# REDUCING MAINTENANCE COSTS ON THE SHUTTLE PROGRAM

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## ABSTRACT

NASA and Lockheed Martin Telemetry & Instrumentation have jointly developed a new data acquisition system for the Space Shuttle program. The system incorporates new technologies which will greatly reduce manpower requirements by automating many of the functions necessary to prepare the data acquisition system for each shuttle launch. This new system, the Automated Data Acquisition System (ADAS), is capable of configuring itself for each measurement without operator intervention. The key components of the ADAS are the Universal Signal Conditioning Amplifier (USCA), the Transducer Electronic Data Sheet (TEDS), and the Data Acquisition System (DAS 450). The ADAS is currently being delivered and installed at Kennedy Space Center. NASA and Telemetry & Instrumentation are actively pursuing commercialization of the ADAS and its associated products which will be available during 1996.

## KEYWORDS

Data Acquisition, Signal Conditioning, NASA Transducers.

## INTRODUCTION

Over the last few years, NASA has been challenged with dramatic budget cuts. Of primary concern were the mounting maintenance costs of the Shuttle program. NASA management thus called for innovative ideas that would reduce costs while retaining performance and safety. The challenge was answered by NASA's Transducers and Data Acquisition Section engineers who developed the concept of a Universal Signal Conditioning Amplifier (USCA) and its associated Transducer Electronic Data Sheet (TEDS). This idea was expanded to become the Automated Data Acquisition System (ADAS).

The ADAS gives NASA shuttle flight test and safety engineers reliable and accurate real-time data at greatly reduced maintenance costs. NASA studies put the savings at 20,000 man hours per year[1]. To understand how this remarkable savings is achieved, some history is necessary.

# BACKGROUND

The Permanent Measurement System (PMS) consists of approximately 800 measurements throughout launch complexes 39A and 39B, and the Vehicle Assembly Building. The system is used prior to and during launch to ensure launch readiness and safety. The PMS supports multiple parts of the launch processing flow. During the stacking of the Solid Rocket Boosters on the Mobile Launch Platform (MLP), the system monitors the strains on the booster hold-down posts. These posts bear the load of the entire vehicle until it is released at launch. The strain measurements allow engineers to verify that the bearing assembly, where the booster meets the post, is not binding as each successive booster segment is stacked. After stacking and testing are complete, the vehicle and MLP are moved to the launch pad for final launch preparations. The system is used at the launch pad to take many different types of measurements during countdown. Some of these are monitored in real time, such as the liquid oxygen pump vibrations, and some are recorded at the time of launch for later analysis. Examples of these are pressure, temperature, vibration, displacement, strains, and acoustic shock.[1]

While most of the system is fixed, changes and upgrades are always being made between launches. This spawns many changes in the measurement system. In addition, normal calibration and maintenance of sensors and transducers is performed on a daily basis. All this contributes to a dynamic system which requires a lot of attention and maintenance. To conceptualize the problem, one need only look at the launch platform with the shuttle installed (see Figure 1). Transducers and sensors are distributed throughout, requiring long cables for the multiplexing equipment housed at the bottom of the launch pad. Each transducer requires specialized and matched signal conditioning. Subsequently, a great deal of maintenance time is spent matching signal conditioners to transducers and tracing down failures in the system. As might be expected, manually tracing problems and their source is a very labor-intensive effort, which is precisely why NASA engineers focused their efforts on reducing maintenance labor.

Careful analysis proved that many hours were spent calibrating transducers, certifying signal conditioners, matching transducers to signal conditioners, and identifying and replacing channels. NASA engineers thus developed the concept of a “universal” signal conditioner that would handle all transducer types. Such a device would eliminate the matching of signal conditioners to transducers. Also, if the channel and signal could automatically be identified, the device would eliminate more costs.

Figure 1. The Automated Data Acquisition System (ADAS)

## DEVELOPMENT OF THE AUTOMATED DATA ACQUISITION SYSTEM

How could a system be designed to recognize different types of transducers without operator intervention? The answer rested with the Transducer Electronic Data Sheet (TEDS). The TEDS is a small circuit which holds all information about a particular transducer (see Figure 2A). The device is physically attached to the transducer and is programmed during calibration. Currently, NASA encapsulates the TEDS in clear potting compound molded into the transducer cable as shown in Figure 2B). Each transducer is uniquely identified by its associated TEDS.

The challenge was to design a signal conditioner that could read the information in the TEDS and automatically configure its excitation, gain, linearity, etc. to each type of transducer. The resulting design became known as the Universal Signal Conditioning Amplifier (USCA). It soon became clear, however, that in addition to being universally adaptable to all types of transducers, the amplifier had to withstand the open salt air and fluctuating temperatures at the launch pad. NASA engineers therefore developed a ruggedized version of the USCA as shown in Figure 3.

A third required component of NASA's new approach came in the form of an advanced data acquisition system. The system was conceived to provide multiplexing, control and setup, database management, archiving, display, and processing of information in real time. As the approach unfolded, this new Data Acquisition System, the DAS 450, would

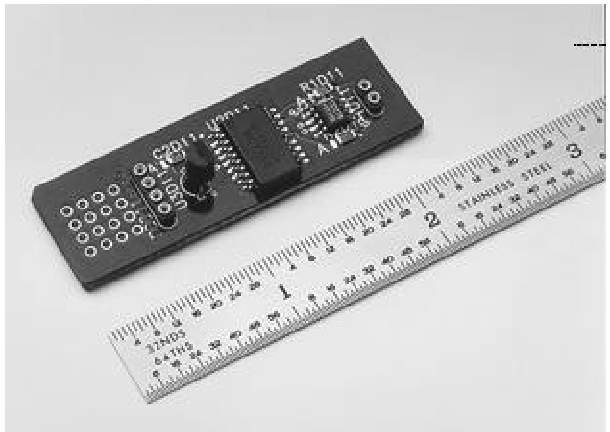

Figure 2A. TEDS Circuit Card

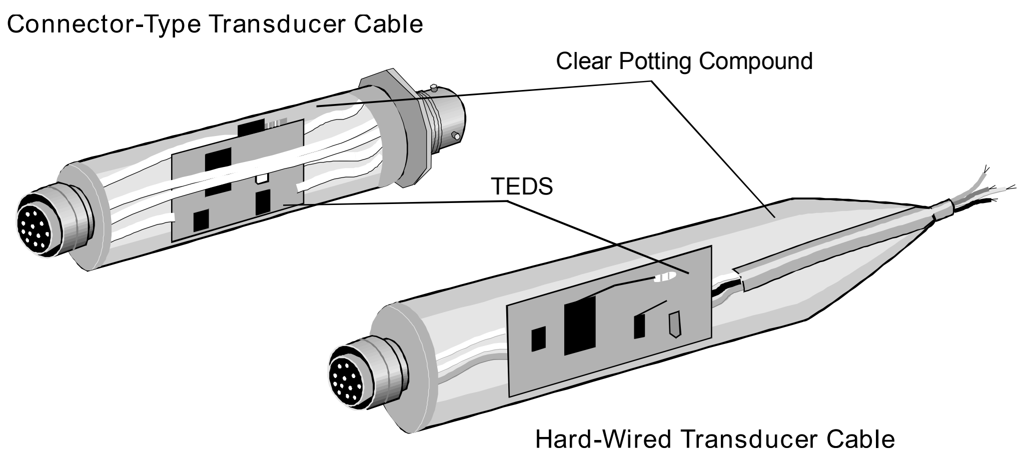


Figure 2B. Encapsulated TEDS in Clear Potting Compound

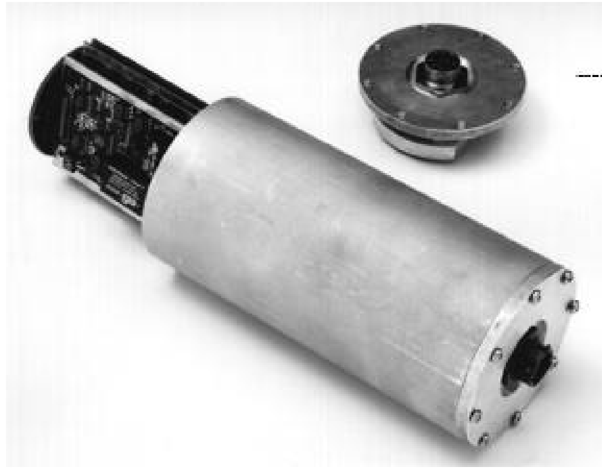

Figure 3. Ruggedized USCA

join the TEDS and the USCA to form the main components of NASA’s new Automated Data Acquisition System (ADAS).

Lockheed Martin Telemetry & Instrumentation has been working with NASA on the development of the ADAS since 1994. The final version of the USCA, TEDS, and ADAS will be delivered by Telemetry & Instrumentation during 1996. The development has been jointly funded by NASA, Lockheed Martin Telemetry & Instrumentation, and the State of Florida Technological Research and Development Authority as part of a NASA technology transfer initiative. Telemetry & Instrumentation is currently designing a commercial version of the ADAS in addition to supplying the ruggedized USCA and ADAS to NASA. Telemetry & Instrumentation plans to make commercial versions of the products available during 1996.

## ADAS OVERVIEW

The main elements of the ADAS are shown in Figure 4. An explanation of each is given in Table 1.

## THE UNIVERSAL SIGNAL CONDITIONING AMPLIFIER

A number of new technologies have been incorporated into the Automated Data Acquisition System, but of them all the star is the Universal Signal Conditioning Amplifier (USCA). The USCA is capable of automatically programming itself to match any transducer in the system without operator intervention. It can also be programmed remotely through the ADAS. This key capability reduces setup and configuration time from hours to seconds.

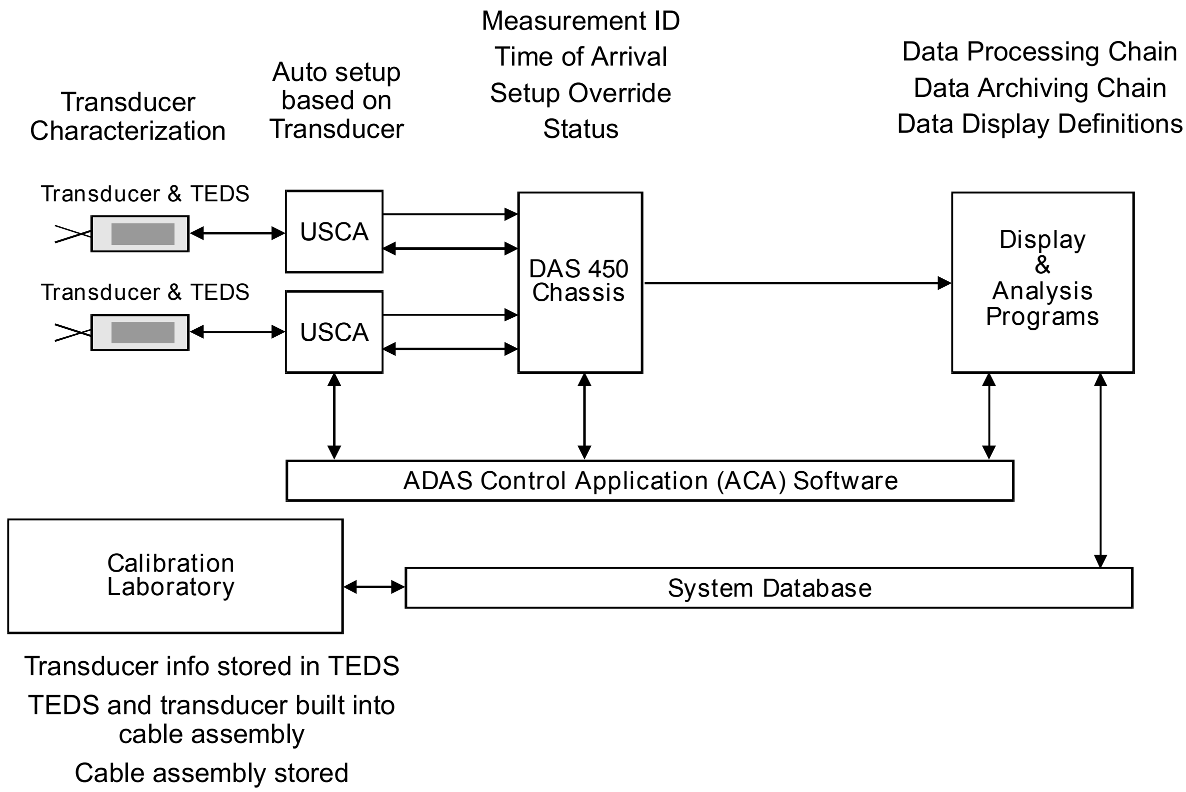


Figure 4. ADAS Block Diagram

The USCA, shown in Figure 5, contains multiple programmable circuits which are selected according to the contents of the Transducer Electronic Data Sheet (TEDS). It consists of:

- Multiple programmable gain amplifiers (0.25 to 2,000)
- Multiple programmable anti-alias filters
- Multiple programmable D/A converters for excitation
- A programmable 16-bit A/D converter
- A Digital Signal Processor for programmable filtering, linearization, and decimation
- DC to DC converters for power and isolation
- Isolated outputs (analog and digital)

Table 1. Data Acquisition Elements of the ADAS

| Data Acquisition Element | Purpose | Comments |
|---|---|---|
| Transducer Electronic Data Sheet (TEDS) | Electronically stores all information about a transducer. | • Reprogrammable<br>• Mounted with the cable assembly of a transducer<br>• Contains all unique information about a transducer |
| Universal Signal Conditioning Amplifier (USCA) | Self-configuring signal conditioner/data processor. | • For LC39, a rugged unit mounted near the transducer<br>• One type for all transducers<br>• Digital output<br>• Self-configuring based on information in the TEDS<br>• No "hands-on" adjustments |
| USCA Interface Module (UIM) | Identifies, time tags, and multiplexes 32 measurements. | • Input to the data multiplexer<br>• Analysis, storage, and display system<br>• Provides remote interface to each USCA |
| Data Acquisition System (DAS 450) | Data multiplexer with different inputs, processing capabilities, and outputs. | • Inputs include UIM, IRIG, and PCM streams<br>• Processing includes large range of algorithms for analysis<br>• Outputs include network, storage, and display |
| ADAS Control Application (ACA) Software | UNIX application program. | • Integrates all elements of the data acquisition system<br>• Reads stored information and provides setup and controls<br>• Provides man-machine interface |

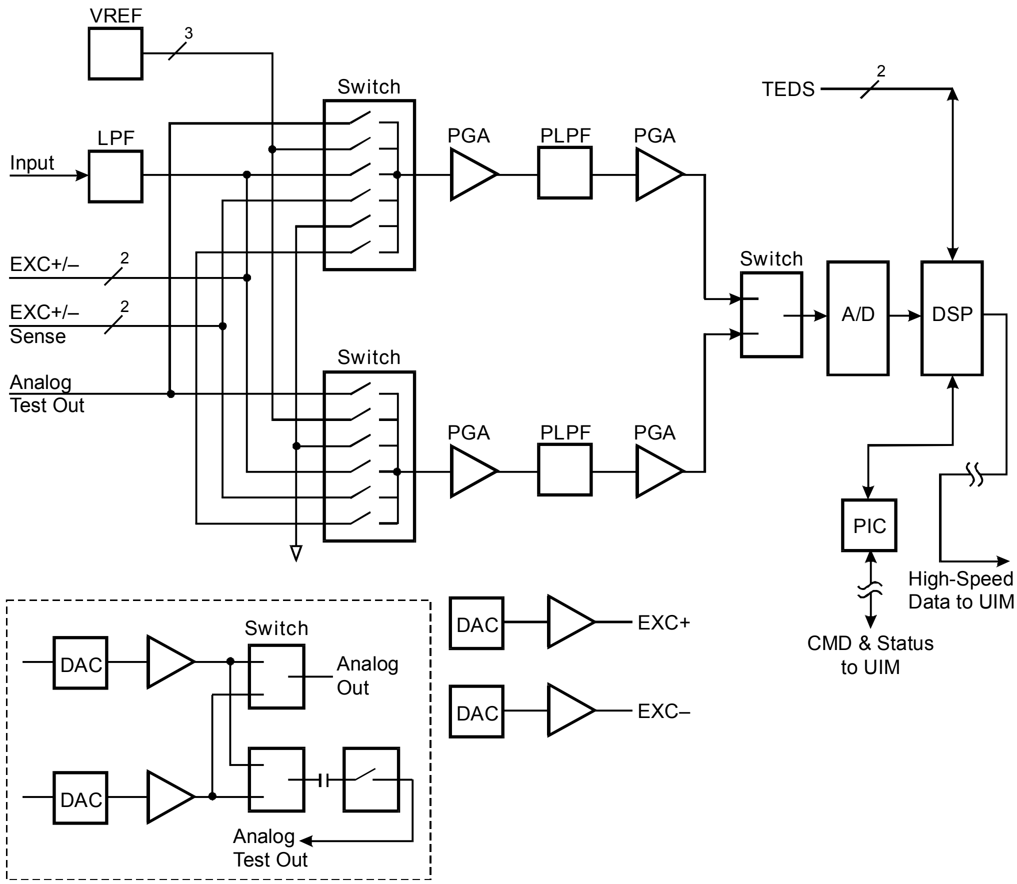


Figure 5. USCA Block Diagram

When the USCA is connected to a transducer, it automatically reads setup information stored in the TEDS memory. This information consists of transducer type, gain, filter type, excitation requirements, linearization coefficients, full scale range, etc. The USCA uses this information to program itself to the transducer's requirements.

Obviously, the TEDS is another key component of the ADAS. In addition to setup data, the TEDS contains other information important to the system, including calibration dates, serial numbers, measurement types, and any other information the user deems important. Once the USCA detects the transducer and configures itself, it notifies the DAS 450. The DAS 450 then reads the USCA for transducer information and measurement ID and passes this information to the database in the application software. The application software in turn updates the database with new parameter identifiers. These identifier tags are returned to the DAS 450 chassis. The USCA is then enabled to read measurement data. This operation is diagrammed in Figure 6.

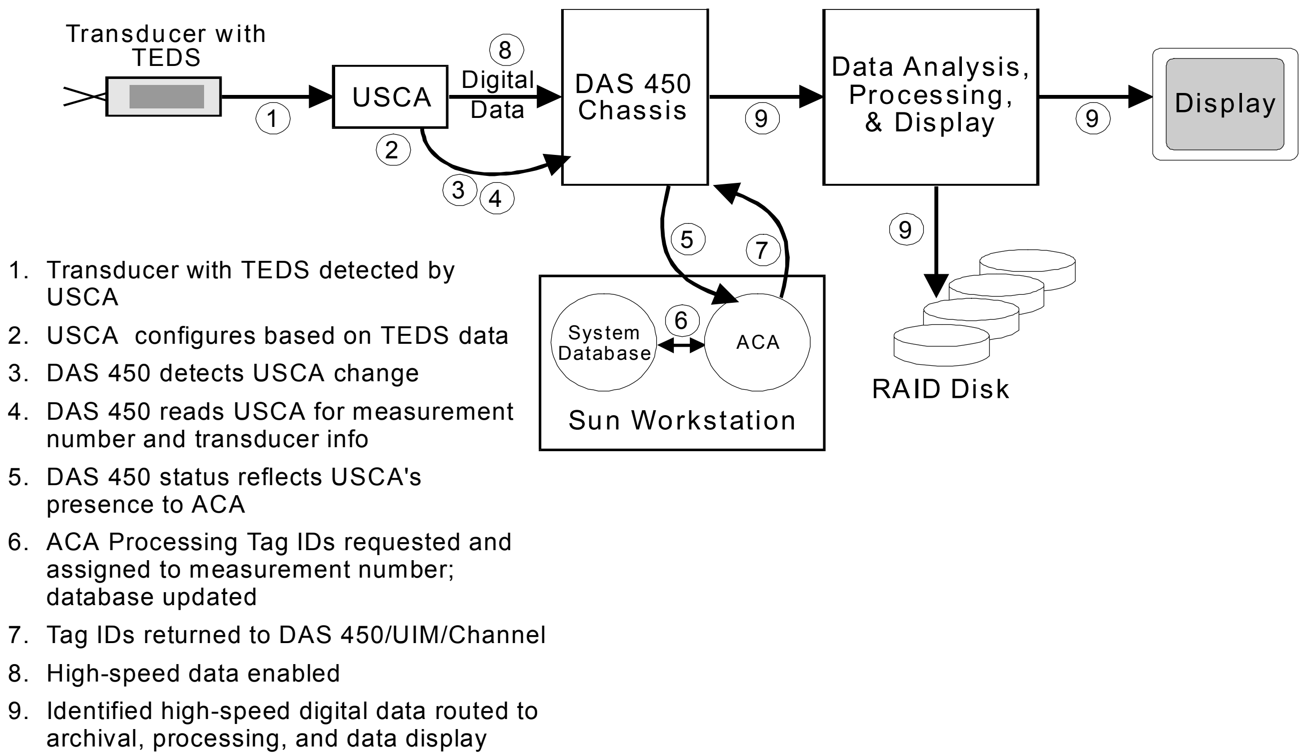


Figure 6. Automated Setup Data Flow with New Measurement

As can be seen, this entire sequence of events is automatic and accomplished without an operator. To start the sequence, a transducer with its embedded TEDS is connected to a USCA. No other operation is required. Since the USCAs are all identical, it is impossible to make a mistake.

## SUMMARY

NASA and Lockheed Martin Telemetry & Instrumentation have developed an Automated Data Acquisition System that reduces maintenance requirements on the Space Shuttle launch complex at Kennedy Space Center. This solution was achieved through technology improvements in signal conditioning which resulted in a self-configuring and universal signal conditioner capable of automatically recognizing any type of transducer and of programming itself to match individual transducer specifications. This technology is being commercialized and will be available to the industry during 1996.

# REFERENCES


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