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## Paper Session I-B - Transducer Development Resources

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## Transducer Development Resources

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# Transducer Development Resources

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## Abstract

The Transducer Development Laboratory, operating under the Kennedy Space Center (KSC) Engineering Development Directorate, performs: Applied research - Advanced Technology Development - Sustaining Engineering functions to ensure the accuracy, reliability, and interchangeability of transducers (sensors). The unique capabilities of the lab provide valuable resources to Ground Support Equipment (GSE) and Space Station Processing Facility (SSPF) systems at the Kennedy Space Center (KSC), as well as for other Government Facilities and programs. In doing so, the lab develops and maintains KSC specifications for GSE and SSPF transducers through extensive testing and applied development. More importantly, the necessary functions to which the lab serves has led to the establishment of unique expertise and testing capabilities. Calibration laboratory-level test equipment and transfer standards, in various disciplines: pressure – temperature - liquid and gas flow – vacuum – force/load - hydrogen gas - hydrocarbon fire, give the laboratory necessary versatility for resolving both long range and quick response transducer issues. The added capability to fully test and troubleshoot devices for electromagnetic interference /susceptibility compliance, gives the lab unique, diverse abilities available in few other places. This paper will briefly illustrate this diversity and the valuable resources available for the resolution of transducer-related development, testing, and troubleshooting issues for KSC, various launch vehicles, and industry.

## Introduction

Throughout the processing and launch cycle for the Space Shuttle vehicle, an assortment of measurements are critical for proper configuration, pre-launch activities, vehicle safety and reliability, and performance metrics. Of these measurements, there are numerous ground support equipment (GSE) transducers associated with the vehicle preparations and pre-launch activities at the Kennedy Space Center (KSC). The GSE transducers, that is those measurements that are in support of vehicle processes while it is on the ground and are not directly connected to the vehicle, involve various disciplines – temperature, pressure, liquid and gas flow, vacuum, force/load, hydrogen gas, and hydrocarbon fire. Additionally, they are utilized in a variety of process needs - subassembly checkout, orbiter/vehicle “stacking,” fuel and oxidizer loading, emergency egress assessment, and post-launch safing.

To support the wide variety of measurements, a vast logistics system exists to assure that each transducer is suitable and available for the process and configuration in which it is required. This logistic system relies heavily on the interchangeability of the transducers and their compliance to established specifications. Process reliability and repeatability is necessary, making measurement accuracy and repeatability crucial. Also, the environment in which they are installed and used is harsh; operating temperatures at and around launch are effected by nearby cryogenic liquids and launch exhaust, while daily conditions involve the hot, humid, salt-rich environment associated with this coastal Florida location. To assure interchangeability and compliance to specifications, the NASA Engineering Development Directorate was chartered to perform this task.

Within the directorate, The Transducer Development Laboratory (TDL) fulfills their chartered role through transducer measurement expertise and an array of test equipment. The resources allow for thorough transducer characterization and environmental effects testing and the development and maintenance of comprehensive transducer specifications. The availability of advanced electronics and hardware design capabilities, within the TDL and other associated labs under the directorate, allows the TDL to also pursue the development and testing of custom, advanced sensors and instrumentation systems. The culmination of these functions and capabilities has created a unique environment where transducer-related development, testing, and troubleshooting activities can be pursued.

## Role

Since 1975, the Transducer Development Laboratory has retained the responsibility for standardization of transducer components and specifications at KSC. Operating under the NASA Engineering Development Directorate

and within the Instrumentation Systems Laboratories, the TDL provides many functions. Primary to its existence, the lab is responsible for the design, configuration control, qualification testing, specification release and maintenance, and coordination of malfunction analysis for transducers utilized in GSE functions; it is the direct interface in matters concerning transducer problems, applications, field testing, calibration methods and procedures, and the development of new transducers as required to support GSE requirements. To do so, the TDL has the responsibility for the preparation and approval/disapproval of specifications for transducers procured at KSC, the evaluation of new technology and developments to determine appropriated changes to existing specifications, and the consultation in matters of design engineering and selection of transducers. As mentioned, activities within the laboratory have expanded to include the development of advanced, custom transducers and instrumentation systems to benefit KSC GSE and vehicle measurements, as well as those of future launch vehicles.



**Figure 1 – Example Transducers**

## Capabilities

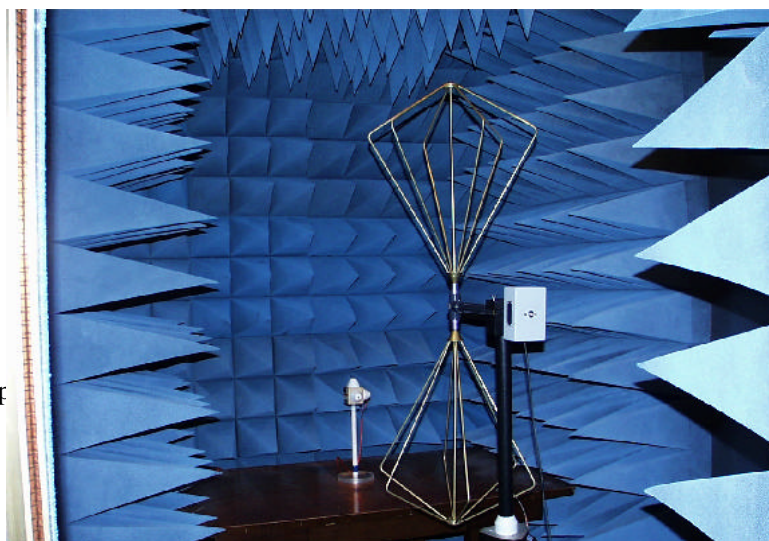
Ground support equipment transducers used throughout KSC involve the measurement disciplines of temperature, pressure, liquid and gas flow, vacuum, force/load, hydrogen and oxygen gas, and hydrocarbon fire (see Figure 1). Consequently, testing capabilities in each of these disciplines have been established within the lab. Primary and secondary measurement transfer standards are maintained and utilized to provide the lab with reliable measurements. But the unique capabilities of the laboratory reside in its abilities to perform a wide range of temperature effects/temperature cycling tests and screening for electromagnetic interference/susceptibility (EMI). Additionally, access to other KSC facilities allows for the performance of

vibration, shock, and thermal-vacuum effects testing, among others.

Since temperature measurement requirements exist from the extreme low temperatures of cryogenic liquids to extreme high temperatures experienced during liftoff or the unlikely event of a fire on the launch structure, the laboratory maintains the ability to reliably test from 10 Kelvin (-273.15 degrees Celsius) to 1273 Kelvin (700 degrees Celsius). Similarly, pressure measurements and testing capabilities exist from fractions of an inch of water column to thousands of pounds per square inch of absolute pressure. Gas flows can be generated and measured from fractions of a standard liter to 280 standard liters per minute; liquid flows capabilities from fractions of a gallon to hundreds of gallons per minute. Load cell testing can be performed to thousands of force pounds. Lastly, with the existence of explosive gaseous to support vehicle launches, the capabilities exist to test sensors associated with hydrogen and oxygen gas detection. Oxygen and hydrogen gas concentrations, mixed with various background gases, can be reliably generated from parts per million to 100% concentrations utilizing the lab's gas mixing equipment and mass spectrometers. Hydrocarbon fire detection is also important, as the potential for combustion of dangerous commodities does exist. Fire detectors, sensing radiation in ultraviolet and/or infrared wavelengths, can be tested through the generation of controlled hydrogen gas and hypergolic liquid/gas fires.

In addition to the abilities to test these various measurement disciplines, the

Teamed with NASA personnel, the TDL of Development Contract.



uniqueness of the laboratory exists in the combination of these capabilities with the availability of environmental, EMI, and hazardous testing (gas and fire detection) equipment and facilities. Four temperature chambers are available within the laboratory to perform temperature effects testing of the transducer articles, as well as other miscellaneous electronic devices. Two 2.2 and one 0.7 cubic feet liquid nitrogen cooled chambers allow for environmental temperature testing from -183 to +315 degrees Celsius. The fourth chamber, a 8.0 cubic foot closed-loop refrigerant system, provides temperature testing from -40 to 190 degrees Celsius, as well as course relative humidity generation from 10 % to 95%. A roughly 900 cubic foot anechoic chamber, various test equipment, and EMI testing expertise allow for electromagnetic compliance testing to MIL-STD-461, among other EMI testing standards (see Figure 2). The labs Remote Hazardous Test Facility (see Figure 3), located near the KSC Fire Training Facility, provides testing resources available few places, if anywhere else. Controlled burns of hydrogen gas, isopropyl alcohol, gasoline, monomethylhydrazine, and nitrogen tetroxide (the later two items being highly corrosive Shuttle maneuvering system fuel and oxidizer, respectively) can be conducted to provide qualification testing of extremely unique fire detectors. The facility could also be utilized for long-term environmental effects testing, exposing test articles to daily sun, humidity and salt air.



**Figure 3 – Remote Hazardous Test Site and Fire Detectors**

## Development

Future launch vehicle activities, at KSC and other NASA facilities, have thrust the laboratory into new technology developmental projects, further increasing the lab's diversity. The participation of the laboratory in vehicle health management system technology demonstrations, where real-time assessment of vehicle subsystems were made non-intrusively, provided a platform in which one-of-a-kind custom transducers and modified commercial-off-the-shelf devices were fabricated and successfully utilized. Advancements in sensor fabrication and the capabilities of today's electronics make it possible for the further development of self-assessing, self-calibrating transducers. Efforts within the TDL are currently being made to bring these types of devices to fruition. The

integration of these devices into future launch vehicles (X-33, X-34, etc.) and within other space exploration vehicles (Mars exploration initiatives) is highly desirable, as the needs for lightweight, low maintenance, "smart" devices increase. The utilization of micro-electromechanical systems (MEMS) will allow for the fabrication of compact, multiple discipline sensors (pressure, temperature, gas sensing, etc. on a single microcircuit). This will enable transducers to improve "real-time" measurement error compensation and provide additional measurements in less space. Ultimately, transducers can be created where hundreds of micro-sensors are fabricated and their outputs multiplexed to create highly redundant, self-health assessing transducers; calibration and maintenance cycles will be increased dramatically and truly "smart" transducers will emerge.

## Conclusion

The Transducer Development Laboratory (TDL) utilizes their transducer measurement expertise, an array of precision test equipment, and the availability of unique facilities for the resolution of transducer-related development, testing, and troubleshooting issues. The culmination of these functions and capabilities has created a unique environment where by the laboratory fulfills their direct charter to sustain ground support equipment transducers throughout KSC, as well as to develop and test transducers to support various launch vehicles initiatives. As with many government facilities, mechanisms exist whereby private industry can gain access to resources such as those described here. To date, the Transducer Development Laboratory has provided a limited amount of assistance to other aerospace companies through cooperative work agreements. Effective, independent testing has been supplied and the cooperative

agreements have allowed organizations, outside of Kennedy Space Center, access to these unique facilities. As the laboratory delves further into advanced transducer development and their assets continue to increase, the potential benefit to other organizations shall increase also; the laboratory looks forward to ever-increasing teamed efforts with industry. Technical assistance, cooperative development, and technology transfer should continue to be encouraged throughout governmental and private industry scientific endeavors.