are modified COTS to comply with KSC and program requirements.

- These requirements are dictated by the different NASA programs and KSC.

- In some instances, there are no available commercial products that will meet the specific requirements of the application. The KSC Transducers Laboratory then develops these products.

- When fully developed, these products become certified GSE equipment and potential for commercialization is assessed and pursued.