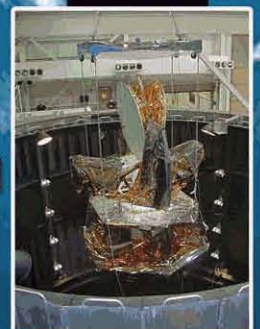


Environmental
Testing:
The Earth–Space
Connection



25th Space Simulation Conference

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Session I

Thermal Vacuum Testing

Methods of Helium Injection and Removal for Heat Transfer Augmentation

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ABSTRACT

While augmentation of heat transfer from a test article by helium gas at low pressures is well known, the method is rarely employed during space simulation testing because the test objectives are to simulate an orbital thermal environment. Test objectives of cryogenic optical testing at Marshall Space Flight Center's X-ray Calibration Facility (XRCF) have typically not been constrained by orbital environment parameters. As a result, several methods of helium injection have been utilized at the XRCF since 1999 to decrease thermal transition times. A brief synopsis of these injection (and removal) methods including will be presented.

The ESA Large Space Simulator Mechanical Ground Support Equipment for Spacecraft Testing

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AOES Netherlands B.V.

ABSTRACT

Environmental test facilities are not suitable in any case to comply with special or complex test requirements without modifications. Dedicated upgrades of the test facility and their subsystems with respect to the test requirements and specifications are often necessary.

The Flight Model of the Planck Space Telescope was tested in the Large Space Simulator (LSS) of the ESTEC Test Centre. Main goals of the test were the verification of the deformation of the Telescope during thermal vacuum conditions at different temperature levels and the validation of the Thermal Model.

The deformations of the telescope have been traced by two Videogrammetry canisters. In order to provide different view positions with respect to the PLANCK Telescope it was necessary to rotate the specimen by +/- 180deg. In addition very stringent requirements for the low temperature level of the thermal environment has lead to a comprehensive test set-up which was divided in four main elements:

- Dedicated support structure for the Videogrammetry canisters providing several DoF for adjustment.
- Structure to support three Infrared panels around the specimen
- MLI curtain to cover the LSS 8m auxiliary chamber opening
- System providing LN2 supply for the rotating PLANCK telescope cold panel

The design, manufacturing and integration of the necessary mechanical ground support equipment to install for instance the canisters and to ensure the $\pm 180^\circ$ rotation of the telescope under cold and high vacuum conditions was an extensive and important part of the entire test program.

This paper will concentrate on the design issues, the implementation and verification of the MGSE provided for the Planck Space Telescope FM Videogrammetry Test in the LSS and the troubleshooting caused by a failure during the first rotation under cold conditions.

¹ Presenting Author

Temperature Stability and Control Requirements for Thermal Vacuum / Thermal Balance Testing of the Aquarius Radiometer

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ABSTRACT

The paper describes the specific temperature stability and control requirements for the thermal vacuum and thermal balance testing of the Aquarius Instrument at the Goddard Space Flight Center in Greenbelt, Maryland. The testing was conducted in the 10' wide x 15' deep Facility 225 Thermal Vacuum chamber. The temperature control stability requirements were less than .14°C RMS thermal variation over a seven-day period. The thermal test specification also called for the ability to impose a high-resolution sinusoidal variation for all heater zones. The special requirements of the Aquarius radiometer test necessitated the construction of a multi-function test fixture and the modification of two existing heater controller racks.

The Liquid Nitrogen System for Chamber A: A Change from Original Forced Flow Design to a Natural Flow (Thermo Siphon) System

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ABSTRACT

NASA Johnson Space Center (JSC) in Houston is currently supplementing its 20K helium refrigeration system to meet the new requirements for testing the James Web Space Telescope in the environmental control Chamber-A (65' dia x 120' high) in Building 32. The new system is required to meet the various operating modes which include a high 20K heat load, a required temperature stability at the load, rapid (but controlled) cool down and warm up and bake out of the chamber.

This paper will present the proposed modifications to the existing helium system(s) to incorporate the new requirements and the integration of the new helium refrigerator with the existing two 3.5KW 20K helium refrigerators. In addition, the floating pressure process control philosophy to achieve high efficiency over the operating range (40% to 100% of the refrigeration system capacity), and the required temperature stability of +/- 0.25 K at the load will be discussed. The refrigeration systems ability to naturally seek the operating conditions under various loads and thus minimizing operator involvement and the over all improvements to the system operability and the reliability will be explained.

¹ Presenting Author

² Presenting Author

Return to Mercury: A Comparison of Solar Simulation and Flight Data for the MESSENGER Spacecraft

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ABSTRACT

The **M**ercury, **S**urface, **S**pace, **E**nvironment **G**eochemistry and **R**anging (MESSENGER) spacecraft is a NASA Discovery Mission spacecraft developed and operated by the Johns Hopkins University Applied Physics Laboratory. It was launched on August 3, 2004 and is currently on a course for Mercury orbit insertion in March 2011.

To date the mission trajectory has taken the spacecraft to minimum solar distances of 0.332 and 0.313 AU and on January 14, 2008 the first flyby of Mercury in 33 years. From launch through the latest perihelion passage temperature performance data has been collected for the sun facing Digital Sun Sensors (DSS), the sun facing phased array and low gain (omni) antennas, the solar arrays, the sunshade and the two sun facing attitude control 4.4 N thrusters. Prior to launch, extensive solar simulation testing was conducted at the Glenn Research Center, Tank 6 solar simulation facility in Cleveland Ohio. Flight hardware qualification units representing these Sun exposed components were tested in solar environments that represented near mission minimum solar distance as to verify the thermal designs and the material used in fabrication.

The paper will review the thermal designs of these components and their thermal performance to date as compared to the solar simulation testing.

Floating Pressure Conversion and Equipment Upgrades of Two 3.5kw, 20k, Helium Refrigerators

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ABSTRACT

Two helium refrigerators, each rated for 3.5KW at 20K, are used at NASA's Johnson Space Center (JSC) in Building No. 32 to provide cryo-pumping within two large thermal-vacuum chambers. These refrigerators were originally commissioned in 1996. Equipment refurbishment and upgrades to the controls of these refrigerators were recently completed. This paper describes some of the mechanical and control issues that necessitated the equipment refurbishment and controls change-over. It will describe the modifications and the new process control which allows the refrigerators to take advantage of the Ganni Cycle "floating pressure" control technology.

The upgrades – the controls philosophy change-over to the floating pressure control technology and the newly refurbished equipment – have greatly improved the performance, stability, and efficiency of these two refrigerators.

The upgrades have also given the operators more information and details about the operational status of the main components (compressors, expanders etc.) of the refrigerators at all operating conditions (i.e.: at various loads in the vacuum chambers).

Capabilities, configuration, and performance data pre, and post, upgrading will be presented.

¹ Presenting Author

Affect of Air Leakage into a Thermal-Vacuum Chamber on Helium Refrigeration Heat Load

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ABSTRACT

NASA's Johnson Space Center (JSC) Building 32 houses two large thermal-vacuum chambers (Chamber A and Chamber B). Within these chambers are liquid nitrogen shrouds to provide a thermal environment and helium panels which operate at 20K to provide cryo-pumping. Some amount of air leakage into the chambers during tests is inevitable. This causes "air fouling" of the helium panel surfaces due to the components of the air that adhere to the panels. The air fouling causes the emittance of the helium panels to increase during tests.

The increase in helium panel emittance increases the heat load on the helium refrigerator that supplies the 20K helium for those panels. Planning for thermal-vacuum tests should account for this increase to make sure that the helium refrigerator capacity will not be exceeded over the duration of a test.

During a recent test conducted in Chamber B a known-size air leak was introduced to the chamber.

Emittance change of the helium panels and the affect on the helium refrigerator was characterized. A description of the test and the results will be presented.

¹ Presenting Author

Session II

Contamination

Special ISO Class 6 Cleanroom for the Lunar Reconnaissance Orbiter (LRO) Project

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ABSTRACT

The parameters and restrictions for a horizontal flow ISO Class 6 Cleanroom to support the assembly of the new LRO (Lunar Reconnaissance Orbiter) were unusual. The project time line was critical. A novel Cleanroom design was developed and built within the time restraints. This paper describes the design criteria, timing, successful performance, and future benefits of this unique Cleanroom project.

¹ Presenting Author

A State-of-the-Art Contamination Effects Research and Test Facility

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ABSTRACT

In the ongoing effort to better understand various spacecraft contamination phenomena, a new state of the art contamination effects research and test facility was designed, and recently brought on-line at The Aerospace Corporation's Space Materials Laboratory. This high vacuum test chamber employs multiple in-situ analytical techniques, making it possible to study both the qualitative and quantitative aspects of contaminant film formation in the presence or absence of VUV radiation. Adsorption and desorption kinetics, "photo-fixing efficiency", transmission loss of uniform contaminant films, light scatter from non-uniform films, and film morphology have been studied in this facility. This paper describes this new capability in detail and presents data collected from several of the analytical instruments.

¹ Presenting Author

Martian Dust Simulator

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ABSTRACT

The Martian Dust Simulator (MDS) was designed to investigate the contamination effects of Martian soil and rock on the performance and function of flight-like microvalves and flight-like filters located within the Sample Analysis at Mars (SAM) instrument suite. The SAM instrument suite, which houses over fifty percent of the science payload, is located on-board the Mars exploration rover. The mission objective of the Mars Science Laboratory Rover is to determine the past, present, and future habitability of Mars. It will serve as a robot geologist, traveling the Mars surface for a period of one Martian year (equivalent to two earth years). The microvalves were designed as a conduit to control the flow of Martian gas to the science instruments. If exposed to particle sizes greater than half a micron, both the science instruments and science equipment, including forty-seven microvalves, could experience performance degradation. As a result, filters were used at various gas inlets to protect flight hardware from particulate degradation. Additionally, the filters serve as the only interface between the Martian environment and the mechanisms within SAM. The MDS operates at 7 Torr (0.135 psi) with a gas flow rate of 0 to 20 m/s. Iron (III) Oxide was the only dust particle specimen used, although several others were initially considered (i.e. JSC-Mars-1, Corundum Powder (Al_2O_3), Hydrated Sulfate, and Belville (Basalt)). The overarching goal of the MDS is to demonstrate that the Mars exploration program is adequately designed and prepared for the Martian mission environment.

¹ Presenting Author

² Presenting Author

Cleanroom Design Practices and Their Influence on Particle Counts

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ABSTRACT

This paper will discuss the adverse effects of deficient cleanroom design practices on airborne particle counts and the rather curious correlation of particle count variations with external environmental pressure fluctuations. Data is also presented that demonstrates that APL building 23 cleanrooms ran well below ISO class 7 (FED class 10,000) during New Horizons and STEREO integration.

Extra Terrestrial Environmental Chamber Design

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ABSTRACT

A vacuum chamber designed to simulate the dusty environment on the Moon or Mars has been built for Goddard Space Flight Center. The path from concept to delivery is reviewed, with lessons learned and pitfalls highlighted along the way.

Contamination Sources Effects Analysis (CSEA)- A Tool to Balance Cost / Schedule While Managing Facility Availability

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ABSTRACT

A CSEA is similar to a Failure Modes Effects Analysis (FMEA). A CSEA tracks risk, deterrence, and occurrence of sources of contamination and their mitigation plans. Documentation is provided spanning mechanical and electrical assembly, precision cleaning, thermal vacuum bake-out, and thermal vacuum testing. These facilities all may play a role in contamination budgeting and reduction ultimately affecting test and flight. With a CSEA, visibility can be given to availability of these facilities, test sequencing and trade-offs.

A cross-functional team including specialty engineering, contamination control, electrostatic dissipation, manufacturing, testing, and material engineering participate in an exercise that identifies contaminants and minimizes the complexity of scheduling these facilities considering their volatile schedules. Care can be taken in an efficient manner to insure correct cleaning processes are employed.

The result is reduction in cycle time (“schedule hits”), reduced cost due to rework, reduced risk and improved communication and quality while achieving adherence to the Contamination Control Plan.

SES and Acoustics at GSFC

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ABSTRACT

This paper presents air and surface cleanliness characterization of the acoustics test facility and large (SES) thermal vacuum chamber at Goddard Space flight Center in Greenbelt, MD during the New Horizons Pluto probe program. It is shown that slow back-fill of the SES chamber is necessary to prevent excessive particle redistribution.

Session III

Structural Dynamics Testing

HST Super Lightweight Interchangeable Carrier (SLIC) Static Test

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ABSTRACT

The HST Super Light Weight Interchangeable Carrier Static Test program calls for a total of 15 load cases with an average of 9 simultaneous push/pull locations per load case. This testing program represents the most complex static test ever attempted at Goddard Space Flight Center. Many unique multi- pull fixtures were designed to apply the simultaneous loading. Additionally, a total of 600 channels of data required processing for each loadcase. A total of 1100 separate strain gages were installed on SLIC. A team of 15 trained technicians were needed to apply test loads via mechanical hand pumps for several load cases. All 15 load cases were successfully conducted within 15 weeks. The ManTech team successfully tested all SLIC 1200 interface clips to the required testing loads. Several unique designs were needed to address testing challenges as loadline interference, Payload Safety, payload flexibility and opposing load applications.

Virtual Shaker Testing: Simulation Technology Improves Vibration Test Performance

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ABSTRACT

In the field of vibration testing, the interaction between the structure being tested and the instrumentation hardware used to perform the test is a critical issue. This is particularly true when testing massive structures (e.g. satellites), because due to physical design and manufacturing limits, the dynamics of the testing facility often couples with the test specimen one in the frequency range of interest. A further issue in this field is the standard use of a closed loop real-time vibration control scheme, which could potentially shift poles and change damping of the aforementioned coupled system.

“Virtual shaker testing” is a novel approach to deal with these issues. It means performing a simulation which closely represents the real vibration test on the specific facility by taking into account all parameters which might impact the dynamic behavior of the specimen.

In this paper, such a virtual shaker testing approach is developed. It consists of the following components: (1) Either a physical-based or an equation-based coupled electro-mechanical lumped parameter shaker model is created. The model parameters are obtained from manufacturer’s specifications or by carrying out some dedicated experiments; (2) Existing real-time vibration control algorithm are ported to the virtual simulation environment; and (3) A structural model of the test object is created and after defining proper interface conditions structural modes are computed by means of the well-established Craig-Bampton CMS technique.

At this stage, a virtual shaker test has been run, by coupling the three described models (shaker, control loop, structure) in a co-simulation routine. Numerical results have eventually been correlated with experimental ones in order to assess the robustness of the proposed methodology.

¹ Presenting Author

Estimating Shock Spectra: Extensions beyond GEVS

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ABSTRACT

Shock response spectra (SRS) are the standard description of some vibration environments on spacecraft for equipment qualification. For shock events produced by pyrotechnic devices, SRS can have significant frequency content as high as 10 kHz. It is difficult to construct and analyze finite element models that can resolve dynamic behavior at such high frequencies. GEVS provides simple, empirically based methods for approximating the SRS for a wide variety of shock events. It begins with a base SRS according to the type of pyrotechnic device, and then provides attenuation relations to adjust this SRS according to distance from the shock source, the type of structural frame and the properties of any structural joints between the source and equipment.

In our paper we extend GEVS to include more detailed information about the spacecraft structure. To retain the general framework of GEVS, we begin with a base SRS and adjust this SRS using attenuation relations. We use modal and traveling wave concepts to derive the attenuation relations for simple canonical structures. Then we show how these concepts can be used to analyze more complex structures using finite element mode shapes to explicitly calculate the attenuation factors. Since the low- to mid-frequency finite element modal information is extrapolated to obtain the low- to high-frequency attenuation relations, the resulting attenuated SRS is formulated as an upper bound rather than as mean predicted values. We illustrate the extended GEVS approach by analyzing the impact response of composite tubes and the shock response of the STEREO spacecraft.

¹ Presenting Author

Structural Dynamic Analysis of a Spacecraft Multi-DOF Shaker Table

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ABSTRACT

Finite element enforced response analysis was performed on a multiple degree of freedom expander head shaker table to aid in the design of the table structure and vibration control system. The payload for this shaker system is a spacecraft with a multitude of flexible modes across a broad frequency band. A Craig-Bampton representation of the spacecraft was used to expedite analysis of multiple shaker table designs. The analysis examines the required forces in the actuators for a constant amplitude base acceleration sine sweep test, the resulting forces in the spacecraft and table attachment restraints, and the resulting accelerations on the spacecraft structure. The results show the spacecraft response at low frequencies is very high near the tip due to the low order spacecraft bending and axial modes. The high response can be addressed by “notching” the input vibration levels to avoid over-testing the spacecraft. At frequencies above 25 Hz, the spacecraft modal effective masses are very small, and the response of the shaker table dominates the response. Anti-resonances of the shaker table in the frequency range of interest reduce the acceleration output and require much higher actuator forces to achieve the acceleration specification. These effects may require stiffening the shaker structure to move the modes out of the test frequency range or increasing the shaker table damping.

¹ Presenting Author

Direct Field Acoustic Testing

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ABSTRACT

This paper presents an update to the methods and procedures used in Direct Field Acoustic Testing (DFAT). The paper will discuss some of the recent techniques and developments that are currently being used and the future publication of a reference standard. Acoustic testing using commercial sound system components is becoming a popular and cost effective way of generating a required acoustic test environment both in and out of a reverberant chamber. This paper will present the DFAT test method, the usual setup and procedure and the development and use of a closed-loop, narrow-band control system. Narrow-band control of the acoustic PSD allows all standard techniques and procedures currently used in random control to be applied to acoustics and some examples are given. The paper will conclude with a summary of the development of a “standard practice” guideline that is hoped to be available in the first quarter of next year.

Session IV

New Capabilities and Facilities

Manufacture of Cryoshroud Surfaces for Space Simulation Chambers

DynaVac Center

Presented By:

Gary S. Ash Ph.D.

DynaVac Center

ABSTRACT

Environmental test chambers for space applications use internal shrouds to simulate temperature conditions encountered in space. Shroud temperatures may range from +150 °C to -253 °C (20 K), and internal surfaces are coated with special high emissivity/absorptivity paints. To obtain temperature uniformity over large areas, detailed thermal design is required for placement of tubing for gaseous or liquid nitrogen and helium and other exotic heat exchange fluids. The recent increase in space simulation activity related to the James Webb Space Telescope has led to the design of new cryogenic shrouds to meet critical needs in instrument package testing. This paper will review the design and manufacturing of shroud surfaces for several of these programs, including fabrication methods and the selection and application of paints for simulation chambers.

The New LOTIS Test Facility

**R.M. Bell, G. Cuzner, C. Eugeni, S.B. Hutchison,
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ABSTRACT

The Large Optical Test and Integration Site (LOTIS) at the Lockheed Martin Space Systems Company in Sunnyvale, CA is designed for the verification and testing of optical systems. The facility consists of an 88 foot temperature stabilized vacuum chamber that also functions as a class 10k vertical flow cleanroom. Many problems were encountered in the design and construction phases. The industry capability to build large chambers is very weak. Through many delays and extra engineering efforts, the final product is very good. With 11 Thermal Conditioning Units and precision RTD's, temperature is uniform and stable within 1°F, providing an ideal environment for precision optical testing. Within this chamber and atop an advanced micro-g vibration-isolation bench is the 6.5 meter diameter LOTIS Collimator and Scene Generator, LOTIS alignment and support equipment. The optical payloads are also placed on the vibration bench in the chamber for testing. This optical system is designed to operate in both air and vacuum, providing test imagery in an adaptable suite of visible/near infrared (VNIR) and midwave infrared (MWIR) point sources, and combined bandwidth visible-through-MWIR point sources, for testing of large aperture optical payloads. The heart of the system is the LOTIS Collimator, a 6.5m f/15 telescope, which projects scenes with wavefront errors <85 nm rms out to a ±0.75 mrad field of view (FOV). Using field lenses, performance can be extended to a maximum field of view of ±3.2 mrad. The LOTIS Collimator incorporates an extensive integrated wavefront sensing and control system to verify the performance of the system.

¹ Presenting Author

Thermal Vacuum Control Systems Options for Test Facilities

John Marchetti

Control Systems Engineer
XL Technology Systems, Inc.

ABSTRACT

This presentation suggests several Thermal Vacuum System (TVAC) control design approach methods for TVAC facilities. Over the past several years many aerospace companies have or are currently upgrading their TVAC testing facilities whether it be by upgrading old equipment or purchasing new. In doing so they are updating vacuum pumping and thermal capabilities of their chambers as well as their control systems. Although control systems are sometimes considered second to the vacuum or thermal system upgrade process, they should not be taken lightly and must be planned and implemented with the equipment it is to control. Also, emphasis should be placed on how the operators will use the system as well as the requirements of “their” customers. Presented will be various successful methods of TVAC control systems from Programmable Logic Controller (PLC) based to personal computer (PC) based control.

Extremely High Vacuum Chamber for Low Outgassing Processing at NASA Goddard

Andrew Webb¹

The Johns Hopkins University Applied Physics Laboratory

Joseph Gelman

ManTech, Inc., NASA Goddard Space Flight Center

ABSTRACT

The levels of vacuum that proceed past the high vacuum range into the ultra high and then the extremely high vacuum range become more difficult to achieve each decade that a system progresses through. This paper will explore the difficulties and cover some of the design principles used in achieving vacuum levels in the low 10-12 torr pressure range. This system was entirely built with commercially-available off the shelf (COTS) components. This chamber was designed in 1998 to provide a very low outgassing environment for the processing and sealing of charge-coupled devices (CCD's) for some of the Hubble Space Telescope replacement optics.

¹ Presenting Author

Precision Cleaning- Path to Premier

Scott E. Mackler

ITT Corporation, Space Systems Division

ABSTRACT

ITT Space Systems Division's new Precision Cleaning facility provides critical cleaning and packaging of aerospace flight hardware and optical payloads to meet customer performance requirements. The Precision Cleaning Path to Premier Project was a 2007 capital project and is a key element in the approved Premier Resource Management – Integrated Supply Chain Footprint Optimization Project.

Formerly precision cleaning was located offsite in a leased building. A new facility equipped with modern precision cleaning equipment including advanced process analytical technology and improved capabilities was designed and built after outsourcing solutions were investigated and found lacking in ability to meet quality specifications and schedule needs.

SSD cleans parts that can range in size from a single threaded fastener all the way up to large composite structures. Materials that can be processed include optics, composites, metals and various high performance coatings. We are required to provide verification to our customers that we have met their particulate and molecular cleanliness requirements and we have that analytical capability in this new facility. The new facility footprint is approximately half the size of the former leased operation and provides double the amount of throughput.

Process improvements and new cleaning equipment are projected to increase 1st pass yield from 78% to 98% avoiding \$300K+ / yr in rework costs. Cost avoidance of \$350K / yr will result from elimination of rent, IT services, transportation, and decreased utility costs. Savings due to reduced staff expected to net \$4-500K / yr.

The New Anechoic Shielded Chambers Designed for Space and Commercial Applications at LIT

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ABSTRACT

The main objective of this paper is to present the capability of the new anechoic shielded rooms designed for space and commercial applications as part of the Integration and Testing Laboratory (LIT – Laboratório de Integração e Testes) in Brazil.

A new anechoic shielded room named CBA2 is in full operation since March/2007 and a remodeled chamber CBA1 is planned to be ready by the end of 2008 replacing an old facility which was in operation for the last 18 years.

Once the Brazilian Space Program started with very small and simple satellites the old chamber CBA1 was conceived in 1987 to accomplish the EMI/EMC tests not requiring significant volumes.

Since the very beginning this facility was also used by the private sectors for other applications mainly due to the absorption of digital electronics in all kind of products. Due to the intense use of this facility during the last years when operating three shifts a day caused a normal degradation and imposed several limitations. Therefore, new chamber totally remodeled was designed considering the state of the art in terms of absorbers and instrumentation associated with.

On the other hand the facility CBA2 was conceived, designed and implemented to test large satellites taking into account the advance of the technology in terms of RF frequencies, power level, testing methodologies and several other factors. A very interesting and unique aspect of this project was the partnership between the private sector and governmental institution. As a result the total investment was shared between several companies and consequently a time-sharing use of the facility as well.

¹ Presenting Author

Extraction of Thermal Performance Values from Samples in the Lunar Dust Adhesion Bell Jar

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NASA Glenn Research Center

John Siamidis

Analex Corporation

Elizabeth M.G. Larkin

Case Western Reserve University

ABSTRACT

A simulation chamber has been developed to test the performance of thermal control surfaces under dusty lunar conditions. The lunar dust adhesion bell jar (LDAB) is a diffusion pumped vacuum chamber (10⁻⁸ Torr) built to test material samples less than about 7 cm in diameter. The LDAB has the following lunar dust stimulant processing capabilities: heating and cooling while stirring in order to degas and remove absorbed water; RF air-plasma for activating the dust and for organic contaminant removal; RF H/He-plasma to simulate solar wind; dust sieving system for controlling particle sizes; and a controlled means of introducing the activated dust to the samples under study. The LDAB is also fitted with an in situ Xe arc lamp solar simulator, and a cold box that can reach 30 K. Samples of thermal control surfaces (2.5 cm diameter) are introduced into the chamber for calorimetric evaluation using thermocouple instrumentation. The object of this paper is to present a thermal model of the samples under test conditions, and to outline the procedure to extract the absorptance, emittance, and thermal efficiency from the pristine and sub-monolayer dust covered samples.

¹ Presenting Author

Session V

Data Acquisition and Analyses

Thermal (Silicon Diode) Data Acquisition System

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ABSTRACT

Marshall Space Flight Center's X-ray Calibration Facility (XRCF) has been performing cryogenic testing to 20 Kelvin since 1999. Two configurations for acquiring data from silicon diode temperature sensors have been implemented at the facility. The facility's environment is recorded via a data acquisition system capable of reading up to 60 silicon diodes. Test article temperature is recorded by a second data acquisition system capable of reading 150+ silicon diodes. The specifications and architecture of both systems will be presented.

Aquarius's Instrument Science Data System (ISDS) Automated to Acquire, Process, Trend Data and Produce Radiometric System Assessment Reports

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Code 568.0- Flight Systems Integration and Test Branch
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ABSTRACT

The Aquarius Radiometer, a subsystem of the Aquarius Instrument required a data acquisition ground system to support calibration and radiometer performance assessment. To support calibration and compose performance assessments, we developed an automated system which uploaded raw data to a ftp server and saved raw and processed data to a database. This paper details the overall functionalities of the Aquarius Instrument Science Data System (ISDS) and the individual electrical ground support equipment (EGSE) which produced data files that were infused into the ISDS. Real time EGSEs include an ICDS Simulator, Calibration GSE, Labview controlled power supply, and a chamber data acquisition system. ICDS Simulator serves as a test conductor primary workstation, collecting radiometer housekeeping (HK) and science data and passing commands and HK telemetry collection request to the radiometer. Calibration GSE (Radiometer Active Test Source) provides source choice from multiple targets for the radiometer external calibration. Power Supply GSE, controlled by labview, provides real time voltage and current monitoring of the radiometer. And finally the chamber data acquisition system produces data reflecting chamber vacuum pressure, thermistor temperatures, AVG and watts. Each GSE system produce text based data files every two to six minutes and automatically copies the data files to the Central Archiver PC. The Archiver PC stores the data files, schedules automated uploads of these files to an external FTP server, and accepts request to copy all data files to the ISDS for offline data processing and analysis. Aquarius Radiometer ISDS contains PHP and MATLAB programs to parse, process and save all data to a MySQL database. Analysis tools (MATLab programs) in the ISDS system are capable of displaying radiometer science, telemetry and auxiliary data in near real time as well as performing data analysis and producing automated performance assessment reports of the Aquarius Radiometer.

¹ Presenting Author

Exhaustive Thresholds and Resistance Checkpoints

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ABSTRACT

Once deployed, all intricate systems that operate for a long time (such as an airplane or chemical processing plant) experience degraded performance during operational lifetime. These can result from losses of integrity in subsystems and parts that generally do not materially impact the operation of the vehicle (e.g., the light behind the button that opens the sliding door of the minivan). Or it can result from loss of more critical parts or subsystems. Such losses need to be handled quickly in order to avoid loss of personnel, mission, or part of the system itself. In order to manage degraded systems, knowledge of its potential problem areas and the means by which these problems are detected should be developed during the initial development of the system. Once determined, a web of sensors is employed and their outputs are monitored with other system parameters while the system is in preparation or operation.

Just gathering the data is only part of the story. The interpretation of the data itself and the response of the system must be carefully developed as well to avoid a mishap. Typically, systems use a test-threshold-response paradigm to process potential system faults. However, such processing sub-systems can suffer from errors and oversights of a consistent type, causing system aberrant behavior instead of expected system and recovery operations. In our study, we developed a complete checklist for determining the completeness of a fault system and its robustness to common processing and response difficulties.

¹ Presenting Author

Reconfigurable HIL Testing of Earth Satellites

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ABSTRACT

In recent years, hardware-in-the-loop (HIL) testing has carved a strong niche in several industries, such as automotive, aerospace, telecomm, and consumer electronics. As desktop computers have realized gains in speed, memory size, and data storage capacity, hardware/software platforms have evolved into high performance, deterministic HIL platforms, capable of hosting the most demanding applications for testing components and subsystems. Using simulation software to emulate the digital and analog I/O signals of system components, engineers of all disciplines can now test new systems in realistic environments to evaluate their function and performance prior to field deployment.

Within the Aerospace industry, space-borne satellite systems are arguably some of the most demanding in terms of their requirement for custom engineering and testing. Typically, spacecraft are built one or few at a time to fulfill a space science or defense mission. In contrast to other industries that can amortize the cost of HIL systems over thousands, even millions of units, spacecraft HIL systems have been built as one-of-a-kind solutions, expensive in terms of schedule, cost, and risk, to assure satellite and spacecraft systems reliability.

The focus of this paper is to present a new approach to HIL testing for spacecraft systems that takes advantage of a highly flexible hardware/software architecture based on National Instruments PXI reconfigurable hardware and virtual instruments developed using LabVIEW. This new approach to HIL is based on a multistage/multimode spacecraft bus emulation development model called Reconfigurable Hardware In-the-Loop or RHIL.

FPGA Control System for the Automated Test of MicroShutters

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Mink Hollow Systems, Inc.

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ABSTRACT

The James Webb Space Telescope, scheduled to replace the Hubble in 2013, must simultaneously observe hundreds of faint galaxies. This requirement has led to the development of a programmable transmission mask which can be adapted to admit light from an arbitrary pattern of galaxies into its spectrograph. This programmable mask will contain a large array of micro-electromechanical (MEMs) devices called MicroShutters. These microscopic shutters physically open and close like the shutter on a camera, except each shutter is microscopic in size and an array 365 by 171 is used to select the objects under spectroscopic observation at a given time, and to block the unwanted background light from other areas. NASA developed and is currently refining the exceptionally difficult process of manufacturing these shutters. This paper describes how the authors used LabVIEW FPGA and a reconfigurable I/O board to control the shutters in a test chamber and how the flexibility of the system allows us to continue to modify the control algorithms as NASA optimizes the performance of the MicroShutter arrays.

¹ Presenting Author

Session VI

Simulations and Special Topics

Ongoing Capabilities and Developments of Re-Entry Plasma Ground Tests at EADS-ASTRIUM

Pierre Jullien

European Aeronautic Defense and Space Company

ABSTRACT

During re-entry, spacecrafts are subjected to extreme thermal loads. On mars, they may go through dust storms. These external heat loads are leading the design of re-entry vehicles or are affecting it for spacecraft facing solid propellant jet stream. Sizing the Thermal Protection System require a good knowledge of such solicitations and means to model and reproduce them on earth. Through its work on European projects, ASTRIUM has developed the full range of competences to deal with such issues. For instance, we have designed and tested the heat-shield of the Huygens probe which landed on Titan.

In particular, our plasma generators aim to reproduce a wide variety of re-entry conditions. Heat loads are generated by the huge speed of the probes. Such conditions cannot be fully reproduced. Ground tests focus on reproducing local aerothermal loads by using slower but hotter flows. Our inductive plasma torch enables to test little samples at low TRL. Amongst the arc-jets, one was design to test architecture design of ISS crew return system and others fit more severe re-entry such as sample returns or Venus re-entry. The last developments aimed in testing samples in seeded flows. First step was to design and test the seeding device. Special diagnostics characterising the resulting flow enabled us to fit it to the requirements.

Operationally Responsive Space Standard Bus Battery Thermal Balance Testing and Heat Dissipation Analysis

Mike Marley

The Johns Hopkins University Applied Physics Laboratory

ABSTRACT

The focus of this paper will be on the thermal balance testing for the Operationally Responsive Space Standard Bus Battery. The Standard Bus thermal design required that the battery be isolated from the bus itself. This required the battery to have its own thermal control, including heaters and a radiator surface. Since the battery was not ready for testing during the overall bus thermal balance testing, a separate test was conducted to verify the thermal design for the battery. This paper will discuss in detail, the test set up, test procedure, and results from this test.

Additionally this paper will consider the methods taken to determine the heat dissipation of the battery during charge and discharge. It seems that the heat dissipation for Lithium Ion batteries is relatively unknown and hard to quantify. The methods used during test and the post test analysis to estimate the heat dissipation of the battery will be discussed.

“Galileo- The Serial-Production AIT Challenge”

Ulrike Ragnit

European Space Agency (ESA)

Presented By:

Otto Brunner

European Space Agency (ESA)

ABSTRACT

The Galileo Project is one of the most demanding projects of ESA, being Europe 's autarkic navigation system and a constellation out of 30 Satellites. The presentation is pointing out the different phases of the project up to the full operational capability and the corresponding launch options with respect to launch vehicles as well as launch configurations.

One of the biggest challenges is to set up a small serial "production line" for the overall integration and test campaign of Satellites. This production line demands an optimization of all relevant tasks, taking into account also well backup and recovery actions.

A comprehensive AIT concept is required, reflecting a tightly merged facility layout and work flow design. In addition a common data management system is needed to handle all spacecraft related documentation and to have a direct input-out flow for all activities, phases and positions at the same time.

Process optimization is a well known field of engineering in all small high tech production lines, nevertheless serial production of Satellites are still not the daily task in Space business and therefore new concepts have to be put in place. Therefore and in order to meet the satellites overall system optimization a thoroughly interface between unit/subsystem manufacturing and satellite AIT have to be foreseen to ensure a smooth flow and to avoid any process interruption, which would directly lead to a schedule impact.

The Space Systems Environmental Test Facility Database (SSETFD), Website Development Status

James M. Synder

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ABSTRACT

The Aerospace Corporation has been developing a database of U.S. environmental test laboratory capabilities utilized by the space systems hardware development community. To date, 19 sites have been visited by The Aerospace Corporation and verbal agreements reached to include their capability descriptions in the database. A website is being developed to make this database accessible by all interested government, civil, university and industry personnel. The website will be accessible by all interested in learning more about the extensive collective capability that the US based space industry has to offer. The Environments, Test & Assessment Department within The Aerospace Corporation will be responsible for overall coordination and maintenance of the database. Several US government agencies are interested in utilizing this database to assist in the source selection process for future spacecraft programs.

This paper introduces the website by providing an overview of its development, location and search capabilities. It will show how the aerospace community can apply this new tool as a way to increase the utilization of existing lab facilities, and as a starting point for capital expenditure/upgrade trade studies. The long term result is expected to be increased utilization of existing laboratory capability and reduced overall development cost of space systems hardware. Finally, the paper will present the process for adding new participants, and how the database will be maintained.

Simulated Reentry Heating by Torching

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NASA Langley Research Center

ABSTRACT

The two first order reentry heating parameters are peak heating flux (W/cm^2) and peak heat load (kJ/cm^2). Peak heating flux (and deceleration, gs) is higher for a ballistic reentry and peak heat load is higher for a lifting reentry. Manned vehicle reentries are generally lifting reentries at nominal 1-5 gs so that personnel will not be crushed by high deceleration force. A few off-nominal manned reentries have experienced 8 or more gs with corresponding high heating flux (but below nominal heat load).

The Shuttle Orbiter reentries provide about an order of magnitude difference in peak heating flux at mid-bottom (TPS tiles, $\sim 6 \text{ W}/\text{cm}^2$ or $5 \text{ BTU}/\text{ft}^2\text{- sec}$) and leading edge (RCC, $\sim 60 \text{ W}/\text{cm}^2$ or $50 \text{ BTU}/\text{ft}^2\text{- sec}$). Orion lunar return and Mars sample lander are of the same order of magnitude as orbiter leading edge peak heat loads. Flight temperature measurements are available for some orbiter TPS tile and RCC locations.

Return-to-Flight on-orbit tile-repair-candidate-material-heating performance was evaluated by matching propane torch heating of candidate-materials temperatures at several depths to orbiter TPS tile flight-temperatures. Char and ash characteristics, heat expansion, and temperature histories at several depths of the cure-in-place ablator were some of the TPS repair material performance characteristics measured. The final char surface was above the initial surface for the primary candidate (silicone based) material, in contrast to a receded surface for the Apollo-type ablative heat shield material.

Candidate TPS materials for Orion CEV (LEO and lunar return), and for Mars sample lander (MSL) are now being evaluated. Torching of a candidate ablator material, PICA, was performed to match the ablation experienced by the STARDUST PICA heat shield. Torching showed that the carbon fiberform skeleton in a sample of PICA was inhomogeneous in that sample, and allowed measurements (of the clumps and voids) of the inhomogeneity.

Additional reentry heating-performance characterizations of high temperature insulation materials were performed.

Micro-Vibration Measurements on Thermally Loaded Multi-Layer Insulation Samples in Vacuum

Georg Deutsch¹ and Anton Grillenbeck
IABG mbH

ABSTRACT

Some scientific missions require to an extreme extent the absence of any on-board micro-vibration. Recent projects dedicated to measuring the Earth's gravity field and modeling the geoid with extremely high accuracy are examples. Their missions demand for extremely low micro-vibration environment on orbit for:

- Not disturbing the measurement of earth gravity effects with the installed gradiometer or
- Even not damaging the very high sensitive instruments.

Based on evidence from ongoing missions multi-layer insulation (MLI) type thermal control blankets have been identified as a structural element of spacecrafts which might deform under temperature variations being caused by varying solar irradiation in orbit. Any such deformation exerts tiny forces which may cause small reactions resulting in micro-vibrations, in particular by exciting the spacecraft eigenmodes.

The principle of the test set-up for the micro-vibration test was as follows. A real side wall panel of the spacecraft (size about 0.25 m²) was low-frequency suspended in a thermal vacuum chamber. On the one side of this panel, the MLI samples were fixed by using the standard methods. In front of the MLI, an IR-rig was installed which provided actively controlled IR-radiation power of about 6 kW/m² in order to heat the MLI surface. The cooling was passive using the shroud temperature at a chamber pressure <1E-5mbar. The resulting micro-vibrations due to MLI motion in the heating and the cooling phase were measured via seismic accelerometers which were rigidly mounted to the panel. Video recording was used to correlate micro-vibration events to any visual MLI motion.

Different MLI sample types were subjected to various thermal cycles in a temperature range between -60°C to +80°C.

In this paper, the experience on these micro-vibration measurements will be presented and the conclusions for future applications will be discussed

¹ Presenting Author

High Temperature Life Testing of 80Ni-20Cr Wire in a Simulated Mars Atmosphere for the Sample Analysis at Mars (SAM) Instrument Suit Gas Processing System (GPS) Carbon Dioxide Scrubber

Cynthia Gundersen
AMU Engineering Inc.

Christopher Hoffman¹ and Bruno Munoz
Ball Aerospace & Technologies Corp.

Timothy Stephenson and Walter Thomas III
NASA Goddard Space Flight Center

ABSTRACT

In support of the GPS for the SAM instrument suite built by GSFC, a life test facility was developed to test the suitability of 80Ni-20Cr wire, 0.0056 inches in diameter, for use as a heater element for the carbon dioxide scrubber. The wire would be required to operate at 1000°C in order to attain the 800°C required for regeneration of the getter. The wire also would need to operate in the Mars atmosphere, which consists mostly of CO₂ at pressures between 4 and 12 torr. Data on the high temperature degradation mechanism of 80Ni-20Cr in low pressure CO₂, together with the effects of thermal cycling, were unknown. In addition, the influence of work hardening of the wire during assembly and the potential for catastrophic grain growth also were unknown. Verification of the wire reliability as defined by the mission goals required the construction of a test facility that would accurately simulate the duty cycles in a simulated Mars atmosphere. The experimental set-up, along with the test protocol and results will be described.

¹ Presenting Author

The Planning and Implementation of Test Facility Improvements

Larry Oberlander
Northrop Grumman SSES

ABSTRACT

As engineering programs develop, and product testing begins, ideas for process improvement soon become obvious. Engineers envision new holding and handling fixtures. Additional custom-made support equipment may be needed. Perhaps modifications to the building or modifications to facility hardware are the order of the day. This is where a flexible creative test organization is needed. We need not be content with the status quo. All of these desired test innovations can make the difficult easy and improve the work flow. At times, implementing these new ideas demands more time or specialized expertise than test team members have. Through the coordinated use of labor resources, the needed improvements can still be made and in a timely fashion that supports program schedules. This presentation provides practical advice and a method whereby test personnel can creatively develop facility improvements and manage them from start to finish. You can control just how much time you invest and what part of your concepts you will personally design.

By wisely defining the requirements and presenting them to the appropriate help sources (vendors, contractors, coworkers, and support departments), you can get the help you need to bring the improvements you have conceived, into fruition. Aspects of this presentation include defining requirements for test facility improvements, choosing labor resources, writing a statement of work, determining cost and benefits, securing department approval, coordinating Procurement, managing the project, and training the end users. The process of successfully implementing test facility improvements is thoroughly explained. It has been tried, proven and improved over nearly 25 years of use. Whether considering a \$50 improvement or a \$50 million dollar improvement, this discussion will provide helpful pointers. Examples of improvements made through this process and their illustration will be included.

Development of a Silicon Carbide Molecular Beam Nozzle for Simulation Planetary Flybys and Low-Earth Orbit

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Southwest Research Institute

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University of Texas at Dallas

W. T. Kasprzak and Paul R. Mahaffy

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ABSTRACT

From commercial origins as a molybdenum molecular beam nozzle, a ceramic nozzle of silicon carbide (SiC) was developed for space environment simulation. The nozzle is mechanically stable under extreme conditions of temperature and pressure. A heated, continuous, supersonically-expanded hydrogen beam with a 1% argon seed produced an argon beam component of nearly 4 km/s, with an argon flux exceeding 1×10^{14} /cm².s. This nozzle was part of a molecular beam machine used in the Atmospheric Experiments Branch at NASA Goddard Space Flight Center to characterize the performance of the University of Texas at Dallas Ram Wind Sensor (RWS) aboard the Air Force Communications/Navigation Outage Forecasting System (C/NOFS) launched in the Spring of 2008.

¹ Presenting Author

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