SESSION 1: FASTER, BETTER, CHEAPER—LESSONS LEARNED

MANUFACTURING'S ROLE IN AEROSPACE BOX TESTING

J. Pete Holub and Mark S. Yoss
Lockheed Martin Space Systems

Manufacturing plays a crucial role in helping to balance the forces of Faster, Better, Cheaper (FBC) in aerospace box-level testing at the Electronics Manufacturing Facility (EMF) of Lockheed Martin Space Systems – Astronautics Operations (LMAO) in Denver, Colorado. Rapid advances in electronic component capability, increased operating frequencies, and higher density packaging have significantly increased the complexity of aerospace black boxes. Simultaneously, the shift from cost plus to fixed price contracts has introduced cost and schedule pressures that inhibit adhering to the established aerospace industry regimen of full and sequential Development, Qualification, and Acceptance programs. Compromises may include breadboard-only development programs, release of flight designs prior to completion of development testing, and deferred qualification testing. As these cost and schedule choices are made, control of engineering design, procurement, and the manufacturing build process become paramount in ensuring successful test programs. Using experience gained from several major aerospace programs at EMF, this paper examines the FBC Lessons Learned in box-level testing with emphasis on the role of manufacturing.

TESTING ISSUES DURING THE USAF SPACE TEST PROGRAM'S ARGOS SATELLITE DEVELOPMENT

Michael N. Lovellette
Naval Research Laboratory

Douglas D. Chism, Michael La Grassa, Andrew Quintero, and Julia D. White
The Aerospace Corporation

Space Test Program (STP) is the R&D satellite development program office managed by the USAF for the purpose of flying Department of Defense space flight instruments that have no other way to space. STP has always in its 30+ year history had to do "faster, cheaper" acquisitions, due to severe budget constraints and the timeliness needs of technology verification and atmospheric modeling. The recent experience with the ARGOS spacecraft offers several lessons learned in the face of renewed pressure for cheaper, and especially faster, development. The ARGOS spacecraft was tested by Boeing, formerly Rockwell, engineers at Seal Beach, CA. The effort melded their experience derived from testing production satellites (GPS) with STP's experience with testing one-of-a-kind spacecraft. Schedule prediction was a challenge. Issues relating to the depth and breadth of data analysis, and the criteria for the need to perform retests, directly traded "faster" for "better".

LUNAR PROSPECTOR: FASTER, BETTER, BETTER, CHEAPER – LESSONS LEARNED

K. Foster and T. Maloney
Lockheed Martin Space Systems

Unavailable at press time.

ONE USAF UNIT'S EXPERIENCE

Col Ralph D. Monfort
Air Force Materiel Command

Many government entities are looking towards commercial off-the-shelf (COTS) technology as a panacea for fiscal shortfalls lured by the promise of "faster, better, cheaper." This paper provides insight into the lessons learned by one government unit which has "flown" multiple satellites over the last three years on a COTS-based system. Perhaps most important of these lessons is the realization that standard Air Force acquisition paradigms in the COTS environment are often inappropriate and sometimes the antithesis of "faster, better, cheaper." Success or failure with COTS systems depends on understanding and adapting to the constraints, challenges, and opportunities of this environment.

SESSION 2: INDUSTRY TESTING STANDARDS—MINIMUM REQUIREMENTS FOR MISSION SUCCESS

ORBITAL SCIENCES ENVIRONMENTAL TEST STANDARDS

K. L. Leith and P. A. Larkin
Orbital Sciences Corporation

The current business environment imposes significant constraints on both the cost and available schedule for verification testing of spacecraft and spacecraft systems. In addition the enforced rigor of well funded and technically savvy customers and imposed government documents defining qualification and acceptance test standards is fast disappearing, both because of changes in the Aerospace market sector and because even such customers have been discouraged from imposing strict, sometimes costly, and perhaps onerous standards. In this environment Orbital has attempted to define the internal environmental test policy and minimum standards that will be used to screen design and workmanship flaws.

AVOIDANCE OF UNVERIFIED FAILURES

B. A. Sande
Lockheed Martin Corporation

Significant cost, schedule and mission risk impacts are incurred in the Launch Vehicle and Spacecraft industries when hardware or software test failure symptoms are lost and the primary cause of the failure cannot be determined. Aerospace industries should develop rigorously defined and controlled failure investigation processes that avoid many of the test, troubleshooting and failure analysis scenarios and "traps" that result in unverified failures. Failure recovery processes must contain the best methodologies for minimizing risk if an unverified failure has occurred. This paper will explore lessons learned from actual unverified failures to assist the Aerospace community in the development of a standard language and process that will mitigate unverified failure risks to system performance, cost and schedule.

FUNCTIONAL TEST SUCCESS CRITERIA AS ILLUSTRATED BY THE SPACE TEST PROGRAM'S ARGOS SATELLITE

Julia D. White, Michael La Grassa, Douglas D. Chism, and Andrew Quintero
The Aerospace Corporation

Michael N. Lovellette
Naval Research Laboratory

The Space Test Program (STP) has been guided by a recommendation made in DOD-HDBK-343. This is expressed as the maxim "Test it like you fly it", or perform mission-like functional tests in as flight-like a configuration as possible. The recent experience with the ARGOS (Advanced Research and Global Observation Satellite) spacecraft offers several lessons learned in applying this maxim, especially in the face of renewed pressure for a faster test phase. Several

versions of this type of functional test were included in the ARGOS test flow. This paper describes the incorporation of STP's experience with doing mission oriented testing on a one-of-a- kind spacecraft with the schedule and cost pressures that came to bear on this satellite. A unique approach was developed for this data driven mission which involved the use of "functional bit error rate" as a criterion for determining the success of the data intensive functional tests.

PAYLOAD ACCOMMODATION IN THE FASTER, BETTER & CHEAPER ENVIRONMENT

Carl Kloss
Jet Propulsion Lab

N. Greg Heinsohn and Tim Girard
Lockheed Martin Astronautics

Mars Global Surveyor has been orbiting Mars for three years and is still returning valuable science data. The performance of the science payloads has exceeded expectations with numerous scientific discoveries. The spacecraft was launched 27 months after contract award to Lockheed Martin, setting a precedent and a new bench mark for Faster, Better & Cheaper planetary programs.

This paper will address the lessons learned from both the successes and failures of accommodating the science payload on the MGS spacecraft. Technical issues will be addressed, but the primary focus will be on the techniques and strategies employed to ensure that the science requirements were met and that each payload was ready for launch. Defining roles, responsibilities and relationships is the key to this process and will be discussed in detail. Management's role, the payload providers' role and the role of the customer (JPL) are fundamental to success and will also be addressed.

SESSION 3: RISK MANAGEMENT IN THE FASTER, BETTER, CHEAPER TEST ENVIRONMENT

RISK ACCEPTANCE v RISK MANAGEMENT

Andrew H. Quintero, Julia D. White, Michael La Grassa, and Douglas D. Chism
The Aerospace Corporation

Michael N. Lovellette
Naval Research Laboratory

Testing of space vehicles is an expensive and time-consuming process. Risks encountered during the design, development, integration and test of these systems must be assessed in terms of on-orbit mission impacts. Numerous studies and failure investigations from on-orbit experiences continue to support and emphasize the need for these complex systems to be tested in a flight-like environment. The pressure to reduce and eliminate various tests is an on-going challenge. The balance between cost, schedule and risk is dynamic in nature since vehicles that are truly representative of a production product are rarely produced. Each vehicle must have the testing decisions based on technical considerations weighed against cost and schedule impacts. In this paper, the objectives of testing is discussed from a risk perspective. Using the Space Test Program (STP) Advanced Research and Global Observation Satellite (ARGOS) as a case study, specific experiences encountered during the integration and test phase is used to illustrate key concepts for consideration in any program. In addition, other examples is folded in from the more expansive knowledge base, typically captured in The Aerospace Corporations Space Systems Engineering Database (SSED). The intent of this paper is to show that substituting risk acceptance (can we get away with it?) for risk management (can we live with the results?) is indeed risky and usually not acceptable.

WHAT ARE THE HUMAN LIMITS TO A "FASTER, BETTER, CHEAPER" MANAGEMENT APPROACH?

David C. Johannsen
The Aerospace Corporation

Managing the risk of executing a "faster, better, cheaper" program must begin with determining if "faster, better, cheaper" is even an appropriate approach to accomplishing the goals of a program. A potentially relevant consideration is that humans are capable of maintaining informal social networks of no more than 150 to 200 people. This means that while groups of people (towns, businesses, religious congregations, even military fighting units) of this size or smaller can be maintained primarily through mutual interaction, larger groups necessarily require an increasingly hierarchical (read bureaucratic) organization to function. Assuming that the same holds true for the core team working an aerospace program, and using four aerospace-industry bodies per million program dollars per year, an program organized around mutual interaction could not exceed about $50M per year. Any program with goals that require a larger effort than this--be it due to a technical scale, the complexity of necessary interfaces, or other causes--is unlikely to succeed without a hierarchical management structure. The need for some level of

bureaucratic "inefficiency" in the management of large programs appears to be an inevitable result of innate human limitations.

APPLYING THE TEST LIKE YOU FLY PRINCIPLE

D. L. Shelton and S. C. Roskie
Lockheed Martin Space Systems Company

The "Test Like You Fly"(TLYF) principle is a key test philosophy to be factored into the test program definition phase of a product's life cycle to ensure mission success. The basic principal is "No function, environment or stress should be experienced by a product for the first time during its mission". This paper provides guidelines and a process for applying this principle, including the criticality of identifying TLYF exceptions, how to mitigate the mission risk associated with the exceptions, and the challenge of dealing with the "Faster, Better, Cheaper (FBC)" driven cost and schedule constraints in relation to TLYF. The paper also addresses a concept for factoring the TLYF principle into retest decisions associated with the processing of a test anomaly. Other considerations and myths are also identified to further assist in the application of the principle. In conclusion, recent TLYF preventable mission failures are used to emphasize the importance of the principle to mission success.

CONSTRUCTION & ACTIVATION OF A CENTAUR HIGH ENERGY UPPER STAGE FLUID SYSTEMS INTEGRATION LAB

Jack Schlank
Lockheed Martin Space Systems Company

A high-energy upper stage fluid systems integration lab (SIL) has recently been constructed at the Lockheed Martin Astronautics (LMA) facility in Denver, Colorado. Built at the Engineering Propulsion Lab (EPL), the facility is centered around a flight-like Centaur cryogenic upper stage. The vehicle is housed in a test cell that provides liquid propellants and high-pressure gases in a manner similar to what is done at the launch pad. This unique facility is a tool to reduce technical risk for the Atlas family of launch vehicles with "Test Like You Fly" capabilities. The Fluid SIL also provides a means to reduce costs by allowing for the demonstration of new products and process improvements off of the launch complex critical path. Schedule time spans are also reduced with the ability to conduct procedure validations, personnel training and various investigations off line of the production flow.

MANAGING RISK FOR THERMAL VACUUM TESTING OF THE INTERNATIONAL SPACE STATION RADIATORS

Jerry A. Carek, Duane E. Beach, and Kerry L. Remp, NASA Glenn Research Center

The International Space Station (ISS) is designed with large deployable radiator panels that are used to reject waste heat from the habitation modules. Qualification testing of the Heat Rejection System (HRS) radiators was performed using qualification hardware only. As a result of those tests, over 30 design changes were made to the actual flight hardware. Consequently, a system

level test of the flight hardware was needed to validate its performance in the final configuration. A full thermal vacuum test was performed on the flight hardware in order to demonstrate its ability to deploy “on-orbit”. Since there is an increased level of risk associated with testing flight hardware, because of cost and schedule limitations, special risk mitigation procedures were developed and implemented for the test program. This paper introduces the Continuous Risk Management process that was utilized for the ISS HRS test program. Testing was performed in the Space Power Facility at the NASA Glenn Research Center, Plum Brook Station located in Sandusky, Ohio. The radiator system was installed in the 100-foot diameter by 122-foot tall vacuum chamber on a special deployment track. Radiator deployments were performed at several thermal conditions similar to those expected on-orbit using both the primary deployment mechanism and the back-up deployment mechanism. The tests were highly successful and were completed without incident.

PREDICTING THE TIME TO PERFORM SATELLITE LEVEL TEST

Bruce Arnheim,
The Aerospace Corporation

A cross-program timeline study was performed to investigate and model the key factors that influence the time required to complete satellite level testing. The study looked at 57 programs that are first in their build series or block purchase. Over 40 spacecraft characteristics from these 57 programs, such as mass, power, and mission type, were used as independent variables to predict spacecraft level test duration. The modeling approach diverges from traditional techniques popular in cost modeling and the results provide some unique insight into the prediction and factors influencing test time. These factors can assist test planners in identifying the characteristics that distinguish faster better cheaper programs and help anticipate risks associated with test scheduling.

PRODUCTION DEFECT PRECURSORS TO ON-ORBIT SATELLITE ANOMALIES

A.V.Rubin
Lockheed Martin Space Systems Company

This paper examines commonly recurring manufacturing defects in satellites that manifest themselves as early flight failures. A recent review of flight performance data reveals that a significant number of such failures are due to a small number of root causes. The paper evaluates the precursors to major failures and process control measures, which in conjunction with acceptance tests, reduce on-orbit anomalies.

Although primarily focused on near earth orbit satellites, the findings can be applied to other flight systems such as launch vehicles and missiles. The data was compiled from Lockheed, Martin Marietta, GE/RCA and other aerospace heritage programs.

SESSION 4: INTEGRATING TEST, MODELING, AND SIMULATION FOR BEST VALUE

USING TEST AND ANALYSIS TO DRIVE DESIGN

Mary Baker
Advanced Test and Analysis Engineering, Inc. (ATA)

Eliminating tests can greatly increase the risk in programs. The goals of NASA and other agencies in suggesting that tests be eliminated can be best be achieved by better integration of test and analysis with design. Strategic use of test early in the program can make analysis effective at guiding design. Integration of test and analysis with design is the key to higher performance at lower cost, time, and risk. Project examples illustrate the importance of doing early testing and the role of analysis and test to drive design.

ENVIRONMENTAL TESTING PHILOSOPHY FOR A SANDIA NATIONAL LABORATORIES' SMALL SATELLITE PROJECT – A RETROSPECTIVE

Jerome S. Cap
Sandia National Laboratories

Sandia has recently completed the flight certification test series for the Multi-Spectral Thermal Imaging satellite (MTI), which is a small satellite for which Sandia was the system integrator. A paper was presented at the 16th Aerospace Testing Seminar discussing our plans for performing the structural dynamics certification program for that satellite. Our testing philosophy was originally based on a combination of system level vibroacoustic tests and component level shock and vibration tests. However, our plans evolved to include computational analyses using both Finite Element Analysis and Statistical Energy Analysis techniques. This paper will outline the final certification process and discuss lessons learned including both things that went well and things that we should/could have done differently.

MODEL AND TEST EFFECTIVENESS STUDY IN EUROPE: INTERIM RESULTS

Piero Messidoro
Alenia Spazio S.p.A

Manfred Bader
Astrium GmbH

Raymond Roumeas
ESA/ESTEC

A Model and Test Effectiveness Study (MATES) is in progress under European Space Agency (ESA) contract since November 1999. It is the first time that the European Space Community is carrying-out a coordinated effort to collect and investigate verification and test data of the completed projects in order to improve the effectiveness of ESA Model and Test Philosophies

and to derive lessons for the future. This paper summarizes the study interim results and anticipates its next steps and relevant expectations.

DAMAGE-BASED ANALYSIS TOOL FOR FLIGHT VIBROACOUSTIC DATA

S. Rubin
Rubin Engineering Company

A method is described for transforming highly nonstationary vibroacoustic flight data to an equivalent stationary test definition based on damage potential. An extended single-degree-of-freedom response spectrum is employed, involving the counting of response amplitudes. Peak response and fatigue potential are considered, including uncertainties in damping and fatigue exponent. The approach replaces the maximax spectral method that can yield grossly over-conservative spectral peaks due to brief bursts of strong oscillation in the flight data. An example is presented using a vibration measurement acquired on seven Titan IV flights, using wide uncertainties in Q of 10, 20, and 40 and in fatigue exponents of 4, 8, and 12. The maximax spectra were as much as 8 dB too high.

SUPERSONIC TURBINE NOZZLE FLOW MEASUREMENTS

T.V. Ferguson and R.D. McGlynn
The Boeing Company; Rocketdyne Propulsion & Power

An accelerated test program to measure the flow field of a rocket engine supersonic turbine nozzle assembly was successfully executed using gaseous nitrogen (GN2) as the fluid medium. Flow field measurements were made with a conical 5-hole pressure probe and attempted with a laser-2-focus (L2F) laser velocimeter. In addition, the first stage turbine rotor was instrumented for static pressure measurements and with strain gages to ascertain blade loads as well. Data were collected in an effort to anchor computational fluid dynamic (CFD) codes describing the flow interaction between the nozzles and the rotor. The test program was characterized by the interplay between economic forces, time constraints and the engineering pursuit of data.

A NEW PREDICTIVE METHODOLOGY FOR LAUNCH VEHICLE FILL FACTORS

Patricia A. Manning
Cambridge Collaborative, Inc.

This paper will introduce a new fill factor prediction methodology that accounts for complex payload shapes. The 1994 NASA standard is based on a cylindrically shaped payload, but realistic payload shapes are often much more complex. The new technique enables calculation of the spatial distribution of fill factor levels, so that correlation with test data can be much more accurate and predictions of the acoustic environment can be more localized. The new technique calculates a frequency-dependent fill factor that accounts for axial and circumferential variations in the radius of the payload. A local volume is used to calculate the percent volume filled, with a length equal to one half of the acoustic wavelength. The new methodology is demonstrated for a Titan IV fairing with a Cassini spacecraft inside.

TEST-BASED SIMULATION BRIDGES THE GAP BETWEEN TEST AND CAE FOR SPACECRAFT VIBRO-ACOUSTICS

Clifford Kaminsky
Vibro-Acoustic Sciences, Inc.

Gerard Borello
InterAC

High frequency response of small payload equipment submitted to highly transient events is difficult to predict at a reasonable cost using standard finite element (FE) computation. Worse, FE models cannot be accurate at high frequencies as the short-wavelength vibrational behavior is not predictable using a deterministic approach. As an alternative, statistical energy analysis (SEA) can easily model the averaged modal behavior of the equipment.

SEA is generally used for steady-state problems due to the inherent steady-state hypothesis in the theory. A technique called "virtual modal synthesis" (VMS) can be used to approximate the transient response of a system modeled with SEA. Also, analytical modeling of complicated structures and junctions can be time-consuming and research-intensive. For this reason it is sometimes advantageous to combine analytical SEA with experimental SEA and FE techniques for more complicated geometry.

In this project, analytical and experimental SEA are combined with FE and virtual modal synthesis (VMS) to predict the unsteady time response of an electronic payload component.

OBJECT ORIENTED APPROACHES TO FASTER, BETTER, CHEAPER TESTING

Daniel Charles McShan
Syzygyx, Incorporated

This paper will evaluate object oriented approaches to spacecraft simulation and testing for the Mars 98 and Mars 01 programs and consider new approaches for our Mars 03 testbeds. The object oriented design philosophy lends itself well to the better-faster-cheaper philosophy of spacecraft design. As better-faster-cheaper programs reuse spacecraft components, a well-modeled test environment reuses software objects to test or simulate these components. Although the design of object-oriented systems does imply a larger initial effort, the effort pays off in the reusability of objects for future programs, making them even better, faster, and cheaper. As better-faster-cheaper programs evolve and improve, it will be necessary to have an object-based infrastructure to efficiently accommodate the multitude of components and the increasing flight processing and science demands. An approach for a distributed object environment for general testbed development for Mars 03 and future better-faster-cheaper will be presented. This environment takes full advantage of the object-oriented methodology and will implement a component architecture throughout the design utilizing C++, CORBA and Java technologies to realize the object relations.

SESSION 5: TESTING METHODOLOGIES, INNOVATIONS, AND CHALLENGES IN THE FBC ENVIRONMENT

INTENSIVE RATE SATELLITE PRODUCTIONS: A CLEAR SUCCESS IN THE RECENT PAST, AN AMBITIOUS CHALLENGE FOR THE NEXT FUTURE

A. Casola – A. Iannarelli - A. Pullara
Alenia Spazio – S.p.A.

Nowadays space system Assembly, Integration and Testing (A.I.T.) is more and more approaching intensive production demands. Tens of satellites have to pass through the A.I.T. process satisfying high production rate needs without decreasing the high-tech and high-quality requirements.

Alenia Spazio (ALS) fulfilled this very challenging objective in the frame of the Globalstar program. During the past three years, Alenia Spazio has been involved in the Globalstar program: the ambitious goal of delivering 64 LEO satellites in about one and half year has been fully hit.

The intensive rate production has been approached and successfully solved in the new Small Satellite Center in Rome where A.I.T. of 64 satellites has been carried on in parallel with A.I.T. of S_Band and L_Band antennas (64+64) included in the Globalstar payload. A final balance of this experience is described in this paper together with the main results of the lesson learned.

Moreover Alenia Spazio is already looking forward to the next future challenges. The lesson learned together with the need to fulfill more stringent requirements will define the future approach to satellite production, starting from the new generation of Globalstar program (8 satellites will be produced during this year). This paper describes the innovations and improvements that will be implemented in the high rate production A.I.T. flow.

THE MICROTEST METHOD TO ADDRESS TEST CYCLE TIME REDUCTION FOR INCREASED COMPLEXITY SPACECRAFT REQUIRING MULTIVARIANT TESTING.

M. Michelson
Lockheed Martin Space Systems

Unavailable at press time.

X-38 COST REDUCTION THROUGH EARLY TESTING

Bruce H. Wendler
The Aerospace Corporation

The International Space Station X-38/Crew Return Vehicle (CRV) project has used a modified “rapid prototyping” approach to produce a lifeboat for the International Space Station for

medical and emergency evacuations. The rapid prototype approach involved testing progressively higher fidelity models to mature requirements, concepts, and design simultaneously instead of sequentially as done in most classic acquisition approaches. This allows testing to be introduced into the design and requirement definition phases of the project. To measure true progress and avoid problems seen in many faster, better, cheaper projects, maturity gates and institution of formal project controls were imposed. This approach resulted in a significant cost reduction, when compared to conventional methods, for the non-recurring development costs of the project.

DEFINITION OF ROSETTA THERMAL VACUUM TEST ON THE BASIS OF TEST EFFECTIVENESS CONSIDERATIONS

Paolo Maggiore
Turin Polytechnic

Giacomo Raimondo, Vanna Barboni
ALENIA Spazio S.p.A.

The Rosetta mission is an interplanetary mission whose main objective is to rendez-vous with the comet 46 P/Wirtanen, in August 2011, besides to study some other asteroids. The spacecraft will also carry the Rosetta Lander (Surface Science Package) to the nucleus and deploy it onto the comet's surface to make in-situ measurements. This mission is characterized by a considerable risk level due to its long duration and to its extended hibernation phase of the spacecraft.

This paper deals with test effectiveness design techniques and how these can be used to develop effective system verification processes. In particular the paper discusses how compiled test data are entering test planning decision process of the ROSETTA program (mainly for TV/TC Test).

Furthermore as confirmation of the validity of the approach, the evaluation of the effectiveness of the environmental tests carried out on SAX is presented and discussed.

MULTIPURPOSE DATA ACQUISITION SYSTEM FOR THE SPACE SIMULATION LABORATORY AT LOCKHEED MARTIN ASTRONAUTICS

Larry W. Mason and Paul M. Samar
Lockheed Martin Space Systems

Commercially available hardware and software were used to develop a multipurpose Data Acquisition System (DAS) for control of two Thermal Vacuum Chambers in the Space Simulation Laboratory (SSL) at Lockheed Martin Astronautics. Several different hardware platforms were used, along with associated signal conditioning elextronics. The hardware installation consists of 520 physical I/O points (tags) per system, including 416 individual thermocouples. Each tag represents an individual analog, discrete, or virtual data value acquired from sensors mounted on a spacecraft. BridgeVIEW application software was utilized for development of DAS, run under the Microsoft NT operating system. DAS includes over 120 individual Virtual Instruments (VI's) that were created to acquire, process data, and implement

control functions in the system. The acquired data measures various chamber conditions and parameters on the spacecraft under test, and is used to control temperatures during test operations. Three related versions of the DAS software reside on multiple workstations and servers, and interact through a dedicated 100-BT Ethernet. The software was developed to operate as a stand alone user interface to the system, and includes real time trending and data display applications, historical trending graphs, alarm notification, data post processing, data/picture overlay, and interfaces to ancillary spacecraft and facility systems. All DAS operations are user configurable, with comprehensive control and graphical data presentation during spacecraft tests.

ADVANCED PROTOTYPING APPROACHES - REDUCTION OF COST AND TIME TO ORBIT (ACTOR)

Pietro Giordano
Alenia Spazio S.p.A.

Raymond Roumeas
ESA/ESTEC

Jean-Marc Franzin
ALCATEL Space Industries

Improvement of European Industry competitiveness calls for both reduction of spacecraft cost and development time. Such reduction is mandatory in the commercial spacecraft field, but also in the specific non-commercial fields such as Science missions and application activities. The mechanical and structural design, development and verification/test and the related issues have been identified as one of the major cost and schedule drivers and offenders. The objective of this activity is to review current approaches in the above domains for Telecommunication spacecraft as used today and identify areas in the commercial field where further improvement can be achieved in an industrial context. Not only, but solution adopted in other non-space fields of industry (e.g. automotive, aircraft), need to be considered, at least those which can be effectively implemented in Aerospace As further objective, the above findings shall be extended and adapted for their application to Earth Observation satellites and to Scientific spacecraft. The paper introduces the ESA (European Space Agency) study on above aspects (ACTOR) carried-out by an industrial consortium including Alenia Spazio as prime contractor Alcatel Space as subcontractor and the Polytechnic of Turin as consultant. The results are presented and discussed.

ACOUSTIC AND VIBRATION TESTING OF SPACECRAFT USING A COMMON FACILITY

Hedayat Ullah Hamid
Lockheed Martin Space Systems Company,

Lockheed Martin Space Systems, Missile & Space Operations (LMSS-MS0) new acoustic chamber offers state of the art facility for development, qualification, and acceptance testing of

aerospace equipment and vehicles subjected to high intensity acoustic and vibration environments. The facility abides on the concept of cost reducing scheme and minimum spacecraft testing time and has played a significant part in LMSSC success to deliver quality and cost-efficient products to its customers in a timely fashion. By having a three-axis vibration shaker system within the acoustic test facility, test cycle times of spacecraft have been significantly shortened as compared with other facilities that offer acoustic and vibration testing capability in physically separate facilities. The system operates reliably and saves setup and data acquisition time by using the same data system and acquisition setup.

QUICK BUCKLING STRENGTH ESTIMATE FOR COMPOUND COLUMNS

Leonard Leguizamo, J. Steve Mills, and Walter Tsui
The Boeing Company

Testing of space hardware using Hydraulic Actuators has a long history. However, estimating the buckling strength of a typical loading assembly with rod ends, load cell, piston rod extension, and tailstock connecting to the bottom of the actuator is a cumbersome task. This paper deals with a new method to tackle the challenge of reducing this complicated classical analysis to just charts where the buckling strength of a compound column can be conservatively estimated in minutes. It expands the application of both Euler's and Johnson's formulas from a simple column to a multiconfiguration compound column with various cross-sections in a single assembly. The effect of elastic and inelastic buckling will also be addressed. The content of this paper has been proven recently in the SO of the Space Station test program where 118 actuators were employed. All actuators were checked by this method.

FOLLOW-ON VALIDATION OF FORCE-LIMITED VIBRATION TESTING

Daniel S. Kaufman
Orbital Sciences Corporation

Daniel B. Worth
NASA Goddard Space Flight Center

A second sounding rocket experiment was performed in the summer of 1998 in a continuing effort to validate the force limits techniques used in random vibration tests. The accuracy of the force limiting prediction techniques has not clearly been sufficiently confirmed with in-flight data as of this time. The flight was on board one of the Black-Brant series of sounding rockets. This vehicle is the one most commonly used for sub-orbital scientific payloads by NASA. An aluminum double deck structure simulating a dynamic source and load was flown. The hardware was instrumented with accelerometers and force sensors that measured input acceleration, forces and acceleration responses on the load. Force limiting analysis methods are compared with the flight measurements in order to evaluate analysis predictions methods and test procedures. This sounding rocket flight is the second in a series of flights that will be performed.

ENHANCED COMPUTER CONTROLLED ATLAS PRESSURIZATION SYSTEM (CCAPS) VERIFICATION

R. John Blanyer
Lockheed Martin Space Systems

As part of process improvement in making testing BETTER, CHEAPER AND FASTER, the Factory Test Engineering and Test Tooling departments automated the testing of Computer Controlled Atlas Pressure System (CCAPS) valve panels. Integrating three test tools, the High Flow Measurement Tool, the High Flow Panel, and the Automated CCAPS Tool, coupled with new LabVIEW â software has provided the user a friendly, reliable, and repeatable valve verification process. The superior performance of this improved verification technology has accelerated its application in other test disciplines.

AN INNOVATIVE ACOUSTIC TEST METHOD FOR THE FASTER, BETTER, CHEAPER ENVIRONMENT

Paul A. Larkin
Orbital Sciences Corporation

In these days of Faster, Better, Cheaper (FBC) spacecraft the verification and test program is often sacrificed as an area where significant cost and schedule savings can be achieved. This is because the testing occurs late in the program when budgets have usually been exhausted and very little schedule time remains. Therefore, testing is often eliminated in favor of reduced cost and schedule while accepting the associated increased risk. In particular, acoustic testing is often cut completely out of FBC spacecraft test programs because the cost vs. benefit can not be justified. This paper presents a new procedure for acoustic testing, which is aimed at reducing the test program cost and schedule while still providing a sufficient acoustic test environment to qualify or provide workmanship verification of the assembled satellite. The resulting methodology is able to provide a more attractive alternative that reduces the risk of high frequency vibration failures.

The new test method presented is for direct, near field acoustic testing of spacecraft structures using commercially available sound equipment. The method employs stacks of commercial concert speaker cabinets that surround the test article and are capable of exciting the structure with direct, near field sound pressure levels up to 146dB. The speaker systems are powered by commercial stereo amplifiers and controlled by standard Norsonic acoustic control equipment. This paper will present the equipment, setup and procedures used to provide a complete, portable acoustic test system.

Validation of the approach has been accomplished by comparing test data from direct, near field excitation of a typical spacecraft honeycomb panel with reverberant chamber data. In addition, actual flight article testing has been completed at Orbital Sciences Corporation on the NASA/JPL ACRIM, USAF TSX-5 and the commercial BSAT satellite programs. The results from these tests will also be presented showing acoustic levels and spatial variations achieved.

Finally, a summary of the cost and schedule savings vs. the risks associated with this test method will be discussed.

POSTER SESSION

VIBROACOUSTIC INTELLIGENT SYSTEM FOR PREDICTING ENVIRONMENTS, RELIABILITY AND SPECIFICATIONS (VISPERS)

Kent B. Bradford
The Aerospace Corporation

Jerome E. Manning
Cambridge Collaborative, Inc.

Prediction of vibroacoustic environments for Department of Defense and commercial launch vehicles, as well as spacecraft, is a costly, labor-intensive process. Yet, such analysis is essential to assure reliability of vehicle structures and airborne equipment. The objective of this program is to develop a software package that will use a combination of theoretical and empirical methods to provide, in an automated sequence, a more accurate prediction of vibroacoustic environments as well as less costly, more responsive processing. The software will be user-friendly, provide thorough reporting capabilities, and include comprehensive help utilities. The software framework being developed will also be applicable to shock.

NETWORK SENSOR SYSTEMS -THE PRESSURE BELT APPLICATION

Fernando Gen-Kuong and Bruce Swanson
Endevco Corporation

A Network Sensor System combines two important characteristics: 1) a networking capability and 2) the consolidation of analog signal conditioning and digital signal processing functions at the sensor. The networking function can be very useful for applications where connecting transducers in a multidrop configuration is advantageous. It can significantly reduce the number of interconnecting cables required. Consolidating the signal processing functions at the sensor results in system cost reductions, high reliability and improved performance. One application of the Network Sensor System is the Pressure Belt, providing multi-point pressure measurements using low profile transducers and electronics attached to a uniquely configured belt. The Pressure Belt was designed for Flight Load Testing applications to measure air pressure across wings and other aircraft surfaces. It replaces traditional flight test pressure measurement systems that require the installation of hundreds of air tubes and channels of analog signal conditioning and data acquisition equipment. In parallel with the Pressure Belt development, a family of Network Sensors (sensor + electronics) and interface modules (electronics only) are being developed to allow a variety of different sensors to interface to a common network bus.

APPLICATION OF A MICROELECTRONIC THERMAL IMAGING SYSTEM TO MEASUREMENT OF THERMAL RADIATION FROM A LAUNCH VEHICLE NOZZLE

Robert Ferro, Gloria To, Patrick Yee, Tony Hsieh, Howard Deacon
The Aerospace Corporation

Infrared microscopy is a well-known technique for measuring temperatures on microelectronic components. An infrared microscope designed for this application was used to measure the emissivity of the material in a launch vehicle engine nozzle extension, at a variety of aspect angles. The result was more accurate knowledge of the emissivity of the nozzle material at glancing angles than could be obtained with an emissometer, which is the conventional method of measuring material emissivity. The emissometer, while accurate, is not well suited to measurements at high aspect angles. The information obtained from these tests was valuable because sensitive electronic systems are mounted at the aft end of the launch vehicle, where they are exposed to thermal radiance from the nozzle. The nozzle material is niobium coated with a thin silica-alumina layer. The results helped to explain a discrepancy between theoretical calculations of radiance and calorimeter measurements made during flight. They also helped to assure that the launch vehicle would perform reliably. The work demonstrated that an instrument intended for microelectronic temperature measurement could be applied to measure launch vehicle thermal properties. Using capabilities developed for one technical area to obtain results in another enables faster, better and cheaper test problem solutions.

DESIGN, DEVELOPMENT AND TEST OF A GRAPHITE EPOXY STRUT FOR USE IN A LAUNCH VEHICLE PAYLOAD TRUSS ADAPTOR

M. Dew, M. Smith, D. Johnson, and P. Nefelbeek
Lockheed Martin Space Systems; Alliant Techsystems

Unavailable at press time.

AN OVERVIEW OF THE USE OF THE LASER DYNAMIC RANGE IMAGER (LDRI) FOR MEASUREMENT OF SPACE STATION STRUCTURAL DYNAMICS

George H. James III
ETM, Inc.

The International Space Station (ISS) represents a unique structure that has a high density of ultra low frequency modes, sparse instrumentation, on-orbit construction, and the need for validated models. To allow the measurement of large uninstrumented sections of this structure, NASA-JSC, Sandia National Laboratories, the University of Houston, and ETM, Inc. have recently developed the hardware and software needed to acquire these measurements in a non-contact fashion. The hardware system is called the Laser Dynamic Range Imager (LDRI). This system uses diffuse modulated laser illumination coupled with an intensity modulated video receiver to produce video and range images. The resulting data produces displacement time

histories at each of 250,000 active pixels from the range as well as the two cross-plane directions.

The analysis software developed to process this data must provide tools to perform the seemingly diverse functions of image processing, spatial calibration, range extraction, point tracking, digital signal analysis, coordinate transformation, and traditional modal analysis. The hardware and software are nearing completion. Ground-based testing has provided significant opportunities to verify and develop the sensor and analysis products. The system is scheduled to be exercised on-orbit as part of ISS assembly flight 4A in December of 2000.

FAILURE MODE VERIFICATION TESTING (FMVT ®) USING A NEW 6-DOF TESTING MACHINE

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Entela Engineering & Testing Laboratories

This paper will describe a method of performing accelerated vibration tests using a pneumatic testing machine developed to expedite design verification. The concept and the machine are presented as a possible tool to be used by engineers to verify new designs, and discover non-intuitive failure modes prior to releasing the design for production.

The theory of operation and performance parameters of the machine will be discussed. Examples of designs that were tested on the machine will be demonstrated, along with the failure modes that were discovered.

A GOVERNMENT ALLIANCE TO IMPROVE MANAGEMENT AND UTILIZATION OF NASA AND DoD SPACE ENVIRONMENTAL SIMULATION CHAMBERS AND ACOUSTIC TESTING FACILITIES

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National Aeronautics and Space Administration

Gary R. Mattasits
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In January 1998, the three Service Acquisition Executives for the Department of the Army, Navy and Air Force, and the NASA Deputy Administrator, signed a memorandum of agreement setting up an Alliance for Space Environmental Simulation Facilities. This Alliance is chartered with shaping the government's test capability to efficiently meet national needs through intra- and inter-agency cooperation. The purpose is to increase cooperation, efficiency improvements, and mutual benefits by leveraging coordinated planning, acquisition, improvement, maintenance, and test facility operation. This paper describes the mission, organization and accomplishment of this Alliance with regards to both government and commercial Space Environmental Simulation Test Facilities.

USING MSC/NASTRAN AND LMS/PRETEST TO FIND AN OPTIMAL SENSOR PLACEMENT FOR MODAL IDENTIFICATION AND CORRELATION OF AEROSPACE STRUCTURES.

Tom Van Langenhove, Marc Brughmans
LMS International

As time-to-market also in aerospace begins to play a crucial role, accurate predictions and simulations of the behavior of new structures based on analytical models become more and more important. A modal identification must be performed to obtain modal parameters which can be compared with the pre-test analytical results using correlation techniques. Based on the outcome of the correlation analysis, the analytical models must be 'updated' such that they more accurately predict the actual test results. Since often the time is lacking to validate each component separately, it is a great challenge to define an optimal sensor set for the complete assembly, including internal components. Also, new materials, hyper-new design and not to forget the ever growing model sizes do not make the job more easy. This paper approaches the sensor placement problem from the standpoint of the structural dynamicist who must use the modal parameters obtained during a ground vibration, or eventually an on-orbit test, to perform a test-analysis correlation and updating analysis. The paper also explains which tools are available to make his life easier. A good choice is crucial not only for experimental observability of the dynamic behavior of the structure, but also for the accuracy of the reduced matrices (for orthogonality calculations). Eventually it will help also the modal analysist during his tests and it will make the (often-difficult) geometric correlation obsolete.