DEWESoft®

AEROSPACE APPLICATIONS

CASE STORIES

Integrated signal conditioner for aerospace propulsion research

ISRO Propulsion Complex, India
By Tirin Varghese, Manager, Dewesoft India Pvt Ltd.

CASE STUDY

What is Dewesoft SIRIUS? For a test engineer, this is a general-purpose data acquisition (DAQ) system only. How strong is your mental and physical health? Is there a way to truly measure it?

The individual has a very complex nervous system and it is impossible to validate its performance in a single interview. A strong person survives challenges in life, and as consequence, he or she produces the best results for the world.

Similarly, after multiple evaluations and performance tests (interviews) in various cases over around eight years the Indian aerospace industries have accepted that the SIRIUS DAQ family is the better choice compared to other DAQ systems as it performs a true measurement.

Introduction

So, configurations of SIRIUS DAQ modules (STG, STGm, ACC, LV, HD STGs) with Analog output (AO) - more than 400 analog channels - are running in various subdivisions of the Indian Space Research Organization (ISRO). These signal conditioners can connect anything from pressure sensors, charge sensors, strain gauges, load cells, temperature sensors to measure everything needed in modern advanced propulsion systems.

Conventional measurement systems are designed and operated according to their functions. They are distributed and interconnected with analog as well as digital buses. It is often more of a choice than a solution. As a result, even though the individual subsystems in the measurement chain offer the best performance the result is ambiguous.

The unique features of the SIRIUS DAQ systems have eliminated many of these ambiguities that have existed for years for customers. It is a total solution in an integrated manner with more versatile programming features.

It has a built-in channel to channel galvanic isolation, sensor signal conditioner, DualCoreADC® technology with a 2x24-bit ADC converter with **160 dB dynamic resolution**. It stores precious data in redundant network drives and also presents data in a versatile application-specific graphical and numerical display.

The built-in post-processing techniques enable users to analyze measured data swiftly. Furthermore, the reporting features made data sharing and communication easy within the scientific community. SIRIUS DAQ system makes everything under the DewesoftX data acquisition software umbrella and generates a feeling of completeness for the customer.

Figure 1. SIRIUS R4 is a compact high-channel data acquisition system with up to 64 analog inputs, 32 counter inputs, and 32 analog outputs with a built-in high-performance computer and SSD data logger.

ISRO Propulsion Complex

ISRO is the main pillar of aerospace research activities in India. It is the key player in the design and development of space launch vehicles. It works on multi-disciplinary technologies like satellites and space technologies for Earth observation, communication, navigation, meteorology, and space science.

The ISRO Propulsion Complex is one of the main centers doing research and development programs. It is focused on liquid propulsion systems for both satellites and launch vehicles. The mandates of the complex are development, qualification, and acceptance of subsystems, integration of launch vehicles, and spacecraft projects. The Centre has built-in facilities to test/simulate upper-stage rocket engines and thrusters/liquid apogee motors of satellites in a vacuum environment.

ISRO is presently working on the development of a high-thrust semi-cryogenic engine1 based on a mixture of liquid Oxygen and rocket-grade Kerosene, Isrosene. It is a great satisfaction that Dewesoft evolved as a working partner in these research programs. The establishment of the related assembly, integration, and propellant storage facilities is in progress and Dewesoft data acquisition equipment and software are some of the main tools for these missions.

No pain, no gain – the challenges

ISRO research capabilities were limited in the absence of a true measurement system. The measurement ambiguity often reduced their confidence level. The ISRO team was desperately looking for their outdated measurement system to be replaced by a precision measurement system for mission-critical applications. Some of the most recent critical challenges are described here.

Distributed manual system for the quality test procedure

The sensors are deployed in the field about hundreds of meters away from the instrumentation station. The signal cables are electrically isolated through an independent instrument. The output of the isolation amplifier is connected to an analog signal conditioner to suppress the bandwidth to limit.

The analog output is digitized and transferred through a redundant network and monitored. The analog data is also sampled in the programmable logic controller (PLC) and monitored. Most of these subsystems need manual tuning.

A block diagram of such a conventional measurement system is shown in Figure 2. Scientists have adopted it and are seasoned with its deficiencies. But it was a tiresome and labor-intensive process to set up these types of systems for mission-critical applications and often gave erroneous results.

Integration of hundreds of sensors and automated measurements

The customer wants to measure more than 200 critical parameters with different types of sensors in an experiment. The sensors were also often changed. It was difficult to manually update the calibration details of the sensor for scaling during the experiment.

Built-in two-point scaling and applying a nonlinear transfer function

The sensors are deployed in the field about a hundred meters away from the instrumentation station. Analog signal losses over the long cable are unavoidable in a distributed DAQ system. The losses in the interfacing cable need to be compensated through a two-point calibration procedure.

Furthermore, the system has to be programmed to convert the physical quantities by applying a nonlinear transfer function derived from the calibration coefficients. Most of the modern data acquisition systems have only one set of scaling. Hence it was challenging to meet this requirement.

Filters on analog output

The conventional signal conditioners have inbuilt analog low-pass filters at the analog output (AO). So, the AO is wideband low-pass filtered. Even though the SIRIUS instrument is equipped with low-pass filters with sharp cutoff frequency characteristics, it was a challenge for the SIRIUS signal conditioner to make low-pass filters with low cutoff frequency for AO.

The output delay is a function of the sampling rate in the SIRIUS instrument. Hence it is difficult to achieve the contradicting requirements. A PLC often gives a false trigger with an unfiltered input signal. Hence the customer has to use an additional external filter unit before the PLC.

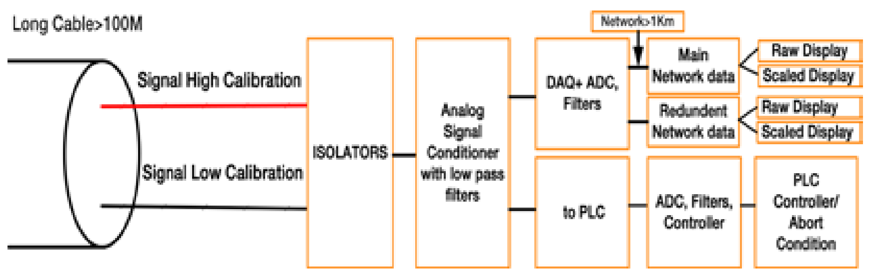


Figure 2. Block diagram of a conventional measurement system.

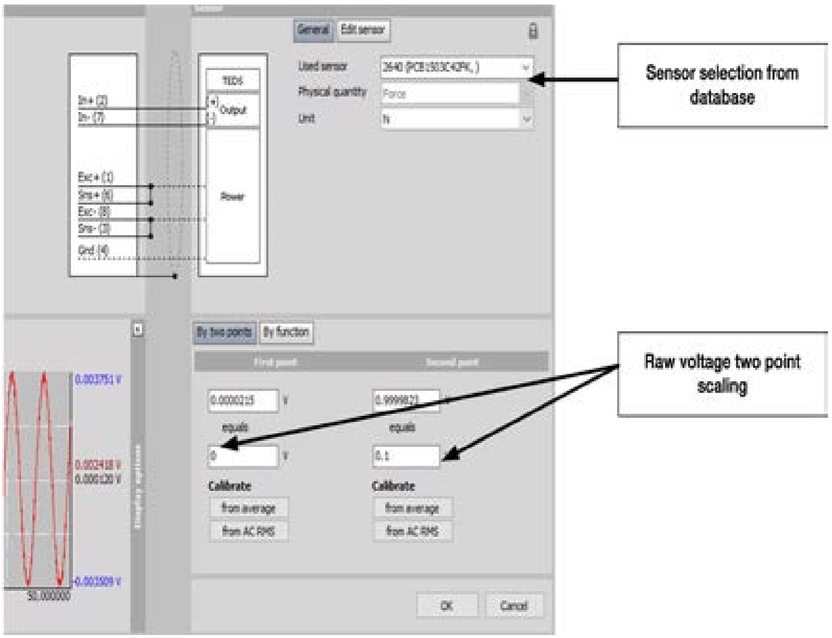


Figure 5: Analog channel setup for raw two-point scaling.

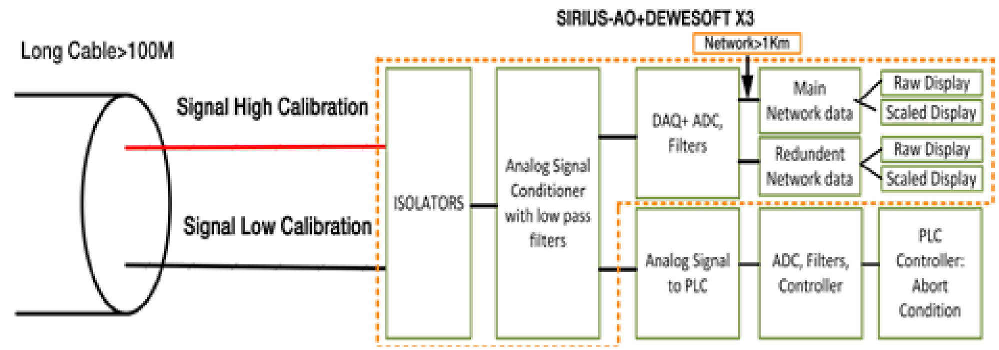


Figure 3. Integrated signal conditioner modern architecture.

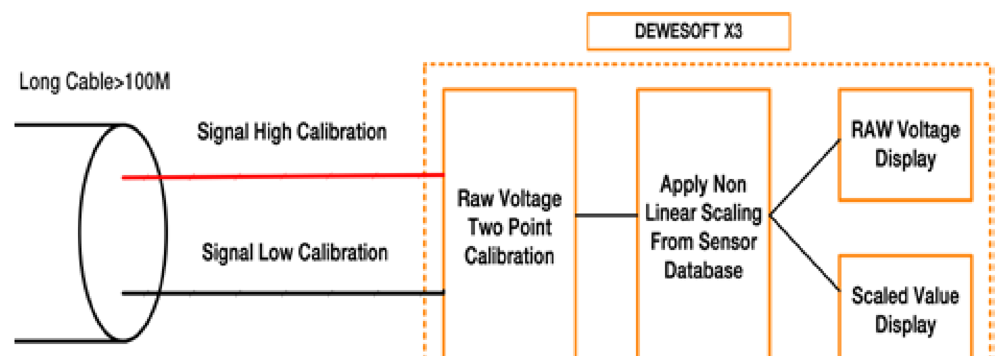


Figure 4. Non-linear scaling procedure.

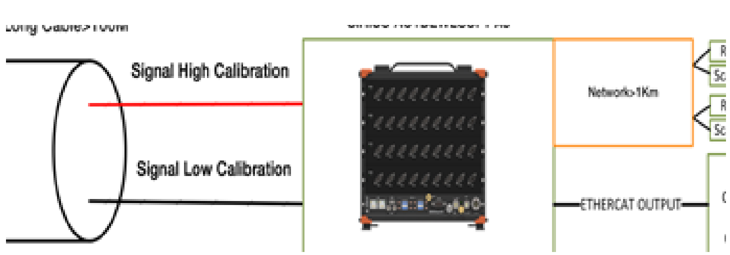


Figure 7: Proposed digital communication through EtherCAT.

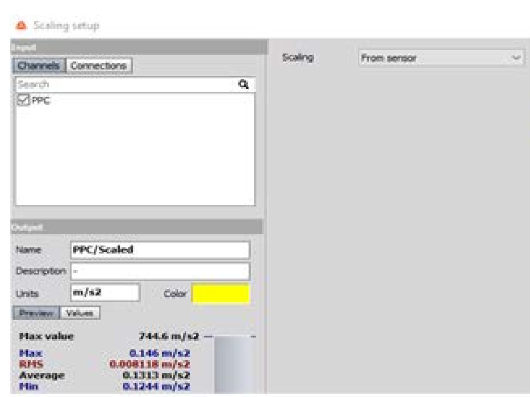


Figure 6: Math scaling setup (Left) and measured data in raw voltage and scaled values (right).

The solution – SIRIUS signal conditioner

The introduction of Sirius modules at ISRO in 2012 was a game-changer for their programs. It was an integrated solution for many issues unanswered for many years. Our hands-on experienced team engineers demonstrated the advanced features of the Sirius modules to ISRO scientists. The team visualized the potential of the Sirius compared to existing measurement systems.

We have visited the facilities in ISRO several times and associated ourselves with the scientists to demonstrate some tailor-made measurement solutions. We also explored system demonstrations in their experiments.

In short, we have rightly served delicious food when the customer was hungry. Now, our hard work is paying off. Today Dewesoft is a leading working partner for measurement solutions in multimillion mission-critical projects.

After strenuous efforts over 8 years, we have successfully established our footprint in the Indian aerospace industry. Of course, this gives us new challenges and raises expectations.

Automated integrated system for the quality test procedure
Initially, it was challenging to convince the ISRO team and change their way of approaching the problem. The Dewesoft solution has most of the functions as an inbuilt feature. It eliminated many interconnecting cables and potential human errors during the measurement. A few challenges were solved after that.

The Dewesoft solution updated the conventional test procedures with its innovative digital technology. Using our DualCoreADC® technology and galvanic isolators in the SIRIUS DAQ system, Dewesoft is always performing one step ahead of any other technology.

Dewesoft NET option -> LINK

The combination of SIRIUS analog output (AO) with powerful DewesoftX data acquisition software has replaced several pieces of old equipment from their test facilities. SIRIUS analog output is a standalone signal conditioner and its functions are not influenced by software, computer, or any other hardware.

Our solution has several built-in features:

- isolated programmable sensor excitation,
- input channel-to-channel galvanic isolation,
- standalone signal conditioning with analog output digitizer,
- main and redundant network storage through DewesoftX NET option,
- the graphical and numerical representation of raw and scaled data,
- post-processing and
- reporting.

Figure 4 is a block diagram of the instrumentation setup for the mission-critical applications with hundreds of sensors deployed in the remote field. Now, the systems are running on integrated single digital technology with modern architecture. Through this setup and method, we have improved the overall performance of the measurement system and minimized manual intervention. The Dewesoft measurement system that replaced the conventional system is shown in Figure 3.

Number of sensors and automated integration
The customer has more than 200 inputs with multiple types of sensors to measure various parameters in a single test. It was a cumbersome task to update non-linear calibration details of the sensors manually.

The only solution we could think of was to import their sensor database into the Dewesoft software. But the sensor database was created in a non-standard text format so we had to convert these data to extensible markup language (XML) for import.

A small application in Excel enables the conversion of this text file to XML. This file can be imported to Dewesoft analog sensor database. Now, we have successfully interfaced with a nonstandard customer database to Dewesoft. A very useful solution to avoid manual entry errors of different sensor characteristics.

Two-point scaling on raw data and nonlinear scaling
A few modern data acquisition systems have only one set of input signal scaling options but they don't have the option to convert the measured signal to physical quantities using calibration factors. Hence such systems didn't meet the essential requirement of the customer. The DewesoftX software has built-in novel features to apply two-point scaling on the input analog signal as well as the option to enter a nonlinear transfer function of the sensor from the sensor database (Figure 4).

The customer prefers two-point calibration of the raw voltage as an established procedure. It corrects the signal drops over a long cable. The corrected voltage is further scaled in Dewesoft with calibration coefficients of the sensors to convert the electrical quantities to physical quantities.

Initially, the raw data is scaled with two-point scaling in an analog channel setup - see Figure 5. The nonlinear calibration coefficients will then be loaded from the analog sensor database in the same channel setup. This raw voltage two-point calibration can be enabled in the settings advanced hardware set up of amplifiers.

The raw data and math scaling options are really useful to solve this problem. After implementing RAW offset adjustment in settings, the customer can now do the two-point scaling on raw data. Also, the technicians get scaled values from the math scaling module - see Figure 6. Checking raw voltage and scaled value in measure mode itself – it's now easy.

Hardware filters on SIRIUS Analog Output

The contradicting requirements of minimum output delay and band limitation at the output signal were challenging. SIRIUS analog output filters work as a function of the input sampling rate and hence the bandwidth. A higher sampling rate gives more quality output with higher bandwidth.

Even though reducing the sampling frequency will result in the low-pass filtered output it also increases the output delay and is unsatisfactory for a control signal. Hence the customer uses an additional analog filter at the input of PLC.

The Dewesoft solution worked on this critical requirement and we are glad to say that SIRIUS analog output was recently upgraded with programmable hardware digital filters starting from 30 Hz. The new analog output is a standalone integrated signal conditioner with hardware programmable digital filters. So, no more need for an additional filter before PLC. This solution is very satisfactory to the customer.

Conclusion

SIRIUS, as a standalone signal conditioner, always produces an amplified AO with minimum delay. It is an integrated solution over the conventional distributed measurement system. It stores data using the Dewesoft X NET option to a remote computer in the control room that is situated about a kilometer away from the field.

The customer analyzes and exports data to different file formats using a custom export rate in our versatile software package. So, the user can interpret and report the test data immediately after the measurement - needing only a minimum of time for preparation.

Compared to a conventional method the overall advantages of this DAQ system configuration:

- The single-user interfaces with rich visualization for all applications
- Quick setup for the measurements and fast reporting
- Total accuracy improvement
- Sirius-AO is standalone—independent of software and computers.
- Easy sensor setup update through XML import
- Programmable excitation for adjusting the field excitation
- Reduced delay to decision-making controllers
- Completely synchronized and No settling time for amplifiers
- Less workforce and more useful space available in the lab
- The additional mathematics reference curve is available to study the parameter behavior

There are still many jobs to do and applications to be explored given this success story. We are confident that a satisfied customer will give us more opportunities. We have further proposed to change the analog output to PLC cable to digital communication via EtherCAT protocol.

This is a great solution for avoiding copious amounts and lengths of cables and their laying. Also, this will reduce the delay to PLC by replacing the additional filter and analog front-end amplifiers. The details of the scheme are given in figure 6.

The engineers and managers at ISRO Propulsion Complex trust us. Project success starts in the field where the sensor is mounted and ends with a report of expected results in the customer's hand. In between, it is brought to life by Dewesoft.

Sources

Indian Space Research Organisation (ISRO) official website

Figure 8. SIRIUS as a standalone signal conditioner.

Large scale aerospace structural testing

Indian Space Research Organization (ISRO)
By Shaji G., Director, Innovative Solution, Chennai, India

CASE STUDY

The largest data acquisition test facility in the Indian aerospace industry is a massive Dewesoft 2264 channel integrated Signal Conditioning and Data Acquisition System.

The DAQ system is engineered for the Structural Test Facility, the first of its kind under the Indian Space Research Organization's Propulsion Research Complex at Mahendragiri, Tamil Nadu, India. Innovative Solution proposed Dewesoft solution, which is primarily planned to be used for the static and dynamic structural testing of launch vehicle domes, and internal payload stabilizing mount fixtures.

Scope of the project

ISRO Propulsion Complex (IPRC) has been entrusted with the task of configuring a data acquisition facility for performing tests to ensure the structural integrity of various subsystems of the launch vehicle. To meet this mandate, a Structural Test Facility (STF) was established.

The state of the art instrumentation focusing on integrated signal conditioning and dynamic data acquisition is proposed for acquiring critical parameters like:

- strain,
- temperature,
- pressure,
- displacement,
- Voltage,
- etc.

The Cable Terminal Room (CTR) located nearly 400 m away from the Control room houses the conditioning modules whereas the control room is equipped with servers, display nodes, etc.

The first main scope of the system is to simulate and map the reliability influencing parameters during flight stabilization. The second scope is the general structural integrity through crucial ambient disparities during stage separation phases or the orbital dynamic adjustments using auxiliary thrusters.

The strategic parameters from the specimen under test to be acquired include the:

deformation scale concerning the designed FEA model, thermal resistance for chamber fuse reliability monitoring, operational pressure stabilization in propellant lines, and

Figure 2. Propulsion system testing at the Indian Space Research Organization (ISRO).

the critical axial displacement at designated locations.

The acquired parameters are in real-time directed to control systems through the synchronized digital outputs available as a part of this IDAS. The acquired main and redundant data is transferred through separate OFC links to the servers in the remote-control rooms.

The critical system features include the dynamic sampling rate set for input channels based on the type of sensor. So, the factors of data throughput and transfer rate had to be carefully calculated to choose the right interface methods and hardware to handle the communication.

Since all the tests carried out will be of large scale and resource expensive, it is very crucial to ensure no data discrepancies or

loss be encountered in the transferred data to the Server and Control Rooms.

Data storage planning is an important factor considering the huge number of analog channels, the high sampling rate, and the nodes where the data is stored. As per the data critical standards specified by the institution, the acquired data has to be stored in several locations:

- in each R8rt data acquisition and control system locally,
- on the local configuration system in the CTR,
- transferred over a network to be stored in the main and redundant servers,
- and in the client display nodes where the archived data should be readily available for data retrieval and post-processing.

The database management includes engineering unit conversion, configuration with proper channel descriptions, tags, and scaling/parameter constants for conversion.

Online and offline data processing

The graphical and numerical data display method in the online mode had to be highly customizable like user-defined data update, triggering actions based on a timing event, the custom color of data, overload indication, etc.

The post-processing of the acquired data is also performed in the connected node systems. The main post-processing analysis includes:

Power spectral analysis on the stress plots.
3D contour plots for frequency reference curve extraction.
Combining multiple data trials for comparison.
Generation of cumulative test reports.

In addition to that, ISRO also had codes to process the selected parameters to the ambient conditions.

The tests were planned to be run for a longer duration. The system health parameters like memory usage, system temperature, multi-core CPU load, storage, etc. had to be continuously monitored and alarmed in case of critical conditions demanding less human intervention.

The extensive error diagnostics and warning system in Dewesoft have also proven very helpful for proper data management during acquisition. Furthermore, the display nodes are linked to shared network printers to automatically generate reports once done with the acquisition and post-processing.

The scale of the project

The complete system is mainly distributed into three major stations:

- Cable Terminal Room,
- Control Room 1, and
- Control Room 2.

The Cable Terminal Room (CTR) contains all the data acquisition systems configured. The configuration is as follows - see also Figure 4:

- 1888 Channels in 15x R8rt racks
- 376 Channels in 4x IOLITEr racks.

In addition, the CTR contains a configuration system and network switches for routing the main & redundant data to the control rooms.

The data link between the CTR and control rooms is extended through OFC Cabling for 400 meters. The control room is where the main and redundant server units are installed and further

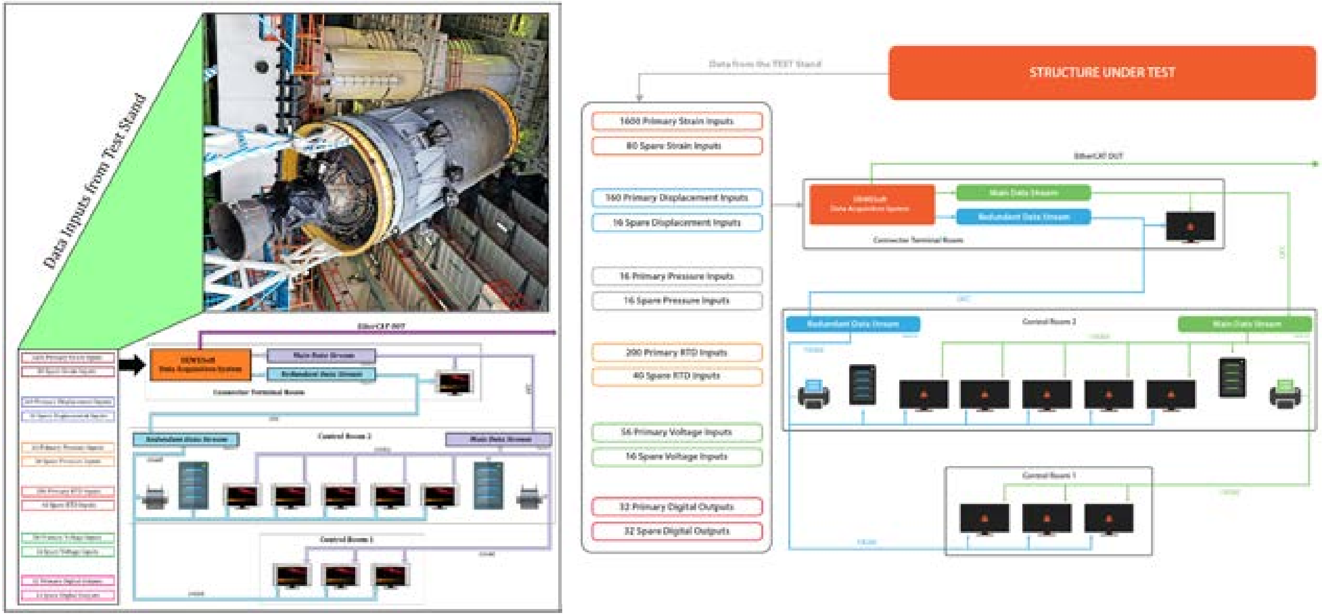


Figure 1: Data connection scheme from the test stand.

distributed to the multiple other systems designated as Display Nodes.

More than 12 kilometers (7.46 miles) of cables were routed from the sensors through multiple 96 core high-temperature resistant PTFE braided cables to the instrumentation racks in the cable termination room where the data acquisition systems are housed - see Figure 3.

The ground connections were provided separately and terminated using ISRO Standard 108-Pin Weidmüller Connectors. Then, the cables are dressed inside the rack and extended as required to connect to the respective channels in the R8rt & IOLITE data acquisition system.

System interfaces

Main networking through GigE

All the individual system elements have a dedicated controller. The collective data from all the R8rt & IOLITE data acquisition systems are channeled to a single configuration system (Node 1 Master) through a multi-layered managed network switch M situated at the CTR for consolidated visualization/storage of all the data.

This main data stream is extended to the Control Room 1 & 2 on optical-fiber cable (OFC) through another multi-layered managed network switchM for reliable communication. The data is then routed to be stored/viewed in server M and five client nodes located in Control Room 2 and three client nodes located at Control Room 1.

Redundant networking through GigE

All the individual system elements have a dedicated controller. The collective data from all the R8rt & IOLITE data acquisition systems are channeled to a single configuration system (Node 1 Master) through a multi-layered managed network switch R situated at the CTR for consolidated visualization/storage of all the data.

This redundant data stream is extended to Control Room 1 & 2 on OFC through another multi-layered managed network switch R for reliable communication. The data is then routed to be stored/viewed in server R and five Client Nodes located in Control Room 2 and three Client Nodes located at Control Room 1.

Synchronization

The time synchronization between the data acquisition systems is established with hardware synchronization cables referencing the ISRO standard IRNSS time source. The cabling runs in a daisy chain method interconnecting every data acquisition node ensuring a synchronized time stamping for the stored/displayed data.

EtherCAT® Out

In addition to the main and redundant data streams, all the data acquisition nodes are designed to provide a direct t output stream. This data stream can be used as a feed to the 3rd-party Programmable Logic Control Systems (PLCs) for feedback monitoring or timed response.

M - Related to the Main data stream
R - Related to Redundant data stream

The Dewesoft role in the project

We, Innovative Solution and Dewesoft have worked on this particular project technically and commercially for more than three years now, to have finally reaped. A total solution from the concept to commissioning, adhering to the safety/standard norms of ISRO was quite a challenge.

The technical involvement of our engineers extends from the planning to the field implementation and testing. The quantum of work involves the selection of data acquisition hardware, choice of the communication/data cables, design of floor plan, efficient routing & termination planning cable dressing models. The total system was implemented in the field with

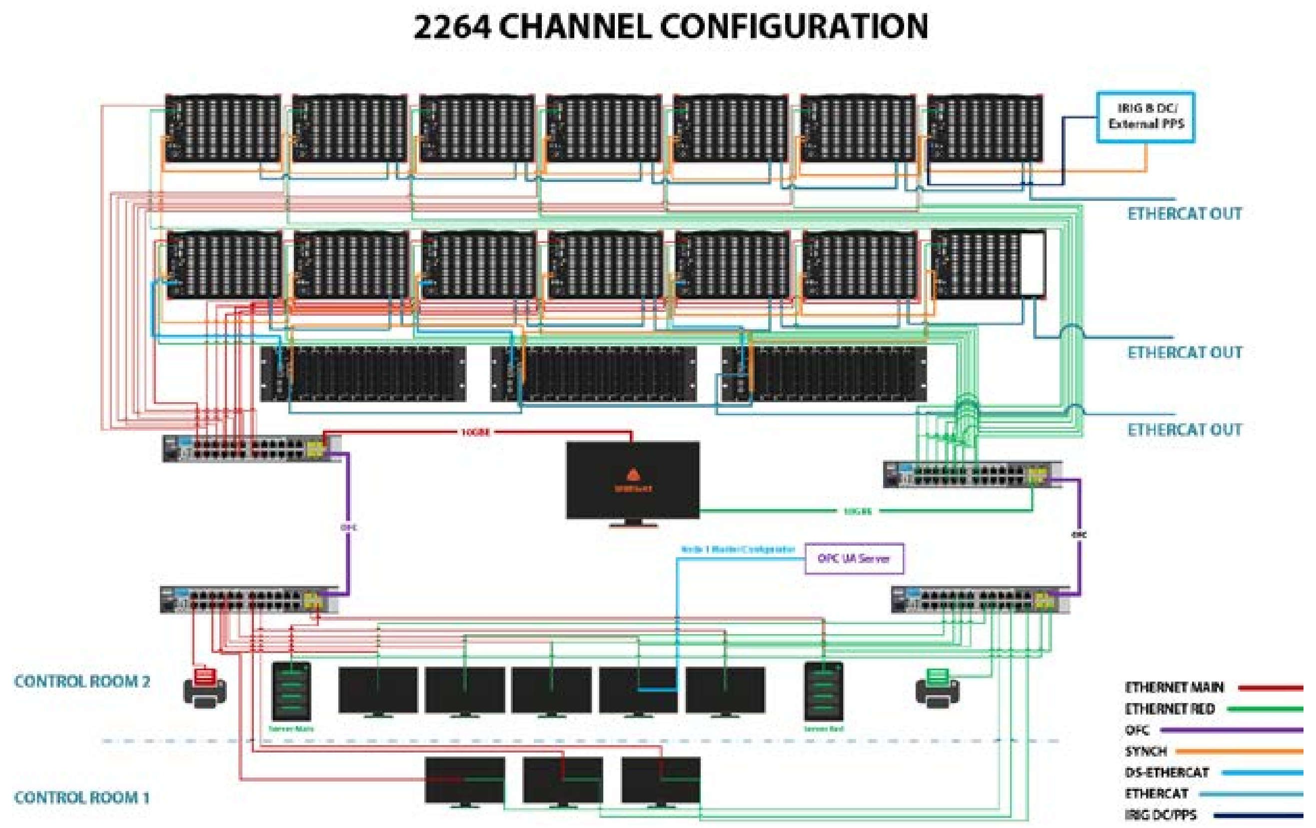


Figure 3. Front view test rigs rack schematic with overall cable routing.

the flexibility of accessibility and ease of identification and maintenance.

The cables from the sensors on the structure under test are routed to the termination room through different cables considering process critical data, sensor type, wiring configuration, etc. The strain gauges data signals are interfaced to the acquisition units with a quarter bridge 3-wire configuration and a 3x single-core tinned copper wires sized 24AWG, PTFE cables meeting the technical specifications of ISRO and respecting their codes.

Wiring for different voltage signals or different functions was terminated separately on dedicated terminal strips/raceways with color-coding. Separate color coding is followed for utility power (fan, temperature monitor) and process power (controller, input modules). The cables were properly routed from the cable managers on the top and bottom of every DAS so that it would be easier to identify channel ID for configuration.

The challenge of EMI/EMC was met by our design team, by suitably positioning the key components and electrical power distribution devices within the system cabinet and by using separate raceways. Standard Polyimide cable glands for main input cables were installed as per the code and due care was exercised during its wiring, routing, termination, and ferrule on both sides.

The project was built to the level it has today with the help of multiple service providers from various sectors relevant to the facility's erection and operation. We are proud to be a part of this strategic mission under the Government of India.

The prompt and constant support rendered by Dewesoft local offices - Dewesoft Austria and Dewesoft India which enabled the realization of this massive scale of project successfully is greatly acknowledged.

Future of the project

The commissioned Structural Test Facility is planned to be subjected to extensive testing for a decade from now, that is till the planned upgrade to a then better system.

Dewesoft is also the forerunner for an even bigger facility under construction, planned to operate with more than 15000 data acquisition channels.

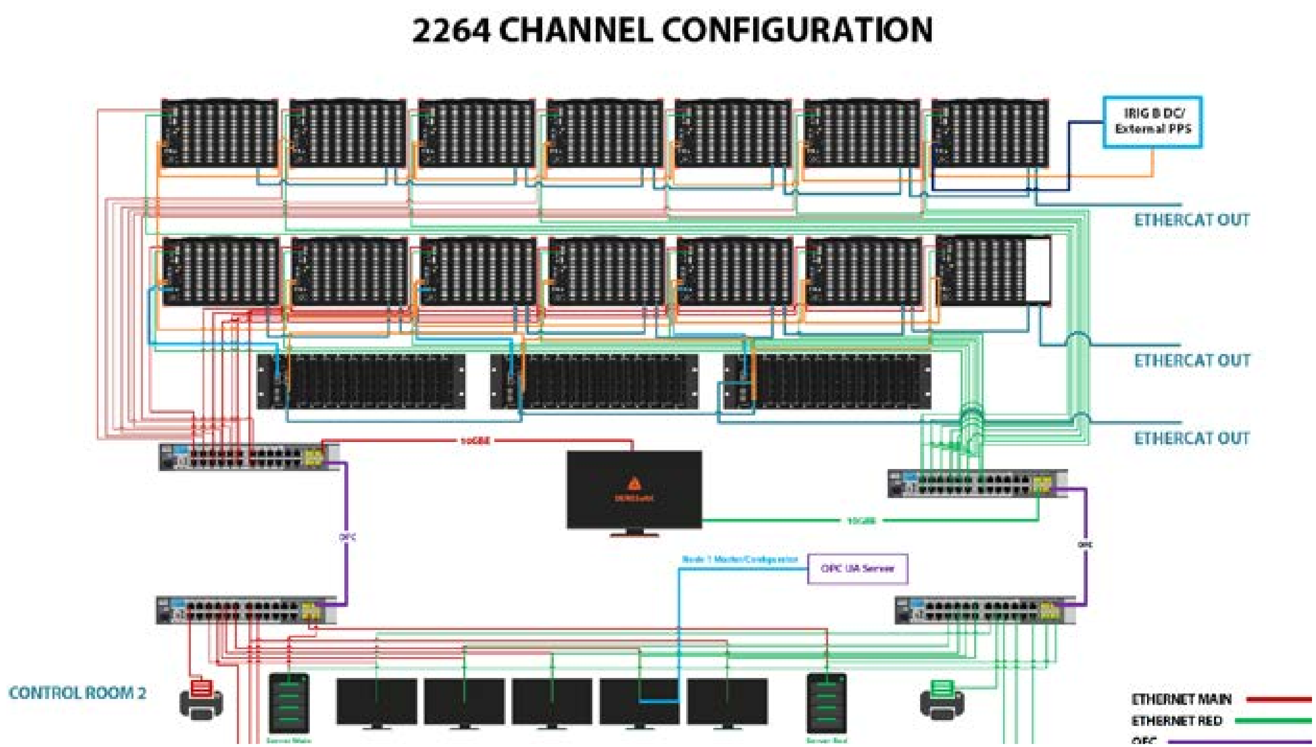


Figure 4. Overall system schematic.

Structural testing of a rocket nose cone

Aeronautics and Space Institute (IAE), DCTA, Brazil
By Vid Selič, NVH engineer, Dewesoft

At the **Aeronautics and Space Institute** (IAE), DCTA, structural dynamic tests, like sine processing, SRS, and modal analysis are performed as a part of the standard procedure on different components of rocket launch systems. In this case, the nose cone of a rocket was tested on a shaker using sine processing.

DewesoftX software improved the time efficiency and the quality of data acquired by supporting the real-time calculation through a designated Sine processing user interface.

CASE STUDY

The Departamento de Ciência e Tecnologia Aeroespacial (DCTA), the Brazilian Department of Science and Aerospace Technology is located in São José dos Campos – the largest Aerospacial Complex in all Latin America.

DCTA functions as the Brazilian national military research center for aviation and space flight and is subordinated to the Brazilian Air Force (FAB) and coordinates all technical and scientific activities related to the aerospace sector involving the interests of the Ministry of Defense.

Testing took place at Instituto de Aeronaútica e Espaço (IAE), the Aeronautics and Space Institute. This institute develops and executes projects in the aeronautical, airspace, and defense sectors, and is co-responsible for the execution of the Brazilian Space Mission.

The issue

The nose cone tested in this particular structural test plays an important role in R&D activities conducted for TEXUS missions - a sounding or research rocket program, serving the microgravity programs of the European Space Agency (ESA) and Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), the German Aerospace Center.

The IAE part of the TEXUS missions focuses primarily on the development of the launch systems intended for and facilitating the exploration of the properties and behavior of materials, chemicals, and biological substances under weightless conditions (micro gravitation). Each launch provides around six minutes of microgravity.

In this case, IAE needed to measure the resonance frequencies of their rocket nose cone to avoid operation in these frequen-

cies, which could compromise the structural integrity and potentially cause mission failure.

They needed a reliable data acquisition system capable of tracking and computing the defined range of responses and transfer functions in real-time.

Sine processing and sine reduction test case

Sine processing is a tool to perform structural tests on large structures. Such a testing approach is widely used for design validation and qualification in the aerospace industry, and typically, hundreds of input channels are required.

By definition, there is no room for error, all structures utilized during a mission must be carefully tested beforehand to ensure proper operation and uncompromised structural integrity.

The evaluation of such large structures is done by exciting them with a sweep of single frequencies on a shaker. Sine Sweep Vibration Testing traverses or sweeps from low to high frequency or vice versa. It is used to identify resonances inside the range of the sweep by comparing response vibrations of the product to the vibrations on the shaker table.

- As desired output, Sine processing returns the following:
- structural resonance frequencies,
- amplitudes,
- phase,
- total harmonic distortion (THD) of response, and also
- transfer functions between excitation and response points.

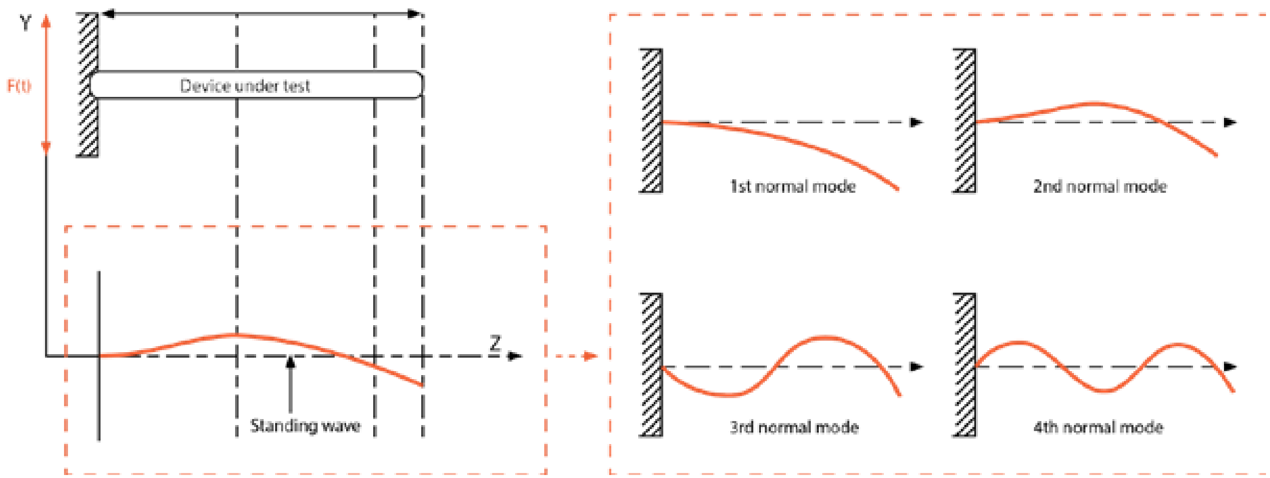


Figure 1. Different modes are resulting from excitation in resonance frequencies.

To evaluate the structure under test in the frequency domain, it is important to accurately extract these parameters from the sinusoidal signal.

Sine processing uses a Constant Output Level Adaptor (COLA) signal to calculate instantaneous frequency and then extracts amplitude and phase from the accelerometers at that frequency. The COLA signal output synchronizes the shaker control system with the DAQ system.

At IAE/DCTA the Dewesoft X3 data acquisition software – with the sine processing plugin - and the Dewesoft SIRIUS data acquisition system were used for the data acquisition.

The sine processing test runs by synchronizing the Dewesoft data acquisition system with the vibration shaker controller (3rd party). The Dewesoft sine processing tool performs one of the two methods of frequency detection:

- Zero-crossing or
- Hilbert transform.

Acquired signals from accelerometers placed on the rocket nose cone are measured together with sweep frequency which is detected from the COLA signal. They are then computed in real-time to provide detailed insight into the structure's response to excitation.

Test and measurement setup

To ensure results relevant for the customer, it was important to perform a sine sweep test from 25-1000Hz, which is the typical frequency range of vibration which a rocket nose cone will undergo during transport, launch, and flight.

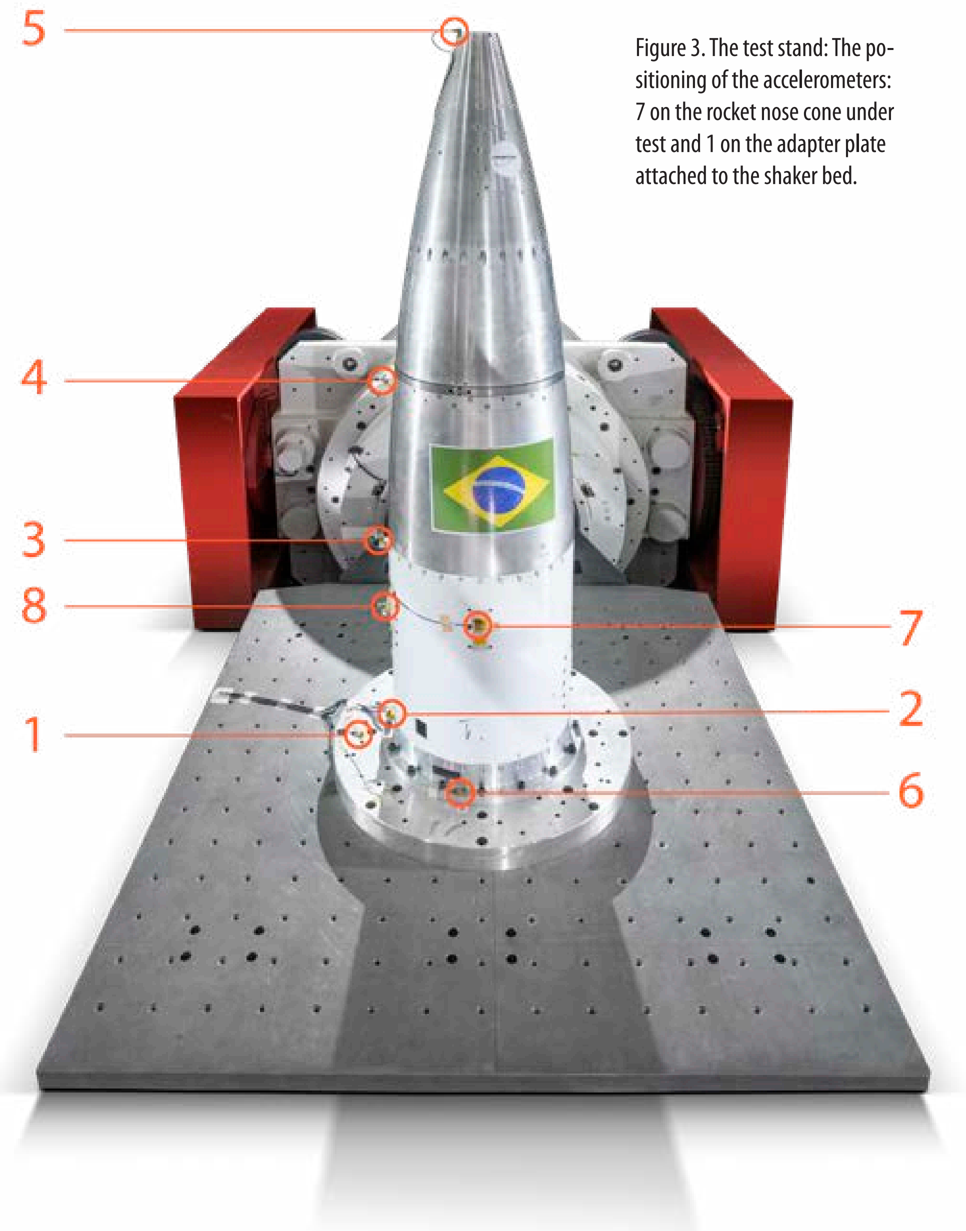


Figure 3. The test stand: The positioning of the accelerometers: 7 on the rocket nose cone under test and 1 on the adapter plate attached to the shaker bed.

For the data acquisition, we were using a system with two SIRIUSi-HD-16xACC slices. The DAQ system offered 32 IEPE accelerometer inputs in total. The same DAQ system also enables IAE/DCTA to perform other measurement tasks and also offers an easy way to extend the input channel count. Additional inputs like IEPE, voltage, temperature, strain gauge, and others can be added easily to form a high channel count system when needed.

To showcase Dewesoft sine processing solution true power, we were running also 1/3rd octave analysis and true FFT with 4.096 lines resolution - the selectable line resolution allows up to 64.000 lines - simultaneously with sine processing on all 31 channels. The only exception being was the input channel used for the COLA signal from the vibration shaker controller.

The sine processing itself runs inside Dewesoft X3 DAQ software, including the ability to connect and measure other useful parameters, such as environmental conditions of the test or include high-speed video to observe how DUT is moving during the test.

8 triaxial accelerometers were attached to the nose cone structure (outer dimensions fi 874mm x 1830mm) in configuration to obtain the best possible desired results.

For the test, we were using five Brüel & Kjaer Type 4520 triaxial accelerometers and three PCB HTJ356B01 accelerometers. Seven accelerometers were placed along with the shape of the structure, and serving as a reference one PCB triaxial accelerometer was placed on the adapter attaching the nose cone to the shaker table - see Figure 3.

One analog input on our two SIRIUSi-HD-16xACC was used to connect the COLA voltage signal for frequency detection of the sweep transmitted from the shaker controller to the shaker and exciting the structure.

The SIRIUS DAQ systems also include two very important technologies that bring measurements and data acquisition to the next level:

- DualCoreADC
- Galvanic isolation

DualCoreADC - high-dynamic DAQ
SIRIUS DAQ amplifiers use two 24-bit AD converters for signal conditioning. The SIRIUS is achieving an astonishing 160 dB dynamic range in time and frequency domain with a 200 kHz sampling rate per channel.

Galvanic isolation
The DAQ system also offers high channel-to-channel and channel-to-ground isolation which prevents unwanted noise, offers the best signal quality and prevents damage to the systems from excessive voltage, and avoids ground loops.

The device under test was excited in the direction of the shaker table movement and our coordinate system was placed correspondingly so that the y-axis was aligned with the axis of excitation.

IAE/DCTA was already using a designated system for the tests and was handling all the transfer function calculations in post-processing. The Dewesoft sine processing plugin can handle the calculation of transfer functions, phase, RMS, Peak, and a lot of other parameters in real-time.

Results calculated in real-time are vital for IAE as DUTs such as rocket launch systems and/or payloads are costly. IAE engineers get immediate insight into the measured parameters of the structure, allowing them to directly monitor if resonance frequencies and corresponding amplitudes are within expected/projected values.

Test conclusion

Dewesoft Sine processing solution coupled with the powerful SIRIUS data acquisition system can perform testing of large structures in real-time on an unlimited number of channels. Additional calculations, not selected to be performed in real-time, can be performed in post-analysis using the time domain data that was stored during the measurement.
IAE Test engineer Domingos Strafacci concluded: "The system is really easy to use and set up. It will save us a lot of time when performing this kind of crucial structural testing".

The measurement that took place, in this case, was only using a single of many nodes that would otherwise be building a larger system. It must be noted, however, that regardless of the number of channels the operational properties of the system will remain unchanged.

As DCTA research and development activities consist of many different projects, they can benefit greatly from the advantages of structural testing and the flexibility of the Dewesoft system, which can be used to perform many tasks such as road data vibration acquisition and GPS tracking of the route, modal analysis on the wing of a plane or SRS measurement during rocket stages separation test.

The IAE dynamic tests leader, Dr. Edilson Camargo said:" As this system is very flexible it will enable us to tackle a variety of our day-to-day measurement tasks, not just sine processing. Through this, we will be able to optimize our cost expenditure".

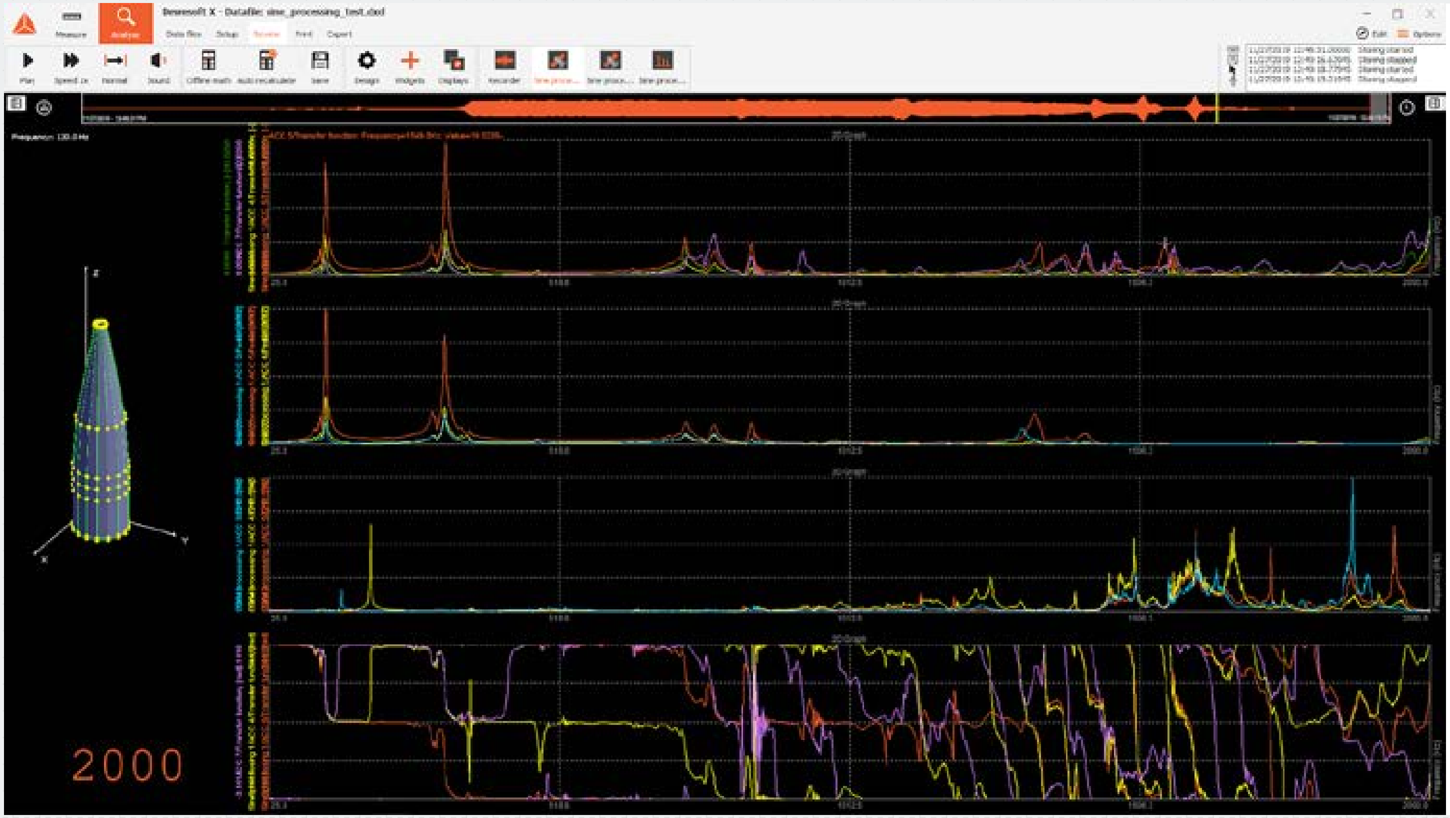


Figure 4. The measurement screen in the DewesoftX software plugin.

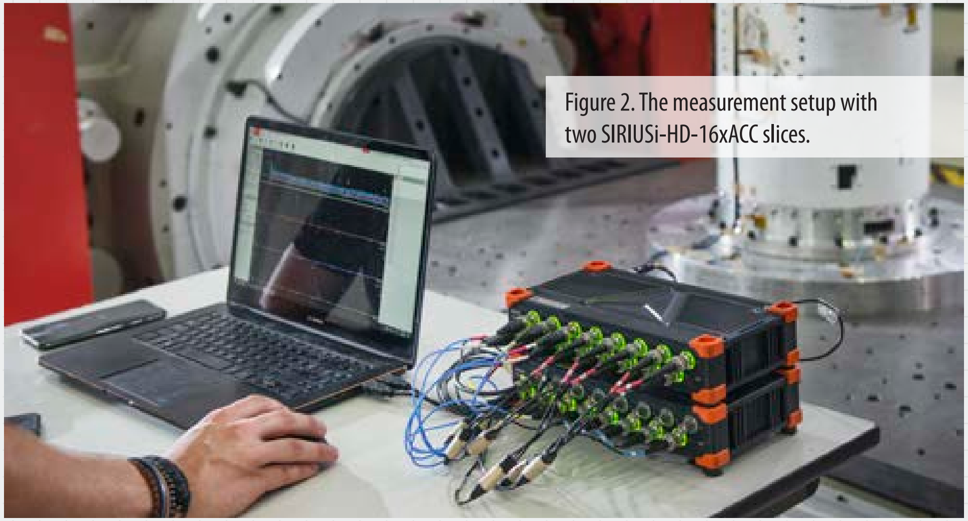
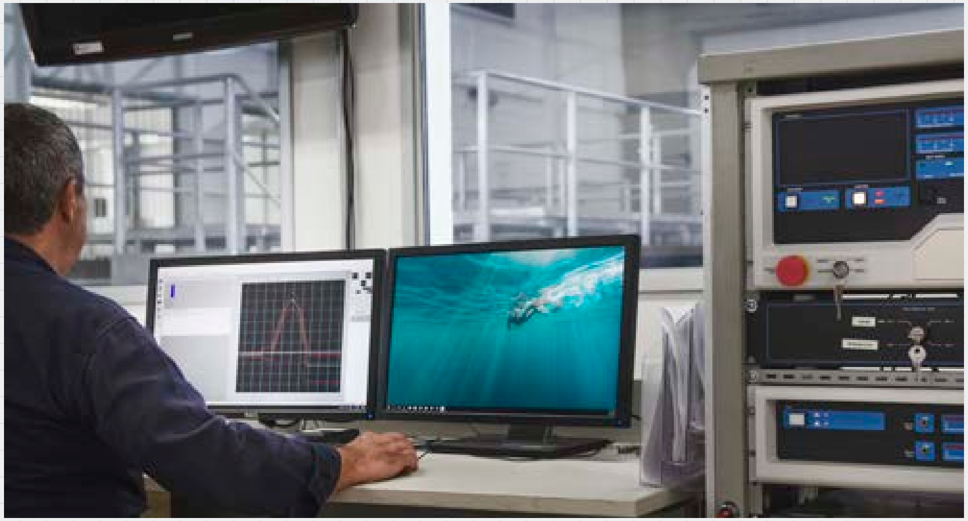


Figure 2. The measurement setup with two SIRIUSi-HD-16xACC slices.



Structural vibration monitoring on the NASA Crawler core systems

NASA Kennedy Space Center, USA
By Jake Rosenthal, Eastern Regional Manager, Dewesoft USA

After working with the NASA Sensors and Data Acquisition (SDAS), a subsystem group on the Mobile Launcher 1 platform, a need was discovered to replace an aging Data Acquisition system that monitors the Crawler Transporter core systems.

This is a large channel count application that requires precision time synchronization and the ability to fit in the same small space of the aging system from the '80s.

CASE STUDY

Introduction

NASA Engineers working at Kennedy Space Center identified some issues with their aging DAQ system on the NASA Crawler Transport System as they prepare for the initial rollout of the Artemis 1 program (SLS rocket - Space Launch System) to the launch pad.

The "Crawlers" were built originally in 1965 for the Apollo missions to move the Saturn 5 rocket from the Vehicle Assembly Building to the Launchpads. Two units were originally built and are still in operation to this day.

Each Crawler weighs in at a total mass of 6 million pounds (2.7 million Kg's = 2.7 thousand metric tons). Has a total lifting capacity from 12 to 18 million lb. The maximum speed of 1 mph loaded, or 2 mph unloaded.

The average trip time from the VAB along the Crawler way to Launch Complex 39 is about five hours. Carries 5,000 U.S. gal of diesel fuel, and it burns 125.7 U.S. gal/m. 4.2 miles to LC39B.

Crawler dimensions:

- Footprint 131 by 114 ft
- The height from ground level to the platform is adjustable from 20 to 26 ft, and each side can be raised and lowered independently of the other.
- The crawler uses a laser guidance system adjustable to 0.16 degrees; about 30 cm (1 ft) at the top of the Saturn V) while moving up the 5 percent grade to the launch site

Figure 1. Each Crawler has eight tracks with each track having 57 shoes, and each shoe weighs 900 kg (1,984 lb.).

The challenge

This application was a straightforward set of measurements with:

- 30 IEPE accelerometers for vibration signals for the structural vibration monitoring,
- 16 channels of hydraulic pressure, and
- temperatures.

The hard part is that the need to do time-correlated measurements across multiple platforms in real-time without the use of GPS time. Using the IRIG-B timecode we can grab this external time source to then line the data up with the other DAQ modules that are on the Mobile Launcher that Crawlers are transporting.

The R8R data acquisition chassis has become the go-to solution for the SDAS team on KSC and using the SIRIUS-STG amplifiers.

This allows for symmetry across all testing needs and the ability to swap chassis around as spares to each other to speed up testing time and utilization of resources. The DSI adapters were chosen to finish the signal conditioning for the IEPE sensors.

Measurement requirements

- Measure 30 IEPE Accelerometers for Structural Vibration Analysis
- 16 Channels of Hydraulic Pressure
- Temperatures
- Replacing old HBM Genesis DAQ system
- Must correlate data real-time with Mobile Launcher SDAS systems

Conclusion

The results are a happy customer with new data acquisition for real-time monitoring, display, and recording of the performance of the Crawler Transport System while it is carrying a priceless load and doing precision movements.

The key to success in this application is the quality and performance of the SIRIUS-STG amplifier. For the price, it offers a brilliant performance!

The R8R chassis is now rugged to support any environment NASA might throw at a Data Acquisition system. The ease of use of the system to an adapter to any type of environment or test allows engineers to spend their time recording data rather than the setup of the system.

Figure 2. The tracked Crawler-transporters are used for transporting Shuttle vehicles.

This test is the offshoot of all the hard work done to support the SDAS Team on its wide variety of testing. This project was a perfect example of a drop-in replacement to quickly upgrade and increase testing capabilities using the always ease to use Dewesoft Testing Solutions.

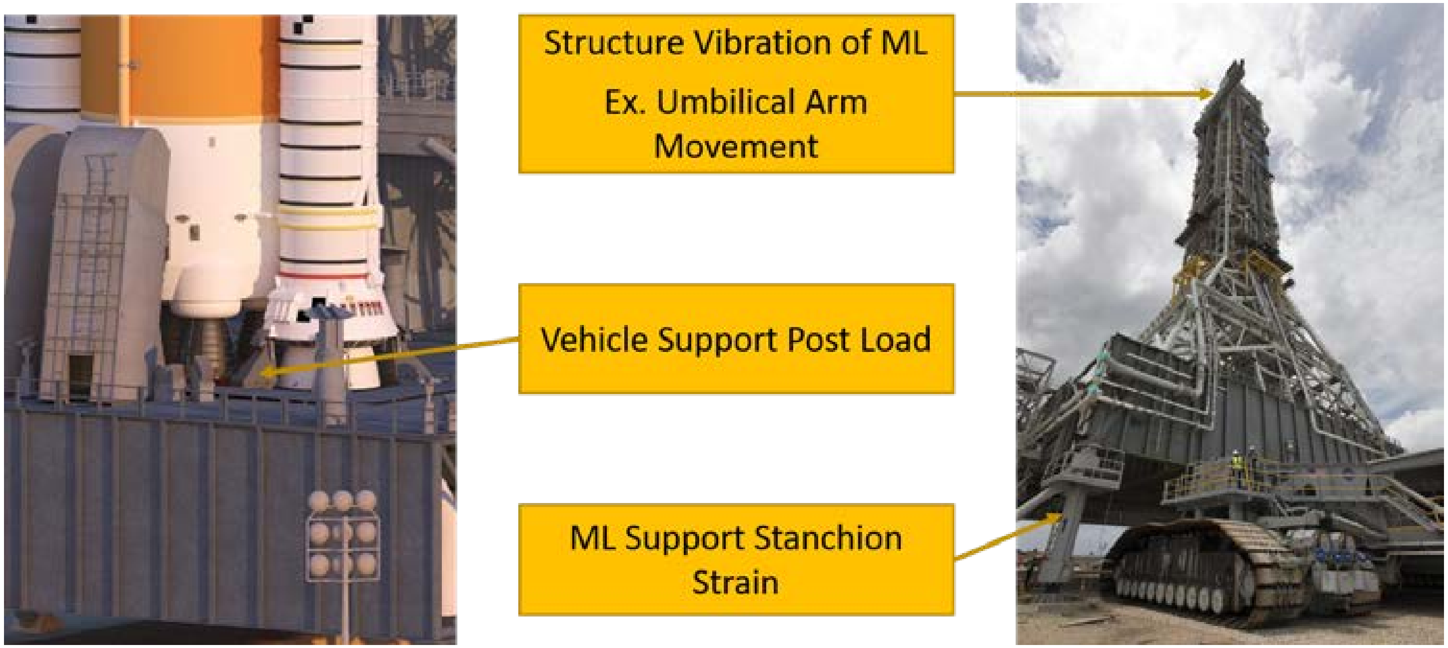


Figure 3. More measurement real-time correlation.

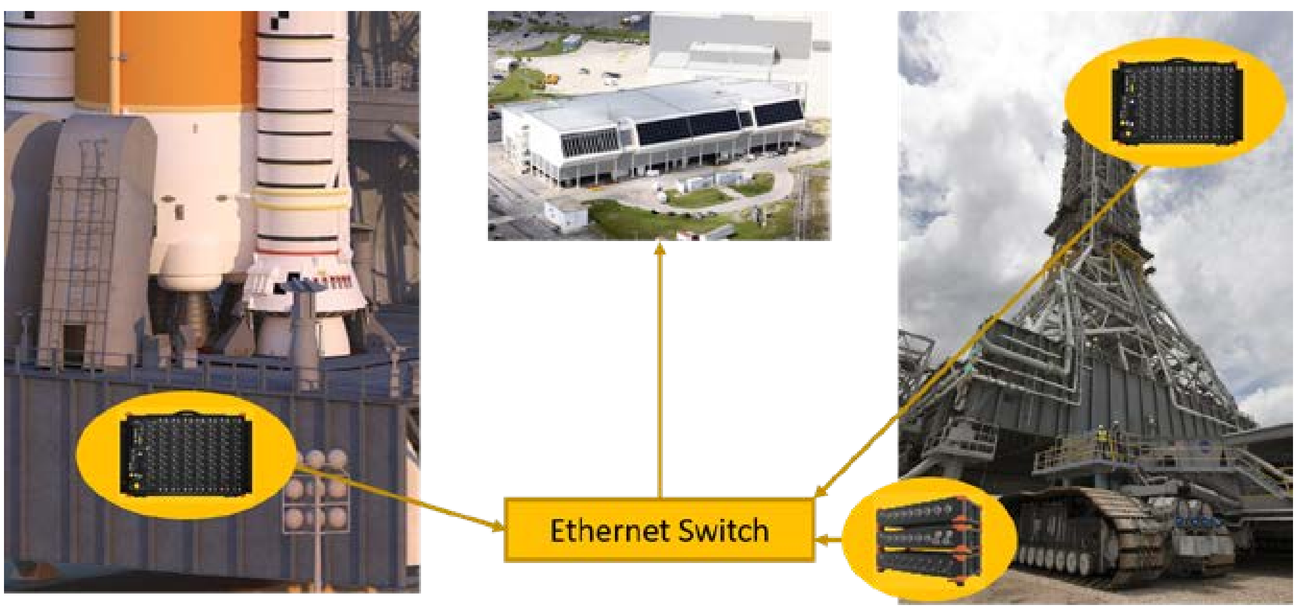


Figure 4. Advantages of the NET option.

Figure 5. R8rt is a high-channel-count DAQ system with high-end signal conditioning, powerful computer, SSD data logger, and low latency data output capability to 3rd party EtherCAT real-time controllers.

Dewesoft on the European test bench for large launcher solid-propellant boosters

CLEMESSY, France

The thrust of the booster is around 4650 kN. Thunder strikes the rainforest; the noise is deafening. The deep rocky drench at the foot of the launch tower is forcefully filled with large clouds of fire and smoke. The trees along the edges are swaying heavily. It is only fired for 135 seconds, but the power of the solid rocket motor is overwhelming.

Supervision and data acquisition on the European BEAP test bench for large launcher boosters in French Guiana is applied by Clemessy and Dewesoft.

CASE STUDY

P120C, the motor tested measures 13.5 meters in length and 3.4 meters in diameter. Packed with 142 tons of solid propellant, the engine was ignited and produced a flood of flames. All to validate its design – to monitor, measure, and document all functions and parts with 600 parameters – simulating the complete burn time from liftoff and through the first phase of flight.

The scene is the European Spaceport located around 10 km to the North-West of Kourou in French Guiana, South America. On the 28th of January 2019, the CNES (National French Space Agency) facilities test-fired its second P120C solid rocket motor, a step toward the initial launches of the Vega-C light satellite launcher late this year and the Ariane 6 heavy satellite launcher in 2020.

The static hot firing was a success – one more important step in the joint European space program to make sure that multi-million payloads reach orbit safely and cost-efficient – and Dewesoft data acquisition played a key part.

Link to video

Clemessy and Dewesoft - the test solution

In the run-up to the test, all the main components of the motor – such as nozzle, igniter, solid propellant, and insulated motor case – had already been tested separately. "This static firing is designed to prove these technologies, materials, and production techniques in combination and validate the behavior of the assembled motor," noted ESA ahead of the test.

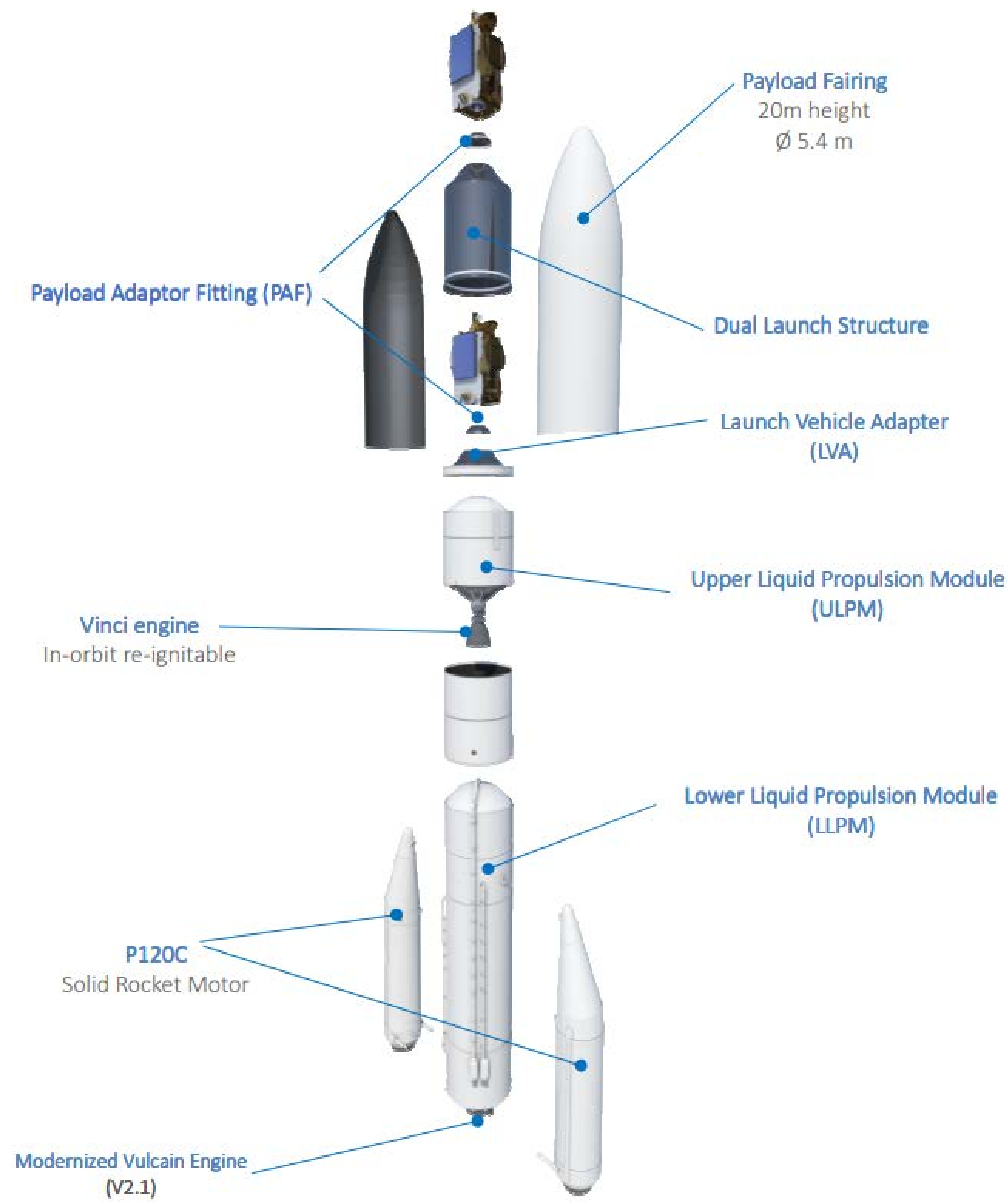


Figure 1. Ariane 6 - schematic overview.

In 2015 CNES on behalf of the ESA put forward the task to improve the Ariane test bench by replacing an analog data acquisition with high-end conditioning and digitizing data acquisition. The provider would face the challenge of interfacing with the existing test bench and providing a high-reliability control command.

This challenge was accepted by CLEMESSY as a system integrator, even with a hard deadline and limited time to complete the project: the firing test date was fixed, whatever happened, teams had to put data acquisition and control-command fully operational for the test.

CLEMESSY is a French company specialized in the engineering and implementation of industrial technical installations. CLEMESSY, a subsidiary of EIFFAGE, was to deliver the system to be used when testing the booster on the Ariane launch and to be in charge of the maintenance of the installations.

For data acquisition CLEMESSY selected Dewesoft. On the hardware side, Syclone ensures the interfaces with the operator, perform the server and real-time sequencer, whereas DEWEsoft is interfaced with the process. The originality is that the Dewesoft system is not only used as data acquisition but also serves data to the Syclone control system in real-time.

Kourou - the European spaceport

The test took place in French Guiana, at the Guiana Space Centre (CSG) -the European spaceport, which has been operational since 1968. This overseas region of France is the size of Portugal – 98% is covered by tropical rainforest – and has a little more

Figure 2. The BEAP test bench - the booster arriving.

than 250.000 inhabitants. The industry is centered around the spaceport and an estimated 15% of the working population are directly or indirectly involved with the space industry.

Geographically, this location fulfills the two major requirements of a spaceport:

- It is near the equator, meaning less energy is required to maneuver a spacecraft into an equatorial, geostationary orbit. Rockets can be launched into orbit with an inclination of as low as ~6°.
- It has an open sea to the east, meaning lower stages of rockets and debris from launch failures are unlikely to hit human habitations. Rockets launch to the east to take advantage of the angular momentum provided by Earth's rotation.

The European Space Agency (ESA), the French National Space Agency (CNES), and commercial companies like Arianespace conduct launches from Kourou. The spaceport was used by the ESA to send supplies to the International Space Station. ESA pays two-thirds of the spaceport's annual budget and has also financed upgrades made during the development of the Ariane launchers.

The day-to-day life of CSG is managed by CNES. CNES provides all needed range support, requested by Arianespace, for spacecraft and launch vehicle preparation and launch. The facilities can process several spacecraft of different customers at the same time, with large clean-rooms and supporting infrastructures. The spacecraft and launch vehicle integration and launch are carried out from launch sites dedicated for special projects; Ariane, Soyuz, or Vega.

The test is all about the Ariane 6 launcher project. ESA's goal is to ensure and maintain independent access to space for

Europe. Beginning in 1973, the development program is working with the CNES as a prime contractor. The maiden flight of Ariane 1 took place on 24 December 1979.

ESA works with an industrial network, led by ArianeGroup, of more than 600 companies in 13 European countries, including 350 small- and medium-sized enterprises, to fine-tune the design and start production. Meanwhile, CNES is preparing its launch facilities at CSG.

The overall mission is to make a cost-effective, reliable, unmanned vehicle that provides affordable access to space – a tool to launch satellites for mobile communication, television broadcasting, meteorology, earth observation, and more other uses.

The exploitation cost of the Ariane 6 launch system is its key driver for development. The final design of Ariane 6 was selected in December 2014, favoring a liquid-fueled core with large solid rocket boosters over the initial solid-fuel rocket design. Ariane 6 is to replace Ariane 5 at half the cost and allow double the number of launches each year.

The Ariane 6 consists primarily of these components:

- A Lower Liquid Propulsion Module equipped with the Vulcain 2.1 engine;
- An Upper Liquid Propulsion Module equipped with the Vinci engine;
- Two or four Equipped Solid Rocket depending on the configuration of the Launch Vehicle: Ariane 62 or Ariane 64;
- A payload fairing;
    - Depending on the mission requirements, a variety of different adapters/dispensers / dual launch structures or carrying structures may be used;
    - Carrying structures for micro, minisatellites, and nanosats.

Figure 3. The P120C booster is on the move.

© CNES/ESA/Arianespace/Optique Vidéo CSG/JM Guillon, 2018

The Ariane 6's Vulcain 2.1 engine is built with fewer parts while holding a greater efficiency, while the improved Vinci upper stage will allow for additional orbital destinations for more flexibility via a wider reignition capability.

BEAP - the test bench

Unlike a lot of solid motor tests, this firing was conducted in a vertical position on the test stand - see Figure 2. The test facility is continuously improved to accommodate European launcher evolution. The all-new P120C solid rocket and testbed were equipped with sensors to gather data on over 600 parameters, mounted the stand, and fired for 135 seconds in the test. The Solid Booster Test Bench (BEAP) is the unique test pad at the Guiana Space Centre. Since 1993, it has performed the testing of Ariane 5 Solid Booster Stage (EAP) motors. None was intended to actually lift off and the facility is equipped with safety systems to prevent a booster breaking loose from the test bench and leaving the ground. In this case, large blades would cut its envelope open, allowing the solid propellant to burn freely without providing any thrust.

BEAP is used to test the boosters of the European ARIANE 5, VEGA, and the future ARIANE 6 launchers to ensure they perform properly. The test bench acquires the measurements and controls the nozzle to check the operation of the onboard electronics.

P120C - the booster

The P120C is designed and built by a European consortium involving a joint venture known as Europropulsion, a venture between ArianeGroup and Avio.

The P120C booster has a thrust of approximately 1 million pounds. It has the world's largest monolithic carbon-fiber composite solid rocket booster casing. The motor's case is one, single, component designed to lower the cost of flying payloads.

The booster is the first stage of the Vega-C, a new launcher developed by ESA, which is expected to debut in 2020, increasing performance from Vega's current 1.5 t to about 2.2 t in a reference 700 km polar orbit. It will also work as the strap-on booster for the Ariane 6 series – either two or four of these boosters can be affixed to the Ariane 6 launcher to provide the thrust required for liftoff.

The P120C, co-developed by ArianeGroup and Avio on behalf of their 50/50 joint venture Europropulsion, consists of two principal parts. The first is the structural casing, built by Avio, an international group engaged in the construction and development of space launchers and solid and liquid propulsion systems for space travel. The casing is made of carbon fiber (filament-wound, automated fabric layup pre-impregnated epoxy sheets).

The second part is the nozzle, built by ArianeGroup and made of various composite materials, including carbon/carbon; it allows high-speed ejection of the extremely hot gases (3,000°C) generated by the motor, thus creating thrust by transforming the combustion gas energy into kinetic energy. The nozzle can also pivot, which enables the launcher to be piloted. Propellant casting and motor final integration are performed in French Guiana.

While Vega-C will continue to launch from the current Vega pad at the spaceport, a new launchpad complex is being built for the Ariane 6, called ELA-4.

For a launch campaign, the core stages will be integrated and prepared horizontally in the Launcher Assembly Building, less than a mile from the launch zone. The central core is then moved to the pad and erected vertically in the mobile gantry. There, the boosters, payloads, and fairing are added, before the mobile structure allows for platforms to access the different levels on the pad. The gantry is moved shortly before launch.

The booster - P120C			
Motor length:	13.5 m	Diameter:	3.4 m
Propellant mass:	142 t	Maximum thrust:	4,650 kN
Motor dry mass:	11t	Specific impulse:	278.5 s
Motor case mass:	8.3 t	Combustion time:	135 s
Average thrust:	4,500 kN		

Two further test stand firings will follow to qualify the solid motor before the first flight of Vega-C in 2019 and that of Ariane 6 in 2020.

SYCLONE - the test control system

The supervision and data acquisition system now implemented on BEAP integrates SYCLONE BY CLEMESSY (Syclone) and Dewesoft data acquisition - see Figure 4.

Syclone is a fully scalable control-command software operating like a toolbox, which makes it possible to develop a customized solution adapted to needs and environments. The software structure combines the worlds of supervision, real-time process control, and physical hardware.

The Decision Support System provides operators at the Guiana Space Center with map support for danger zones during risky operations such as launching a rocket. The objective of the system is to analyze and cross-check meteorological and pyrotechnical parameters over an area of 2,200 km^2 and display information in real-time for up to 10 dangerous operations conducted simultaneously for coordination purposes.

In the early phase of the project, advanced features were requested by the end customer; one, to see the global system as

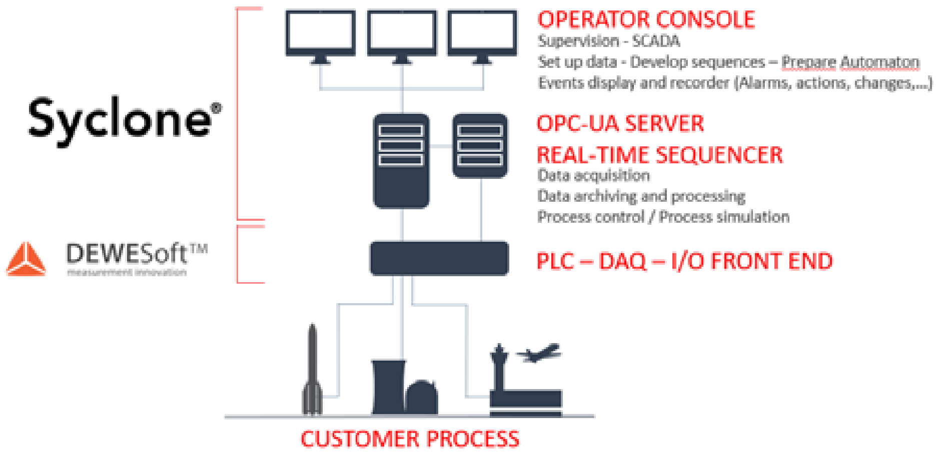


Figure 4. The Syclone and Dewesoft system setup.

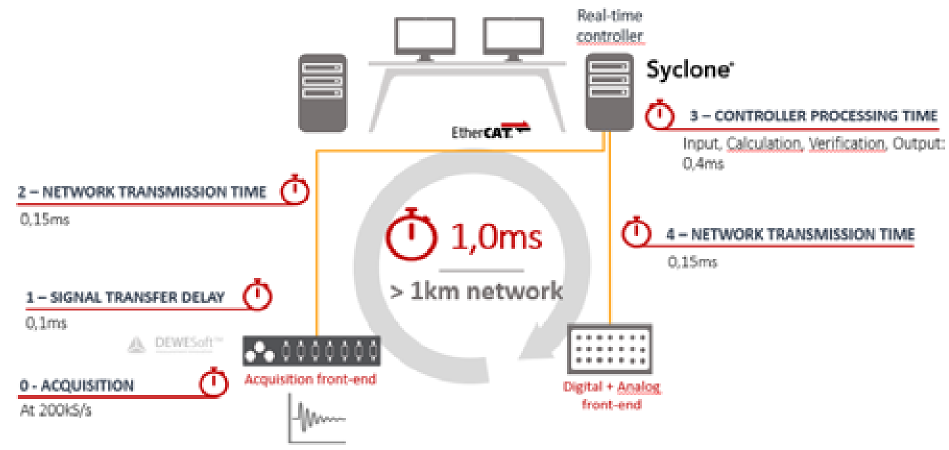


Figure 5. The system performances - its architecture combines both data acquisition and real-time control-command.

if it was only one measurement unit, and two, to have a cross trigger that triggers all the units on the same event. Lastly, cybersecurity requirements are very high and were dealt with since the beginning of the project.

When testing launcher boosters or engines, the uniqueness and the high added value of the units tested, as well as the high pyrotechnic risks, require optimal safety and reliability of the control command for a system that must be able to be used for several decades.

In this case, the Product Under Test is unique and has a value of around 50M€. The test cannot fail, it has to be right at the first time – and naturally, the safety of the teams involved is a mandatory concern.

Sylone has to ensure data acquisition and real-time measurement as well as control and monitor the entire rocket testing process. The tests carried out may require up to 1000 channels with 64 at 200k samples per second.

Once processed the drive front-end transforms the network frame into an analog signal. Imagine an ignition firing signal. All the 500 analog channel starts. These data are acquired in the data acquisition software at very high speed up to 200 kHz per channel, fully synchronized, and is at the same time available to the control system with less than 500 microseconds latency including the sigma-delta group delays.

Data are processed in the controller to generate the test case prepared: What are the tank pressures? What is the position of the nozzle? What is the next step in the sequence? 400 microseconds required. Lastly, a delay is induced by the drive front-end. The consequence is a processing loop time of 1 ms on a network of about 4 kilometers. 1 ms of loop processing time is important, but there are also other key features to consider.

To fulfill the requirements of such impressive tests, the real-time measurement and monitoring system has to reach very high levels of performance - keeping in mind that the data acquired are directly used to drive the nozzle. The test bench reaches high levels of speed for loop processing, even if the equipment is distributed over kilometers of networks. The loop time between the sensor event and the action on the nozzle must be about 1 ms - see Figure 5.

Data acquisition is interfaced with the sensors and signals are acquired on the Dewesoft system, Dewesoft SIRIUS, and SBOX R8 - both communicate perfectly via an EtherCAT network. Thanks to the EtherCAT bus, data are collected over the networks and are calculated in the real-time controller.

SIRIUS and SBOX R8 - the data acquisition

Data acquisition units from Dewesoft were used during the test. They are now an integrated part of the European Solid Booster Test Bench (BEAP) and the French space agency CNES (National Centre for Space Studies) to equip Ariane 6 launch pad with 800 channels DAQ SIRIUS STG isolated in 19" racks.

The solution also includes the SBOX R8 Real-Time, which offers a key function; the dual-mode. Data are spread towards the data-acquisition supervisor and at the same time also send towards the real-time controller.

R8 instruments are high channel count, standalone DAQ systems with built-in powerful data processing computer, SSD data logging capabilities, designed for maximum portability. Systems can be configured with up to eight SIRIUS DAQ slices for a total of 128 analog inputs for virtually any sensor. R8 DAQ systems include an EtherCAT master port with built-in synchronization for connection and extension of an EtherCAT-based DAQ system like SIRIUS DAQ.

On the data acquisition, only SIRIUS STG isolated is used. Firstly, because it covers a wide range of sensors in a very high level of performance. Secondly, to have a modular approach on the 16 test benches and to have only one reference to handle during the maintenance phase.

The SIRIUS instrument – appropriately named after the brightest star in the sky, the Dog Star - is well-suited for the task. It comes with DualCoreADC® technology, which solves often faced problems with signal measurement - input overload, noise, and artificial frequencies in the signal caused by aliasing. Each channel amplifier has two ADC's that always measure the high and low gain of the input signal. This prevents the signal from being clipped and keeps results in the full measuring range of the sensor.

With this technology, SIRIUS achieves more than 130 dB signal-to-noise ratio and more than 160 dB in dynamic range - 20 times better than 24-bit systems and 20 times less noise.

The SIRIUS instrument also comes with high galvanic channel-to-channel, channel-to-ground isolation (CAT II 1000V with ranges up to 1600V), and includes isolated sensor excitation. Such isolation allows measuring high voltage potentials. Measurements, like vibrations, temperatures, or any other measurement where non-isolated sensors are placed next to a high voltage potential against the DAQ system ground, are safe.

The hardware can read different signals like the voltage, strain, ICP/IEPE, charge, CAN, counter, encoder, and digital. With the included Dewesoft X3 software, data are acquired and combined from additional interfaces like GPS, Flexray, Ethernet, Serial, PCM telemetry, and many more. Though each data source may have different sampling rates, timing and GPS synchronization technologies ensure that all data are perfectly synchronized.

SIRIUS utilizes a patented technology called SUPERCOUNTER® in every counter/encoder input. Counter inputs can measure RPM and the angle of rotating machines. Supercenters can extract accurate values like 1.37, 1.87, 2.37, etc. fully synchronized for time and amplitude. The counter inputs are fully synchronized with analog, CAN bus, and other data sources enabling even the most demanding applications, even rocket booster tests.

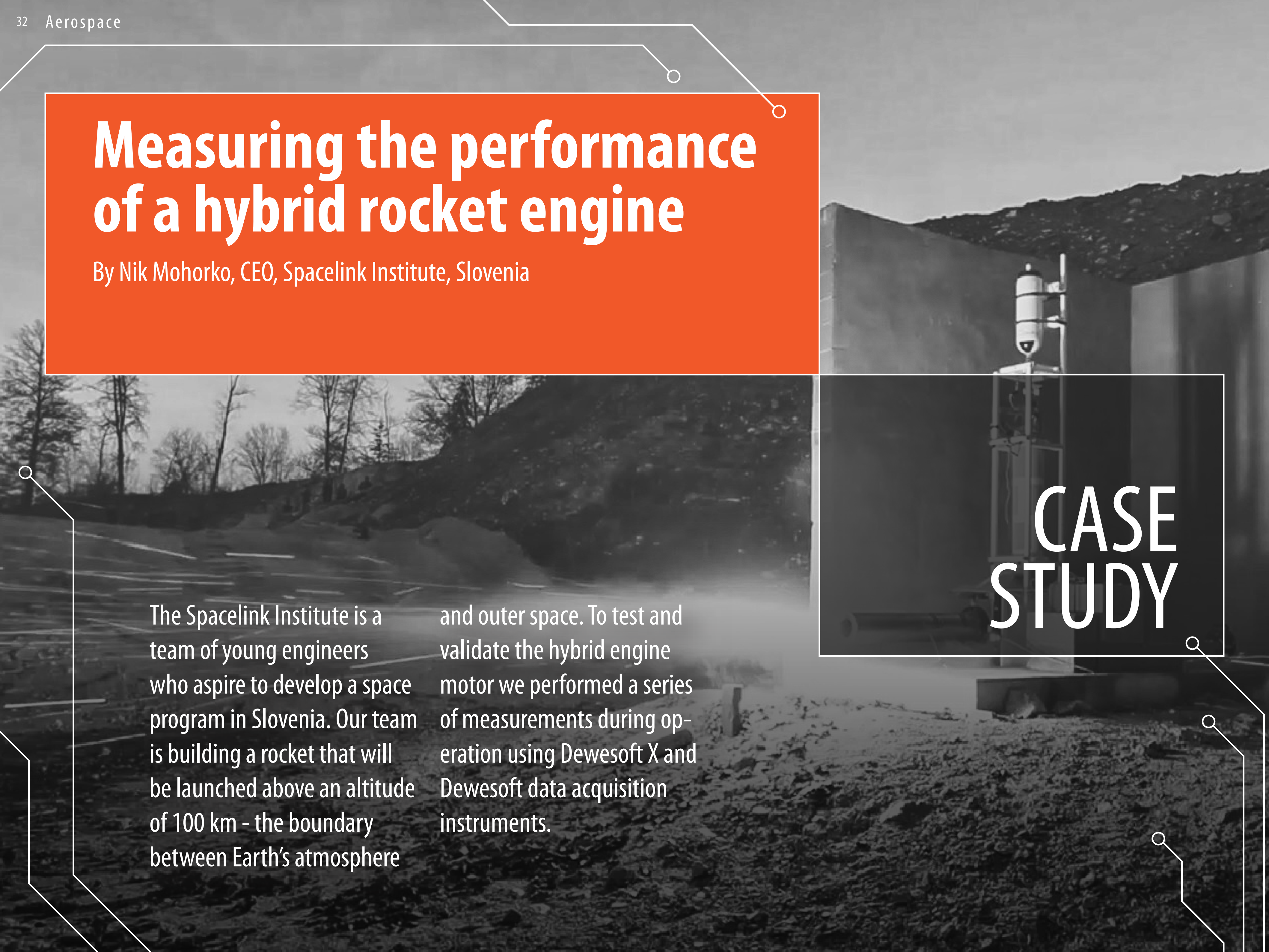
Conclusion - the future

To become part of the ARIANE project has been a step-by-step process. In 2016, 16 Dewesoft DAQ channels were qualified as part of SYCLONE BY CLEMESSY – and by the test, in January 2019 up to 600 DAQ channels were used. CNES intends to use the same technology for Ariane 6 and especially the firing test in French Guyana of the Vulcain 2.1 rocket motor.

Furthermore, comparable projects are being addressed worldwide and not only in booster firing tests. DEWESOFT and SYCLONE BY CLEMESSY combine the best of both worlds: high-end DAQ capacity and control front-ends with efficient and full performance control-command software solutions. The high level of quality required by the National French Space Agency and more generally the European Space Agency has increased Dewesoft and SYCLONE BY CLEMESSY solutions maturity and robustness for large test benches with hundreds of channels.

One more test stand firing will follow to finalize the qualification of the solid booster P120C before the first flight of Vega-C and that of Ariane 6 in 2020. The thunder of the motor will roar again, trees and bushes will have to bow as fire and smoke fills the rocky drench in Kourou. At the same time loads of data are streaming at extreme speed to ensure control and monitoring of the test. The partnership of CLEMESSY and Dewesoft boosts the lift-off.

Figure 6. SIRIUS-STG-CNT.



Measuring the performance of a hybrid rocket engine

By Nik Mohorko, CEO, Spacelink Institute, Slovenia

CASE STUDY

The Spacelink Institute is a team of young engineers who aspire to develop a space program in Slovenia. Our team is building a rocket that will be launched above an altitude of 100 km - the boundary between Earth's atmosphere and outer space. To test and validate the hybrid engine motor we performed a series of measurements during operation using Dewesoft X and Dewesoft data acquisition instruments.

More than 50 years have passed since humans put the first satellite into orbit and the first crew on the surface of the Moon. But only in the last decade has access to space become so affordable, that we are capable of launching commercial payloads. Nevertheless, this is still achieved with large launchers with inflexible schedules and long turnaround times, which limits the true potential of space use and exploration.

Hybrid propulsion engine design

As an alternative, there has recently been a lot of development in the field of hybrid rocket propulsion, which drastically reduces the complexity of flight vehicles and can be used to produce small-in-size, simple, and inexpensive small-satellite launchers.

Hybrid propulsion usually involves a liquid or gaseous oxidizer and solid fuel. The main benefits of hybrid propulsion are lower maintenance and development costs and ease of storage and transport. A common fuel in hybrid rocket engines is polymers - such as rubber, often in combination with liquid oxygen as an oxidizer. Due to its strong oxidizing capabilities, organic materials can burn rapidly in its presence, while materials such as oil or charcoal can even become explosive.

In this project, we used Dewesoft hardware and software for data acquisition during the development, calibration, and testing of the SL-2 hybrid rocket motor, a flight-ready motor, prepared for use in the Stella 1 rocket. Powered by paraffin fuel and liquid oxygen, SL-2 produces 4 kN of thrust and is designed to lift an 80 kg rocket to an altitude of 10 km, serving as a proof of concept for further development of this technology. Thorough measurements and analysis of all operating parameters allowed us to get the most information possible out of each engine static test, and thus reduced the total number of tests needed.

Stella 1 - the rocket

Stella 1 will be Spacelink's first rocket, which will be propelled by the SL-2 engine and will reach an altitude of 10 km. It will be equipped with a two-stage recovery system, consisting of a drogue and a main parachute.

Figure 1 The SL-2 rocket motor.

In contrast to military rockets and larger rockets that carry astronauts, Stella 1 is passively stabilized, meaning that vertical flight is assured with fixed fins. These become effective only at a certain velocity, which means the rocket needs to be guided in the first meters of flight. To this purpose, we designed and fabricated a launchpad consisting of a three-legged base and a tower.

Rocket technology is a complex topic, involving high temperatures and pressures, vibration, acceleration, and fluid dynamics. Precise measurement of performance is essential for the optimization and troubleshooting of such systems.

Spacelink

Spacelink is a team of young, innovative engineers who aspire to develop a space program in Slovenia. Our team is building a rocket that will be launched above the Karman line, which lies at an altitude of 100 km and represents the boundary between Earth's atmosphere and outer space.

There has been a lot of development effort in miniaturizing satellite technology, resulting in the increasing production of micro- and nanosatellites. These range from under 1kg to a few hundred kilograms in mass. Currently, transport to orbit allows very little flexibility with the final orbit, launch frequency, and schedule.

At Spacelink we believe we can differentiate by developing small-in-size and high-performance rockets based on hybrid rocket propulsion to change the way payload is launched into orbit.

SL-2 – the hybrid rocket engine

Launcher development usually starts with developing and testing the propulsion on the ground. In our case, we started with the SL-2 rocket engine, which is a scaled-down version of what will be later used in the full-scale rocket with a hybrid rocket propulsion system. Nevertheless, it is still equipped with all sorts of sensors and is designed to provide as much information as possible.

The motor consists of three main parts – a combustion chamber horizontal in the bottom, a liquid oxygen tank in the middle, and a pressurized tank at the top. Between the tanks, there is a valve with a closed-loop regulation system that takes high-pressure air from the top tank and feeds it into the oxidizer tank with a lower and constant pressure of 40 bar.

When the main solenoid valve below the oxidizer tank is opened, liquid oxygen is fed through the injection nozzle, which disperses it into fine droplets. In the combustion chamber, droplets mix and react with molten paraffin. This produces superheated gas products – more than 3000 °C, which is accelerated to supersonic speeds when passing through the main nozzle. Fast-moving gases produce thrust and deafening noise.

We needed a way to measure the main performance parameters of the SL-2 in a remote test location, with the ability to observe them in real-time in case the test needed to be aborted or some changes needed to be done manually.

For some measured quantities, we only needed to know the maximum/minimum value, for example, the temperature of the chamber wall, while others changed with a high frequency,

Figure 3. Pressure transducer.

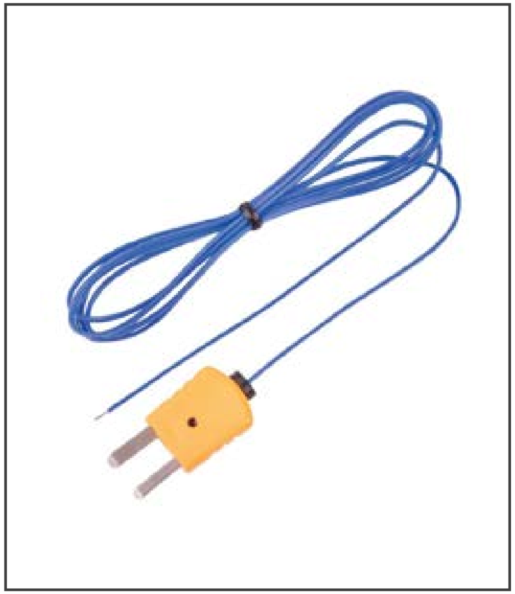


Figure 4. Thermocouple.

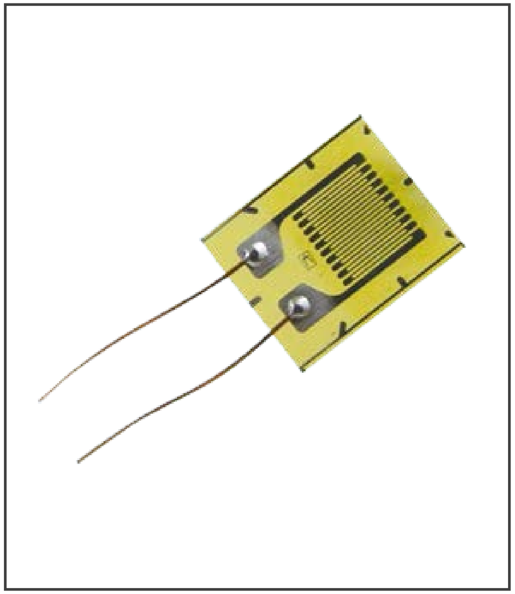


Figure 5. Strain gauge.

Figure 6. Capacity fuel level sensor.

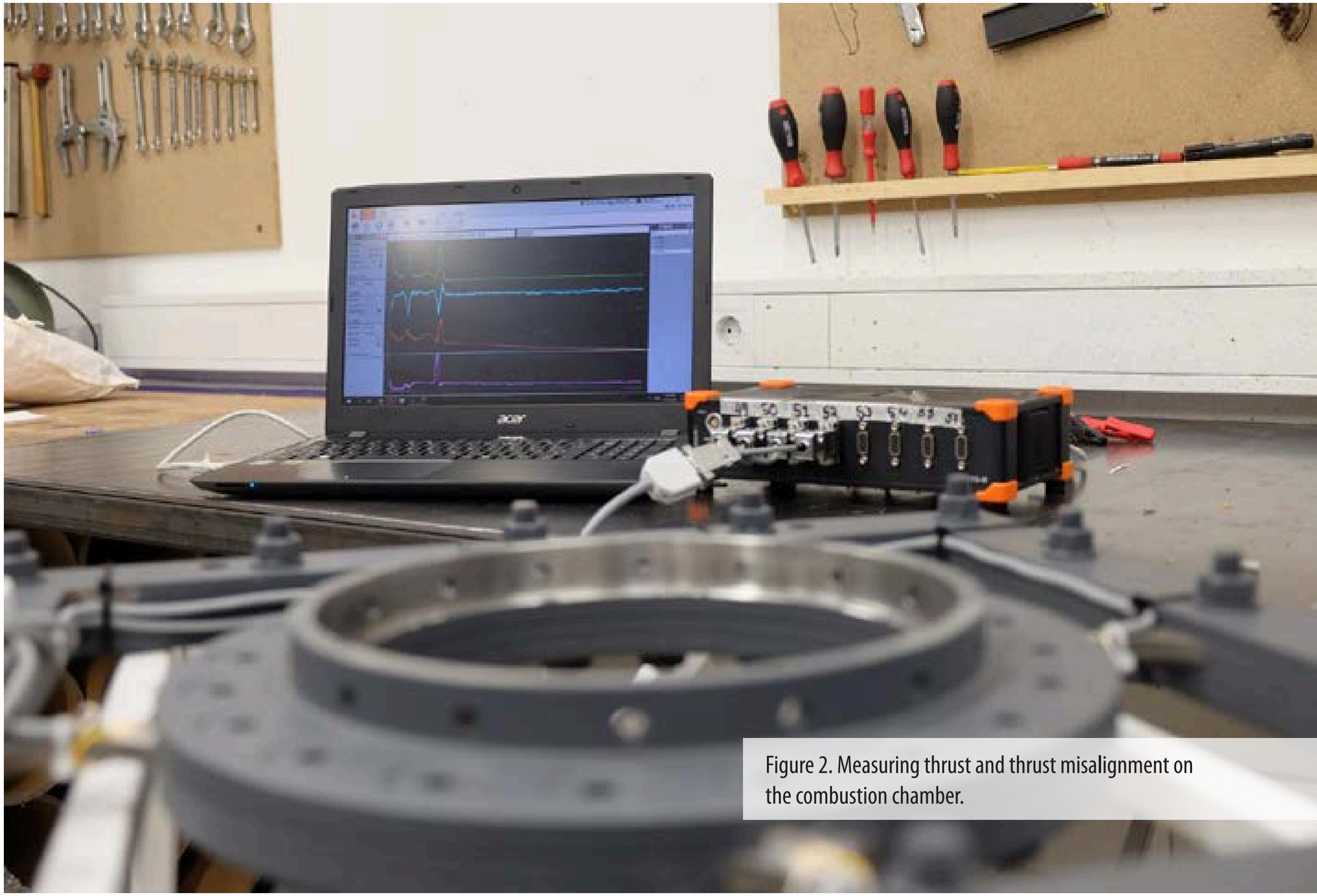


Figure 2. Measuring thrust and thrust misalignment on the combustion chamber.

such as the pressure of the combustion chamber. It was also important that data from different sensors were time-synced - that way we could spot what caused abnormalities in engine behavior such as changes of oxidizer level readings due to increased pressure in the tank.

The entire testing sequence was controlled by our flight computer and its onboard software. It consisted of filling the tank with liquid oxygen and cooling the piping, pressurizing the system, 5 seconds of burn time, venting, emptying the remaining oxidizer, and finally warm-up. During the testing, we focused mainly on the analysis of those 5 seconds when the motor was operating. See the YouTube video of the engine firing.

Performance measurement system setup

Our measuring setup consisted of two Dewesoft DAQ units, one Sirius and one Krypton, daisy-chained together to achieve a sufficient number of channels. The devices were connected to a laptop through a 100 m ethernet cable. Our testing required the acquisition of a range of physical parameters and thus the use of more types of sensors.

Pressure transducers

There are several methods of measuring pressure, such as capacitive, optical, piezoelectric, etc. In this case, an industrial piezoresistive transducer was used. An integrated microprocessor-based amplifier picks up resistance changes of the ceramic sensor and converts them to standard 4-20 mA current output. The transducer is connected to the Sirius DAQ via an external 50-ohm shunt.

Thermocouples

Thermocouples are simple temperature sensors that consist of two different electrical conductors forming an electrical junction. They produce a temperature-dependent voltage that is picked up by the DAQ device and converted to temperature. They are widely used in various industries due to their low cost, interchangeability, wide measuring range, and low thermal mass.

Strain gauges

Strain gauges are devices used to measure the strain of an object. They are usually attached to the surface with an adhesive and deform together with the surface, which changes the gauge's resistance. With proper calibration, they can be effectively used to measure force and are therefore commonly used in load cells, force sensors, and scales.

Capacitive level sensor

For measuring the level of liquid oxygen in the tank during filling and motor operation we developed a capacitive level sensor that can operate in a cryogenic, oxidizing environment. It consists of two concentric stainless-steel tubes, submerged in liquid oxygen. Rising or falling of the liquid level is registered by the processor as a change of electrical capacity and converted into a PWM signal. This signal was then analyzed with Dewesoft Supercounter technology to determine the duty cycle and convert it to the level of the liquid.

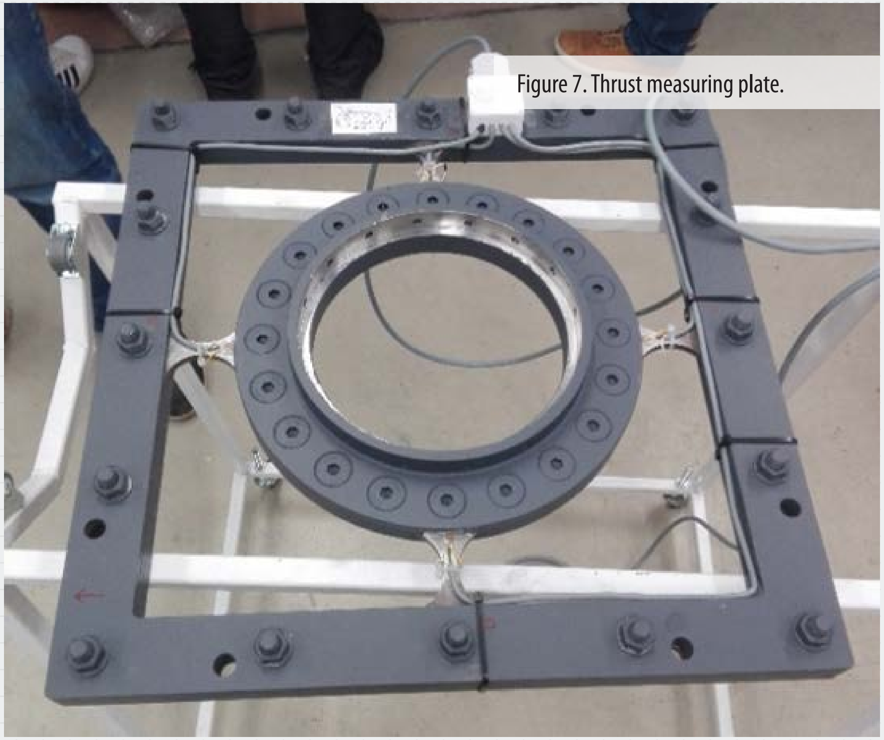


Figure 7. Thrust measuring plate.

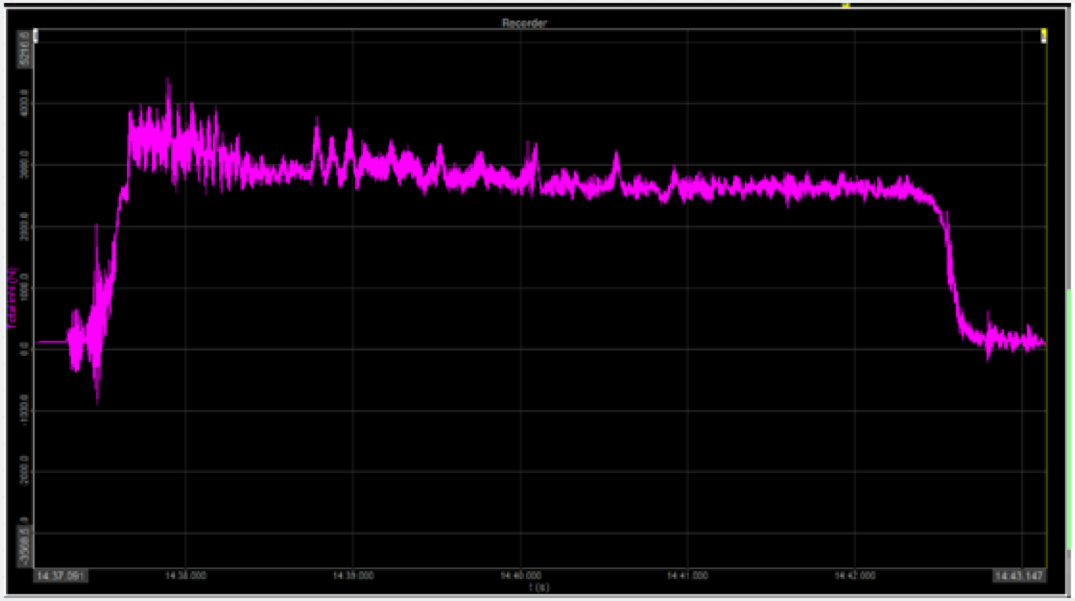


Figure 8. Measurement screenshot: Thrust [N].

Engine performance measurement analysis

The measurement data provided the basis for a thorough analysis of the key performance factors that contribute to the behavior of the rocket motor.

Thrust analysis

To measure thrust and thrust misalignment the combustion chamber was mounted on a measuring plate - see Figure 7. One strain gauge was attached to each side of the four metal beams, giving four half-bridge configurations.

All four channels were connected to Dewesoft Sirius' internal bridge amplifier and combined to give the total thrust.

This configuration also allowed us to measure side forces, which can be used to determine the misalignment of the nozzle or to characterize the thrust vector control system if one is used.

The two most important parameters we were able to get from the collected data - see Figure 8 - were:

- The time until nominal thrust: this is important for achieving a high initial acceleration of the rocket.
- The total impulse - this parameter is related to the final achieved altitude of the rocket.

Combustion chamber pressure analysis

One pressure transducer was connected directly to the combustion chamber to monitor the pressure inside. The purpose of that is to observe combustion instabilities (oscillations), fuel efficiency, and potential issues such as nozzle blocking. In this case, we noticed two distinct combustion instabilities, one low frequency, and one high frequency, which appeared because of the acoustic properties of the combustion chamber.

Pressure regulation analysis

The liquid oxygen tank was pressurized with an external high-pressure tank. To achieve the constant pressure of the oxidizer, we developed an active regulation system. It uses a motorized valve, a pressure transducer, and a PID controller. The pressure sensor was connected in parallel to the Sirius for the acquisition of data for post-analysis.

Combustion chamber thermal management

To determine the effectiveness of chamber thermal insulation, four K-type thermocouples were attached along the length of the combustion chamber external surface and connected to Dewesoft Krypton. Temperatures were monitored during motor operation and several minutes after to determine delayed heat transfer. We concluded that the existing internal insulation worked perfectly, as the wall temperatures never rose above 40°C.

Test conclusion

Many factors contribute to the behavior of rocket motors. They have to be measured and optimized from one test to another to achieve stable, reliable, and efficient operation for further use of in-flight vehicles. Furthermore, we believe that, if there is one thing that you should trust in any industrial R&D, it is the measuring equipment. Since our measurements took place on-site, the hardware needed to be robust and suitable not only for laboratory use.

In our case, Dewesoft hardware and software have not only proven to be reliable but also incredibly versatile - with minor modifications we could use just about any sensor available. Once our team members became a bit familiar with Dewesoft software, they found it to be very rich in features and functions, while still staying clear and straightforward.

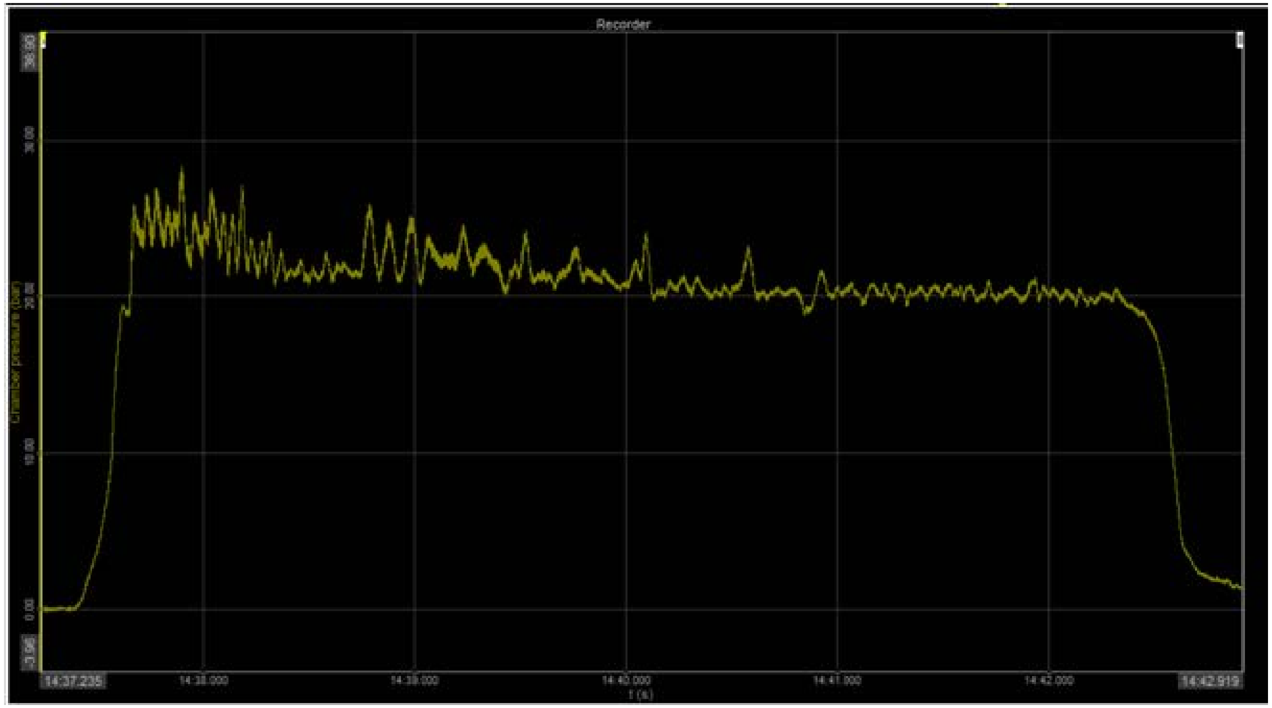


Figure 9. Measurement screenshot: Combustion chamber pressure [bar].

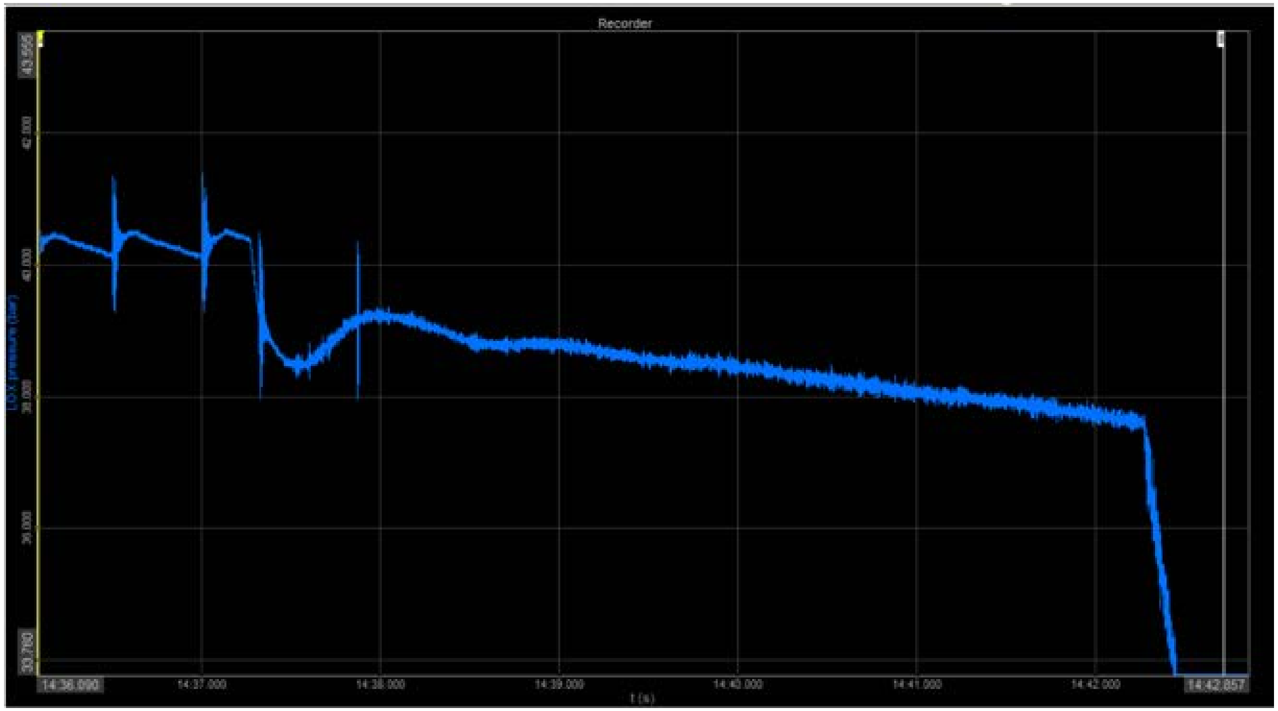


Figure 10. Measurement screenshot: Liquid oxygen tank pressure [bar].

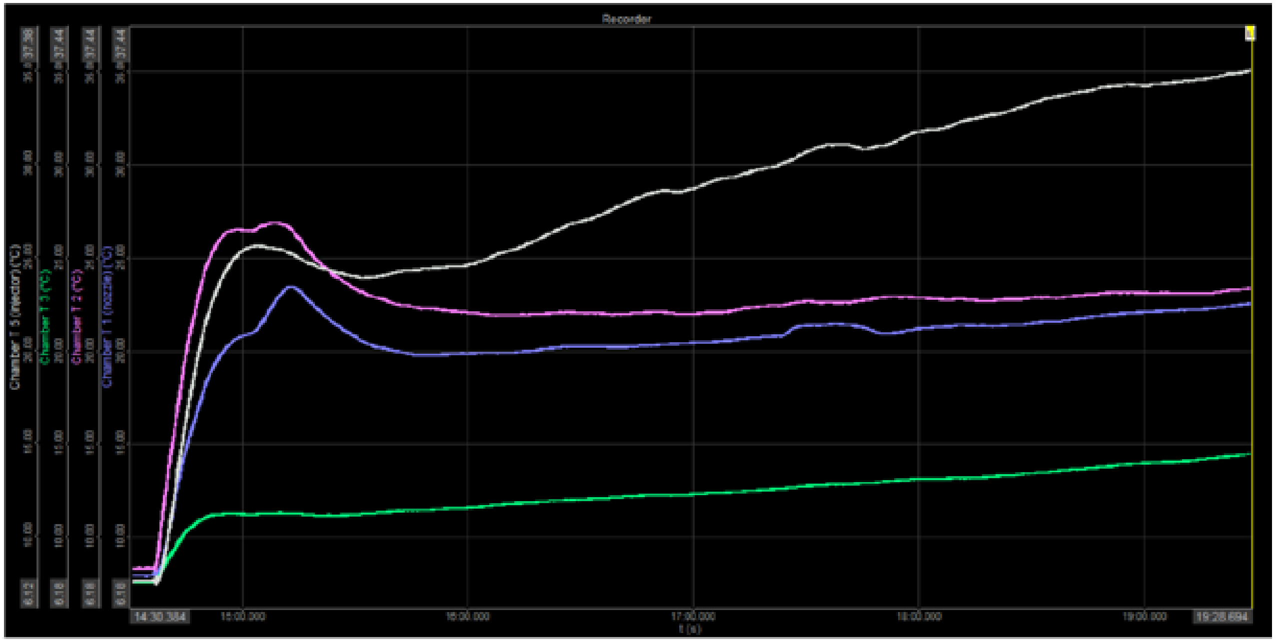


Figure 11. Measurement screenshot: Combustion chamber external temperatures.

Record & Playback Subsystem (RPS) for telemetry processing station

NASA - Launch Control Center (LLC), Florida, USA

CASE STUDY

For the new Space Launch System (SLS) rocket NASA has changed the Telemetry configuration to be all Ethernet packet-based using USGS DEM standard spatial file format headers to decode all the messages. Together Dewesoft and the Realtime & Playback Subsystem laboratory have developed a power troubleshooting and data collection tool - an Ethernet Receiver software plugin for Dewesoft X. In the end, Dewesoft delivered eleven state-of-the-art data acquisition systems and transferred customer Dewesoft licenses to the new instruments.

NASA, the National Aeronautics and Space Administration, is an independent agency of the United States Federal Government responsible for the national civilian space program, as well as research in aeronautics and aerospace technologies.

The Space Launch System (SLS) is a super heavy-lift expendable launch vehicle, which is under development as of August 2019. It is the primary launch vehicle of NASA's deep space exploration plans, including the planned crewed lunar flights of the Artemis program and a possible follow-on human mission to Mars.

The Launch Control Center (LCC) is a four-story building at the southeast corner of the massive Vehicle Assembly Building in the Launch Complex 39 area of the spaceport at NASA's Kennedy Space Center on Merritt Island, Florida. Since the unmanned Apollo 4 launch in 1967 LLC has managed launches of spacecraft, including all American space flights with human crews. NASA's 52 Space Shuttle program also used LCC. The center has recently been renovated in preparation for the upcoming SLS missions, which are scheduled to begin in 2020 with Artemis 1.

From 2016 to 2018, the LLC and Launch Complex 39B have seen complete upgrades tailored to the needs of the SLS rocket and Orion spacecraft, and for commercial partners. Among others, Launchpad 39B has been modified and upgraded with state-of-the-art communications and weather instrumentation systems.

The telemetry laboratory

Physically connected to the Vehicle Assembly Building, the LCC contains offices and laboratories for telemetry, tracking, and instrumentation equipment, the automated Launch Processing System, and four firing rooms.

The launch of the space shuttle Endeavour and the start of the STS-130 mission was monitored from Firing Room Four of the Launch Control Center at NASA Kennedy Space Center - Launch Pad 39B has been modified and upgraded - Dewesoft software is still there. Photo Credit: NASA/Bill Ingalls.

The Dewesoft end-user at LLC is the Realtime & Playback Subsystem laboratory responsible for all real-time Telemetry data processing – the systems acquire measurements or other data at remote or inaccessible points and automatically transmit these to receiving equipment for monitoring and analysis.

The telemetry monitoring systems independently verify mission data from ground support equipment/rockets/spacecraft and for vehicle and payload troubleshooting - see Figure 1. They provide:

- Real-time plotting and retrieval functions at the Firing Room console or in the office
- Real-time and near real-time troubleshooting tools - data for offsite users
- Translates data into information with capabilities such as data fusion, health, and persistent data
- Digital storage and file transfer of analog data
- Real-time or post-test bit anomaly detection and measurement scaling
- Data Analysis at the bit level
- 24/7 intelligent, autonomous based data monitoring Data acquisition, Engineering Unit conversion, and analysis
- Variety of data output methods and report formats

200,000 channels of Ethernet data

The Dewesoft X3 is now processing over 200,000 channels of Ethernet data from the SLS rocket. Data to include PLC booster data, main engine data, umbilical control data on Launcher (data required consumables), rocket avionics data, 2nd stage telemetry, and full capsule telemetry links as well.

LLC needs the capability to process this data into manageable subsets of more than 200,000 parameters. Thus, needing the usage of multiple Dewesoft processing stations decommutating raw Ethernet channels to parameters defined by the Engineering Unit. The challenge was configuration management along with the display processing of over 300 parameters in a single display.

Furthermore, the data then has to be sent to the Firing Rooms for analysts with real-time display and for comparison with the data in the NASA-built Launch Control Software for the SLS Rocket.

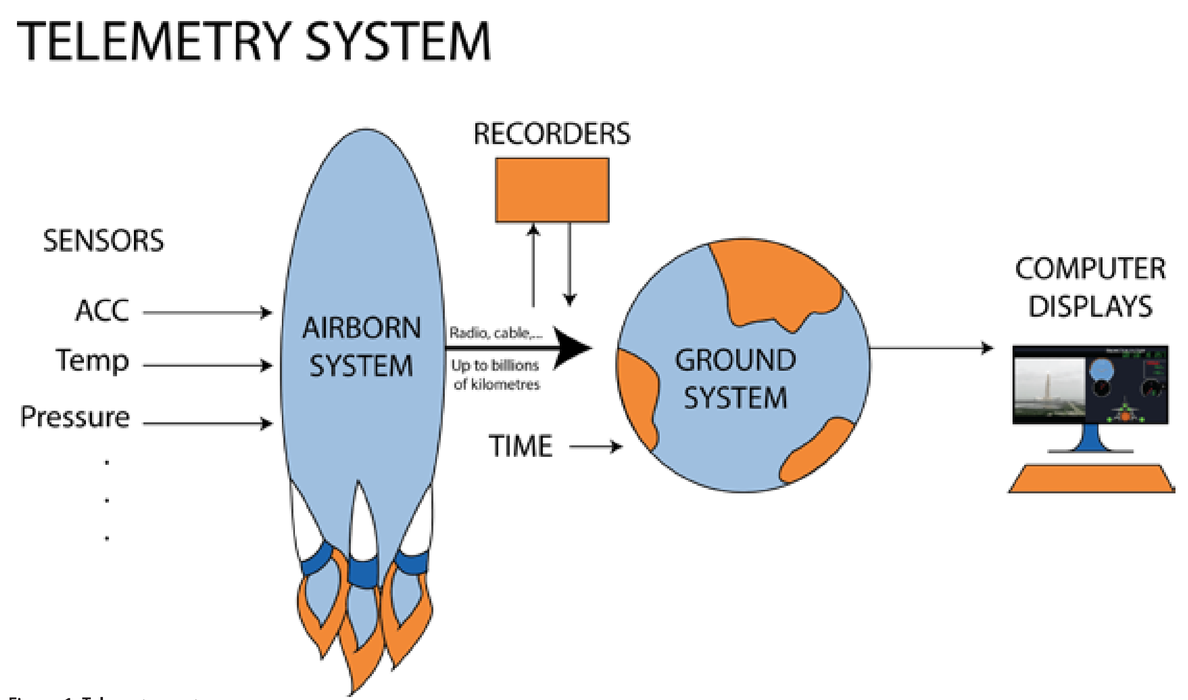


Figure 1. Telemetry system.

Standard IRIG 106 – Chapter 10

Dewesoft has a variety of data acquisition hardware that can interface with the telemetry market and uses DewesoftX software that can read and decode the IRIG 106 Chapter 10 data from any telemetry data recorder in real-time over the ethernet or a pre-recorded Chapter 10 file. It allows the acquisition, storage, visualization, and analysis of multiple, synchronized data sources. The software can combine standard analog data acquisition solutions with telemetry data, aircraft bus data (PCM, ARINC 492, MIL-STD-1553, iNet), video, and many others.

In this case, the solution was to use SIRIUS R3 – eleven R3 chassis with full Dewesoft licenses to complement the three Windows servers that were already running the Dewesoft software in a Virtual Machine configuration as a mainframe processing station for data reduction and recording.

SIRIUS R3 are rack-mountable DAQ systems built into standard PC chassis. R3 features DualCoreADC® analog inputs with 160 dB dynamic range and acquisition speeds of 200 kHz per channel or optional high-speed amplifiers with speeds up to 1 MHz per channel. One R3 chassis can hold up to three SIRIUS DAQ slices with a total of 48 analog channels, 24 counter/encoder channels, 72 digital channels and 3 high-speed CAN bus ports. An array of different amplifiers is available for virtually any signal and sensor.

At LLC the R3 chassis were fitted with an extra Ethernet Port card. The software licensing could then be moved and each system was outfitted with the DewesoftX for professional developers, Ethernet Receiver, iNet plugin, and the Net option for client-server broadcast, as well as the PCM Plugin and a Chapter 10 Plugin.

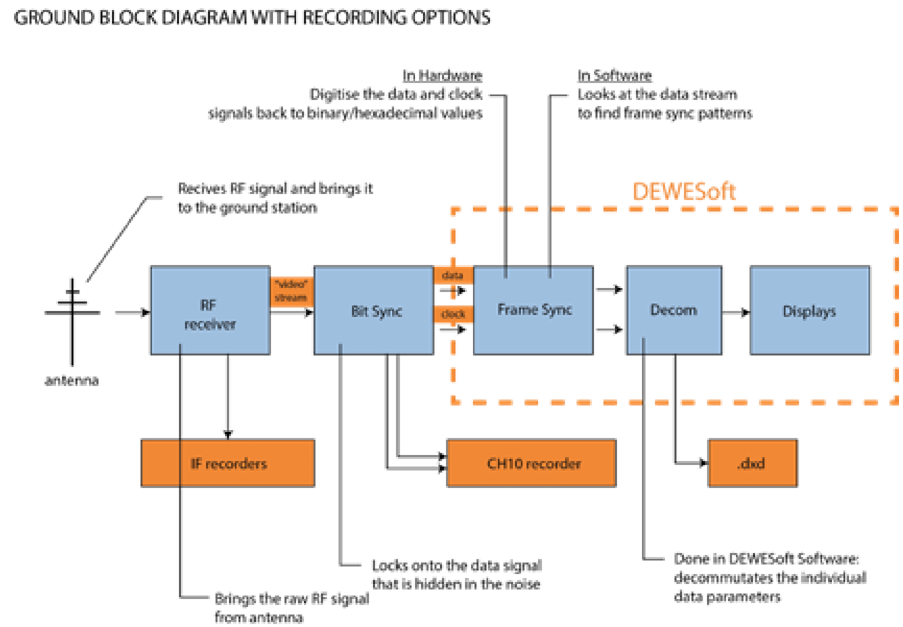


Figure 2. Dewesoft Direct PCM Ground Station.

Software plugins

Chapter 10 is part of the Standard for Digital Flight Data Recording, IRIG 106, a comprehensive telemetry standard to ensure interoperability. Chapter 10 - Digital On-Board Recorder Standard defines the operation and interfaces for digital flight data recorders.

The Dewesoft Chapter 10 plug-in is a specialized plug-in to read a closed recorded data file or a real-time Ethernet stream of Chapter 10 formatted data. The plugin will receive the incoming Chapter 10 data stream from a closed file playback from the hard drive or real-time Ethernet stream, and will then find the embedded time in the Chapter 10 file to set the Dewesoft master clock too.

Then the Chapter 10 Plug-in will prepare each data channel included in the data stream for processing. For the Analog, Video, and Discrete data the plugin will organize the data channels for proper processing and display. More complex data types like PCM and Arinc429/Mil-1553 data will be directed to their appropriate plug-ins in Dewesoft for further processing.

Through configuration management tools all the processing stations can run simultaneously processing the same data. Using the Dewesoft IRIG-ACDC card inside each of the R3 chassis all the systems can be synchronized in time to have perfect data correlation.

Pulse Code Modulation (PCM) is the simplest form of waveform coding. PCM telemetry encoders are used to encode the data in a serial digital format and transmit it on a carrier to another location for decoding and analysis. The PCM plug-in includes the bit sync, frame sync, decommutation for SIRIUS-PCM-FS2 Ulyssix cards, or Chapter 10 plug-in. It can decode thousands of channels from those interfaces, supports embedded streams and FFIs. The data are again synchronized with the use of IRIG to the analog data and video streams.

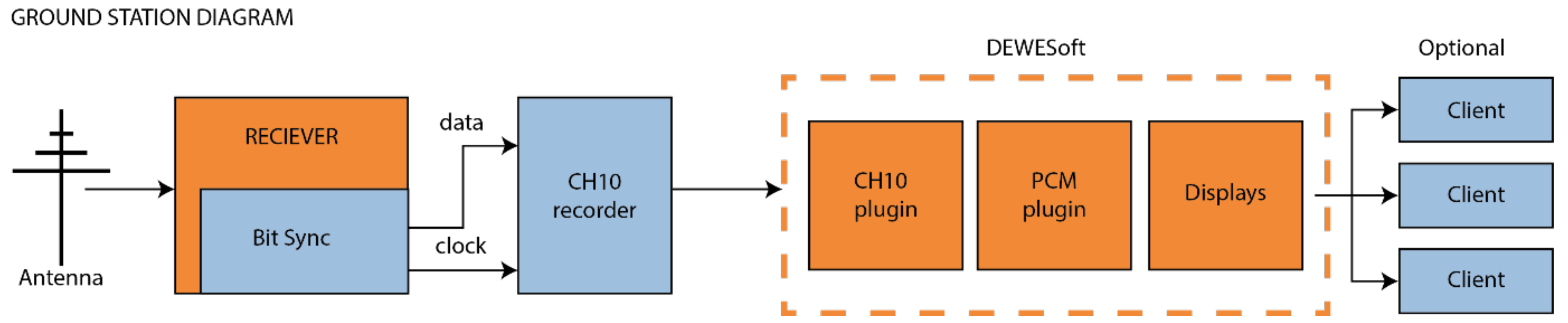


Figure 3. Dewesoft Chapter 10 based Real-Time Ground Station.

IRIG 106 - Chapter 10 Ground Station

With plugins Dewesoft X can fully decode, visualize, and analyze IRIG 106 Chapter 10 data - see Figure 3 - and utilizes standard input format for telemetry data interface ethernet packets real-time consisting of:

- PCM Data (unpacked, packed, and throughput)
- MIL-1553 and ARINC-429 bus data
- iNET data recording from up-to-date telemetry standards
- Video
- Ethernet & UART channels
- Analog
- Ethernet data
- TMATS (setup channel)
- Timing (absolute time)

The ability to record data in throughput-packed and unpacked modes gives the flexibility needed and provides an all-in-one processing and recording package for the ground station. The software can also replay Chapter 10 files. Data is frame synchronized and decommuted giving the ability to playback and process Chapter 10 files without tying up an entire ground station.

The Dewesoft system will always store raw data and leave optimal possibilities for offline data processing and visualization.

Conclusion

Cooperating with a long-time customer like LLC creates a mutually trusting relationship. For more than 10 years Dewesoft and LLC have had open communication working together to expand the capabilities of their laboratories - along with helping advance Dewesoft capabilities from their feedback.

This effort of working alongside has enabled the development of the Ethernet Receiver plugin as a power troubleshooting and data collection tool. With the Filter Chains and Engineering Unit conversation setups now, it can sniff any Ethernet stream from any source and chart parameters within the power of Dewesoft.

Dewesoft X3 can receive and decode data from multiple ethernet streams. Different filter capabilities are available (TCP, UDP, filter data) and support data decoding with various formats (Motorola, Intel, float, signed, unsigned ...). Linear and non-linear (polynomial) scaling is possible.

The Ethernet Receiver is suitable for Industrial Market, Test Stand data collection and troubleshooting, Telemetry Ground Station, and many more. To help engineers understand its true power, this tool should now be called "the Wire Shark on steroids".


IOLITE
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Spaceplane thermal protection system (TPS) fitting and bonding control

Sierra Nevada Corporation (SNC), USA
By Jake Rosenthal, Eastern Regional Manager, Dewesoft USA

CASE STUDY

The Dream Chaser® space plane is a reusable space plane being developed by Sierra Nevada Corporation (SNC). Space vehicles that enter the Earth's atmosphere require the use of a thermal protection system (TPS) to protect them from aerodynamic heating and the heat of the sun.

TPS tiles are one of the major hardware components used on Dream Chaser and cover nearly the entire craft. To bond these tiles to the structure the staff needed to measure and display a multitude of parameters. The Dewesoft solution automated calculations and enhanced quality control while also being fast and easy to use.

Introduction

The Thermal Protection Systems group or TPS is the engineering team that is primarily responsible for the "Heat Tiles" and fabrics that are surrounding the exterior of the Dream Chaser spacecraft. The engineers use similar technology as that used to protect the space shuttles when they flew.

This is a complex protection system of fiberglass-based tiles and thermal protective blankets perfectly fitted to protect the spacecraft on re-entry to the Earth's atmosphere.

The spacecraft project - the Dream Chaser

SNC's Dream Chaser spaceplane is a multi-mission space utility vehicle designed to transport crew and cargo to low-Earth orbit (LEO) destinations such as the International Space Station.

Dream Chaser was selected by NASA to provide cargo delivery, return, and disposal service for the space station under the Commercial Resupply Service 2 (CRS-2) contract. Dream Chaser will provide a minimum of six cargo missions to and from the space station carrying critical supplies like food, water, and science experiments and return to Earth with a gentle runway landing. Dream Chaser can gently return critical cargo at less than 1.5 g's.

The vehicle is designed for high reusability, reducing overall cost and a quick turnaround between missions. The ability to launch on top of multiple launch vehicles and land at a variety of approved runways makes Dream Chaser a flexible option for reliable transportation.

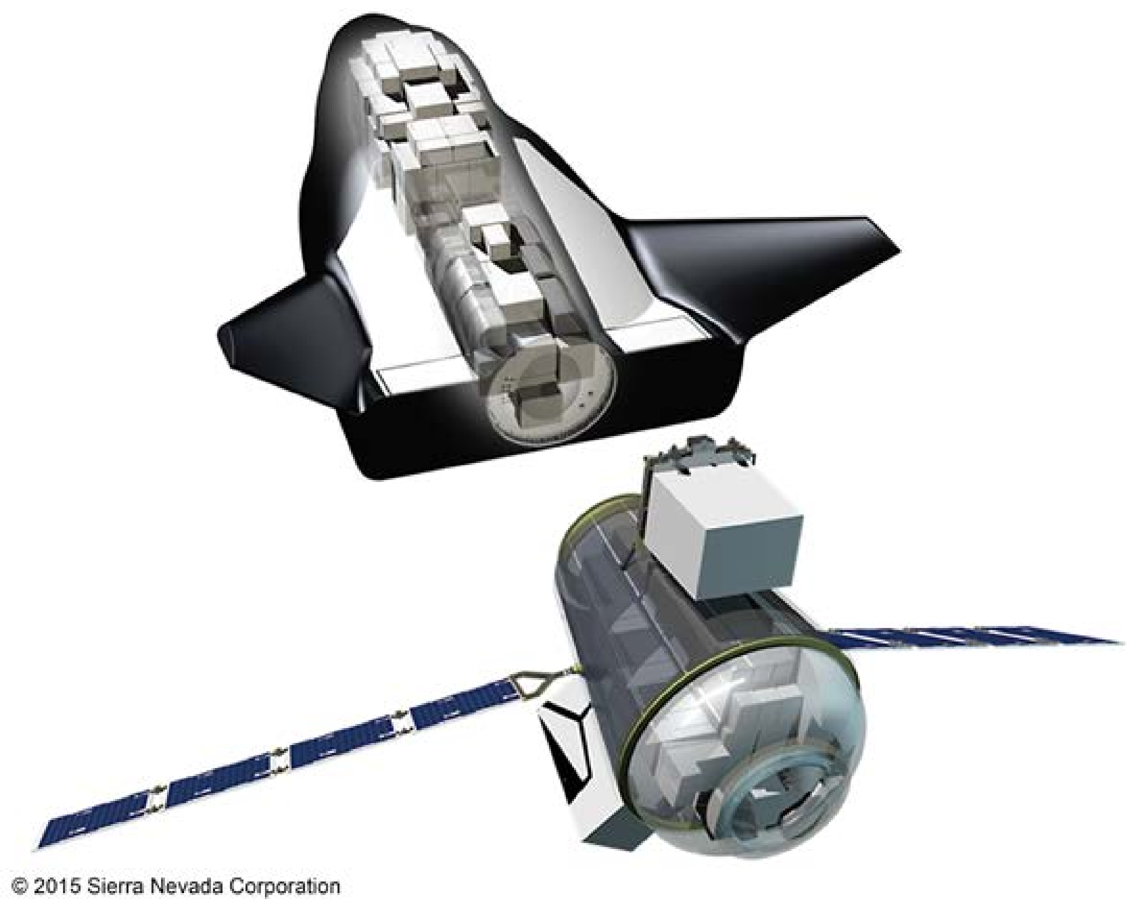

Figure 1. SNC's un-crewed Dream Chaser with transport vehicle and visible cargo.

Dream Chaser was originally designed as a crewed spaceplane, in part under NASA's Commercial Crew Program, capable of carrying up to five astronauts to and from the space station and other LEO destinations.

Dream Chaser is 30 feet, or nine meters, long which is roughly ¼ the total length of the space shuttle orbiters and can carry the same crew size as the shuttles.

The crewed version of Dream Chaser is approximately 85% common to the cargo system and has environmental control and life support systems, windows for crew visibility, an integral main propulsion system for abort capability, and major orbital maneuvers. [1]

The Thermal Protection System (TPS)

A TPS is designed to protect the spacecraft from the aero-thermal heating when reentering the Earth's atmosphere – temperatures that can reach 1,650°C (3,000°F). In the case of spaceplanes, the TPS ensures a safe entry, descent, and runway landing.

The TPS includes a coating made of various heat-resisting materials – in the cases of both the Space Shuttle Orbiter and Dream Chaser this coating is made up of tiles.

Dream Chaser is about 1/4 the size of a space shuttle orbiter and only needs 2,000 TPS tiles compared to the 24,000 tiles used on the space shuttle. Fewer tiles are needed as the craft is smaller, but also the tiles are bigger. Dream Chaser tiles are approximately 10 by 10 inches, while the tiles used on the shuttle were about six by six inches.

SNC TPS engineers utilize a room temperature vulcanizing (RTV) silicone, which can withstand high temperatures, to keep the tiles bonded to the vehicle at all times. The bonded tiles are all tested by a pulling mechanism, to avoid issues of the tiles falling off.[2 and 3]

The challenge – quality and speed

The lead TPS engineer at SNC was initially looking for an inexpensive Data Acquisition system to help measure five force sensors for testing the fit of a thermal protection tile to the Dream Chaser spacecraft structure.

All five sensors need to be measured simultaneously in a production environment to make sure the protective tiles are formed perfectly for their unique design to protect the spacecraft.

The end desire was to hand press the tile to the structure and the DAQ system would measure the load to see them all showing the same pressure within a certain tolerance. The system should provide a green light to the technician that the tile was formed properly and ready to be attached to the structure. To allow this to be done on the production floor and run off a laptop the system needed to be modular and movable.

The initial challenge was based on our price point compared to the basic DAQ system the customer had used on previous projects. They had so far used a simple DAQ system that could measure the loads and display them. Everything was hand tracked for being within a tolerance and hand calculations were done to determine that all loads against each other were within the required tolerance.

An additional challenge was the need for several identical systems to operate easily for the technicians who were not used to using test equipment.

Upon investigation with the customer of the entire process that goes into attaching these tiles to the structure, we were able to uncover additional points where Dewesoft could help. Points

Figure 2. Bonding the Thermal Protection System tiles to the Dream Chaser structure.

that would help in speeding up the process and allow additional quality control resources using the exact same system.

The measurement solution

After reviewing the process, it was determined that there were several key areas in which Dewesoft could assist the TPS group to improve by using our KRYPTON DAQ modules with strain gage amplifiers (STG) and thermocouple amplifiers (TH) connected to an SNC Laptop.

KRYPTON is a family of rugged and distributed EtherCAT data acquisition systems for field measurement in extreme and harsh environments. They offer IP67 degree of protection and can operate in the extreme temperature range from -40 to +85°C and offer high shock protection. Krypton units can be distributed over a large area with distances up to 100 meters between DAQ nodes.

KRYPTON rugged DAQ -> YouTube Video
KRYPTON distributed DAQ -> YouTube Video

The KRYPTON STG version has universal differential voltage and Full/Half/Quarter bridge input and is available in 1, 3, and 6 channel configurations compatible with DSI adapters.

The DewesoftX, data acquisition, data recording, and data analysis software, is included in all Dewesoft data acquisition systems.

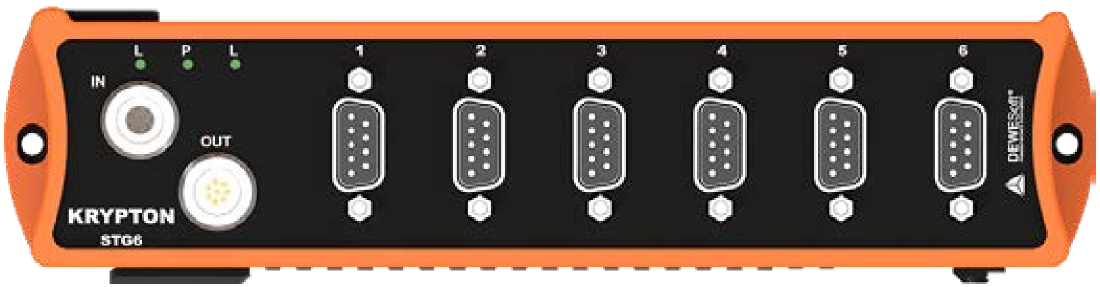

Figure 3. KRYPTON-6xSTG DAQ module - differential voltage and Full-bridge, half-bridge, and quarter-bridge signal conditioner

Pre-fit verification testing

This testing was the original requirement that started our interest in the application. Here five extremely thin force sensors are applied to the back of the thermal tile. One at each corner and one in the middle of the tile. The tile is then placed against the structure to read the 5 loads generated.

The loads are measured in the DewesoftX software having a comparative math channel to see if all five pressures are within a certain percentage of each other - confirming a uniform fit of the tile.

Using the record feature of Dewesoft X software the technician can now enter the tile serial number and location on the structure as header information. When the test is run a simple green or red pass-fail indicator is shown along with each Load cell reading. Finally, an automated report is generated from the data for quality control documenting that the test has been completed.

Instrumentation verification

In certain critical areas along the Spacecraft, exterior pressure and temperature sensors are built into the tiles. These sensors are to help engineers and flight operators see what is happening on the exterior of the spacecraft at critical times of flight.

Since the Dewesoft DAQ hardware is flexible to the inputs these sensors can now be 100% checked both before and after the tile is installed to confirm functionality and accuracy of readings.

Vacuum bagging process monitoring

Once the tile is confirmed to fit properly, and instrumentation is checked, it is ready to be permanently mounted to the structure. The tiles are hand attached to the structure using RTV (Room Temperature Vulcanizing) silicone and several other instruments are used to confirm it's in place - see Figure 4. To cure the tie to the structure the tile is placed in a vacuum making sure it is attached perfectly to the structure.

Advanced mathematics is built into the DewesoftX software, including the Dewesoft Sequencer which allows control of the flow of tests within the software without requiring programming skills.

The Sequencer is a powerful tool that can create sequences, ordered lists of procedural commands, that the Dewesoft software will execute one after another. Multiple sequences can be combined to fully automate test procedures, use pass/fail criteria, and automatically generate reports - see Figure 5.

In this case, the Dewesoft Sequencer is now used to send a signal to the vacuum pump controller and a pressure sensor to provide a feedback control, regulating the vacuum to be accurate. It monitors and alarms if correct pressures are not met and finally creates a report of the entire vacuum process for Quality Control.

Bond verification

When the tiles have been properly mounted to the spacecraft structure a bond verification test is performed as a final check of the adhesion of the tile to the structure.

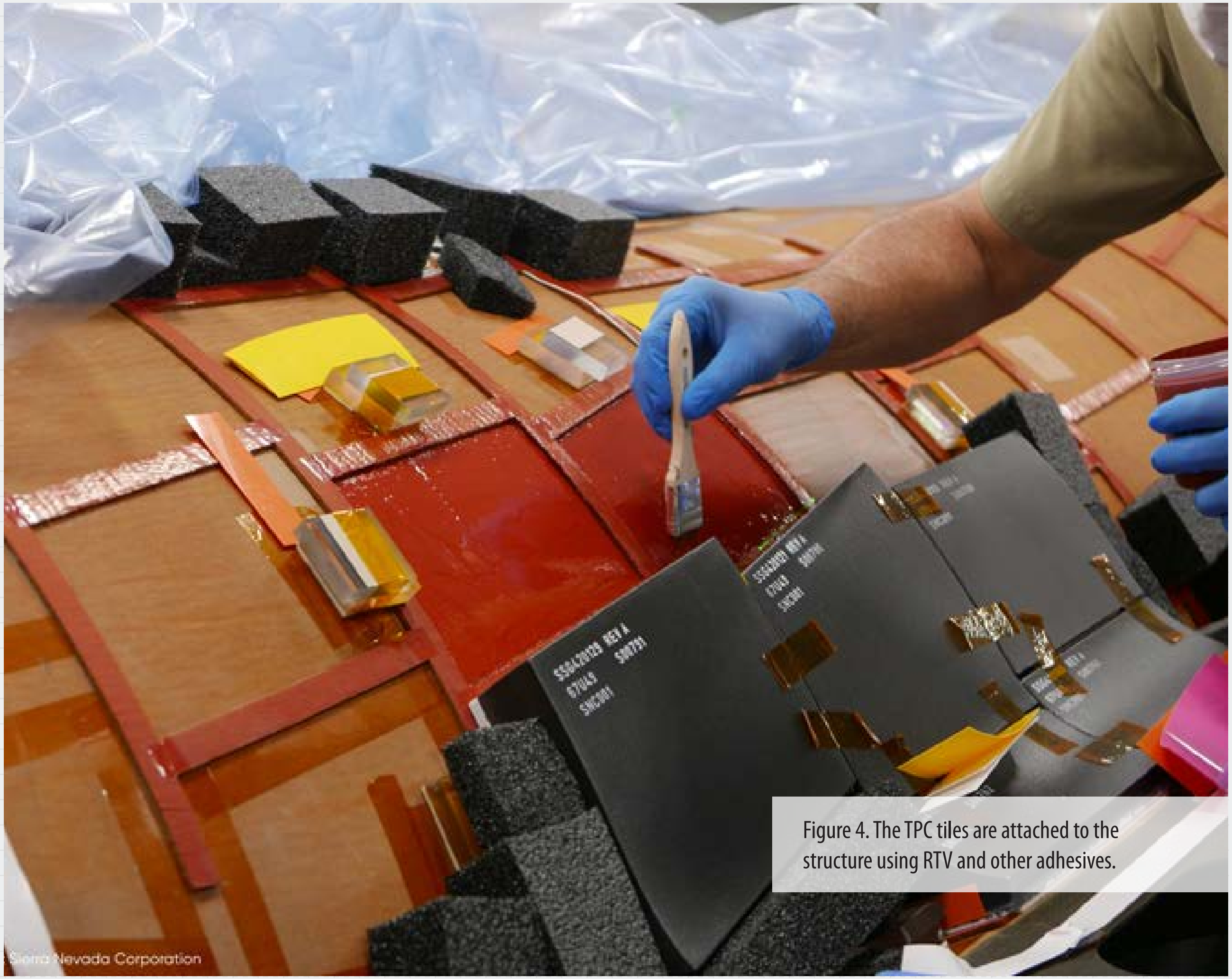

Figure 4. The TPC tiles are attached to the structure using RTV and other adhesives.

A load cell that is attached to a vacuum chuck that matches the outer mold line contour of the tile is measured - see Figure 6. Through the User Input fields in the Dewesoft X software, the operators can enter key variables for the tile surface area and locations on the structure. These inputs are brought into a math calculation to determine the proper load for pulling the tile to test the strength of its bond.

In the first phase of this Bond Verification testing, the tile will be pulled by hand – measurements and alarms in Dewesoft X will make sure the test runs properly. The second phase of this testing is to use an actuator controlled by a Dewesoft PID (Proportional, Integral, and Derivative) loop - a form of closed-loop mathematical calculation - to automate the control of the load the tile is pulled against.

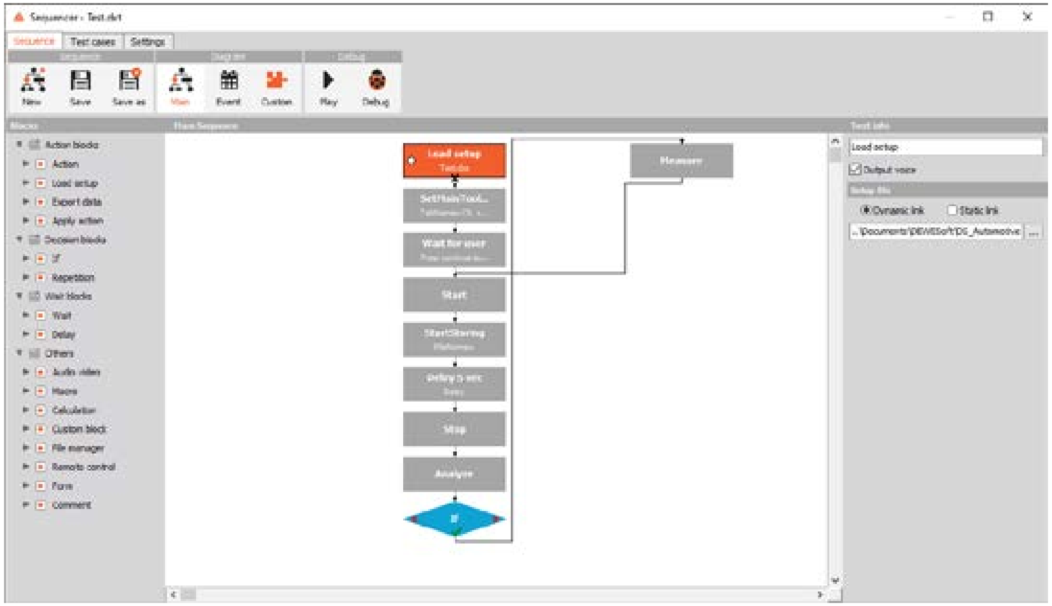

Figure 5. DewesoftX Sequencer designer user interface

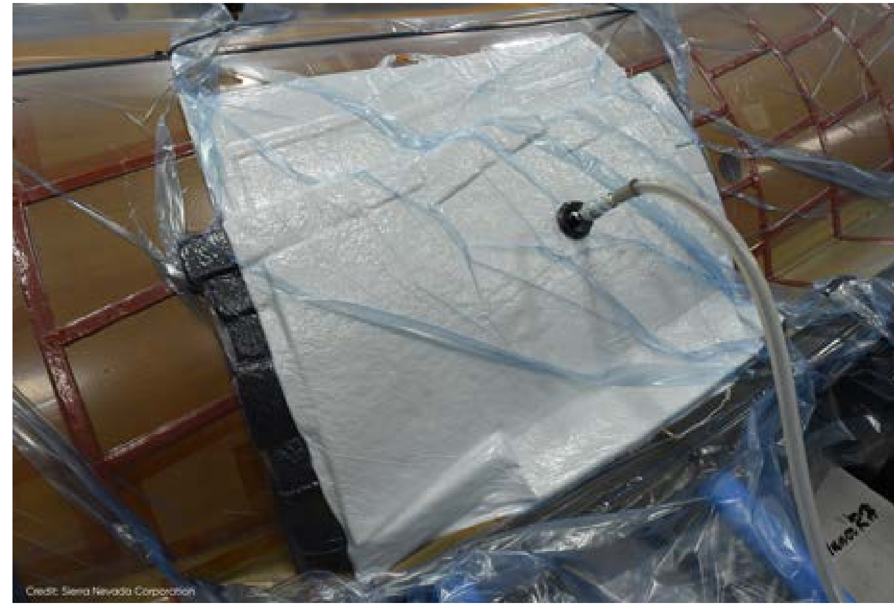

Figure 6. With the load cell attached to a vacuum chuck, a bond verification test is performed to check the adhesion of the tile to the structure.

Conclusion

Dewesoft was able to deliver 8 identical Krypton systems for different technicians to use on their production carts and SNC continues to grow its sequences to improve automation and process control of each step in the construction.

We helped to identify additional applications which improve the Dream Chaser build process and showed how one and the same hardware could enhance more processes. Digging deeper than the initial need allowed for further capabilities to be utilized. The ease of the Dewesoft Sequencer to do automation ultimately did the trick.

Sources

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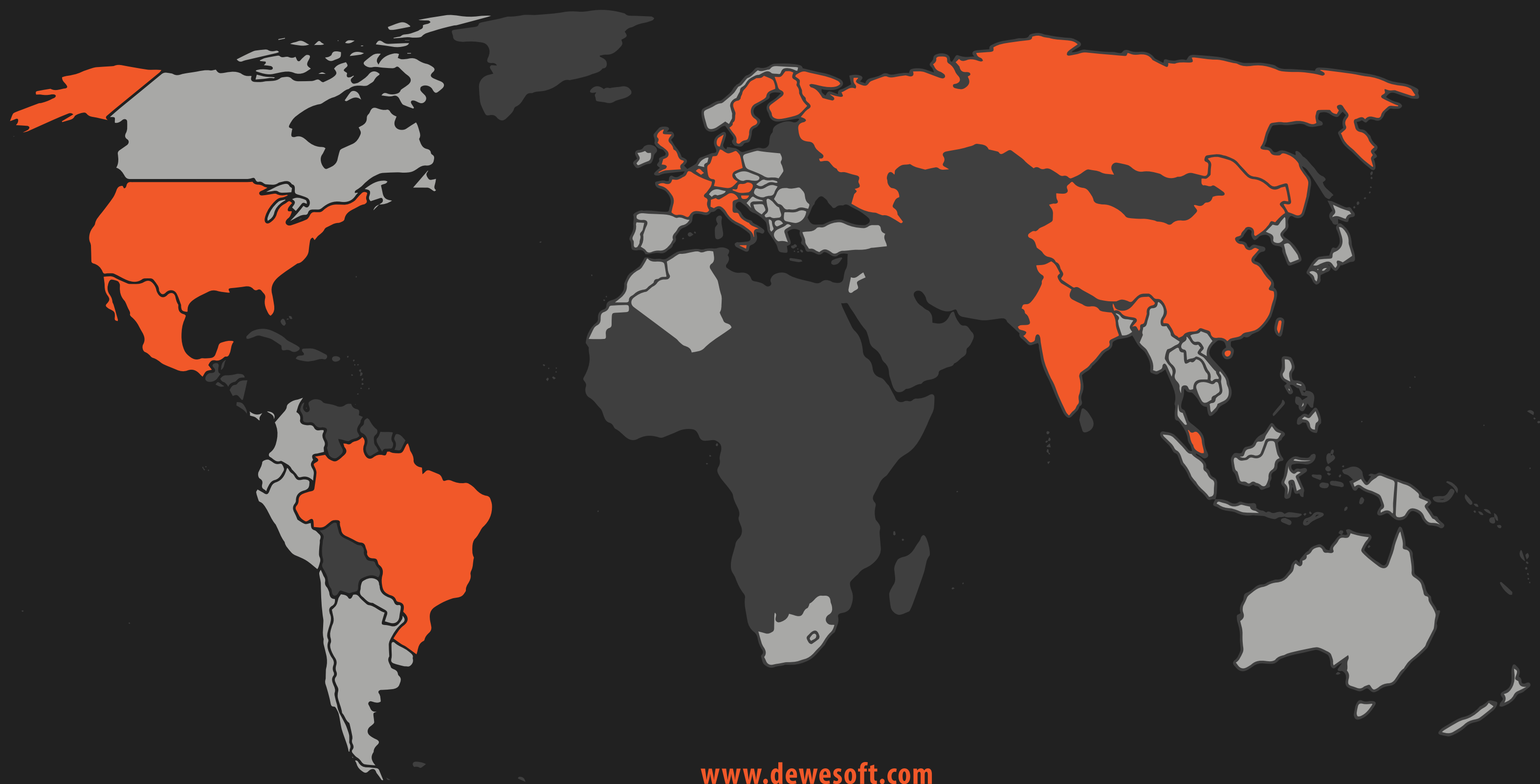

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