INSTRUMENTATION – MAKE IT COMMON

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ABSTRACT

The Hardened Subminiature Telemetry and Sensor System (HSTSS) is a model program; executing Department of Defense (DoD) initiatives, such as Acquisition Reform, Industry Partnering, and the use of Integrated Product Teams (IPT). The HSTSS is partnering because the unique expertise needed for the high g instrumentation system is spread across industry and the Government. The approaches used to reduce risk in the development of instrumentation systems will be described. Also technical strategies will be addressed. In this paper a discussion about the affect that the IPT process has had on HSTSS to make the program successful. This paper will describe the strategy used to leverage existing technologies, processes, and to market the components that has been developed. The information presented here will address how partnering and the use of commercial technology will reduce the program costs as well as the unit cost. The importance of working together within the Services and sharing funds and technology to accomplish more with less will be addressed. This paper will address how we are delivering a low cost, miniature, high-g (100,000 g's), and modular instrumentation system. This instrumentation is to be used for indirect fire and direct fire projectiles and small missiles. The building blocks for this instrumentation system include batteries, transmitter, pulse code modulation (PCM) encoders, and a variety of sensors (pressure, spin rate, etc.). Instrumentation requirement for HSTSS is to collect data from launch to impact.

KEY WORDS

Commercial Technology, Partnering, Building Blocks, Integrated Product Teams

INTRODUCTION

An IPT under the HSTSS project is having instrumentation systems developed that will allow the Government to test weapon systems that are being delivered to the field. Quantities to be tested are usually limited in number because of the unit cost per test sample and the test budget, so the Government market is not sufficient for industry to commit their own limited resources. This results in an instrumentation system that is one of a kind and is expensive and non-reusable. In order to reduce the cost and risk, the focus for HSTSS has been on commercial technology and leveraging this technology. The HSTSS Project has made effective use of the IPT process and partnering. The IPT has selected the building block method for developing the instrumentation to satisfy the tri-

Service needs of HSTSS. This also reduces the affects of obsolescence and allows ready insertion of advanced technology. It is important for Government leaders to realize that because of the limited resources available, different activities and services must team together. If the activities and Services try to maintain individual programs, they will end up duplicating efforts. The HSTSS has been successful in leveraging and working with other programs to help meet their requirements and reduce duplication. Competition between services has been detrimental because information is not shared and efforts are duplicated.

BACKGROUND

The HSTSS project was started in 1992. This project started off as an Office of the Secretary of Defense (OSD) sponsored Test Technology Development and Demonstration (TTD&D) program. It has transitioned into an OSD Joint Improvement (JIM) program. The HSTSS is a low cost, microminiature, high g (100,000 g's), modular instrumentation system. The HSTSS instrumentation will be used on projectiles and small missiles, which will allow measurements to be made on board during flight. Data will be collected from launch to impact. The limiting factors in the design of the HSTSS instrumentation are the package size and the high-g environment. Because the size and shape of the space available for instrumentation varies, the tri-Service users wanted a modular/component design so that each user could repackage the system to meet their particular needs, especially the volume constraints. During flight, accurate data can not be collected with present systems. Present systems are too large. During the early phase of HSTSS, it was determined that the hardest component to shrink would be the battery. After much market research, it was decided that most battery manufacturers were not interested in taking on a development project because in test instrumentation there was a limited market. Most manufacturers want quantity buys in the thousands per month, not ten. One company was willing to work with U. S. Army Research Laboratories (ARL), Weapons and Materials Research Directorate, and through this effort we now have a battery that withstands 100,000 g's and can be configured to the subminiature package (less than a cubic inch) without taking up all the space. From the experience of the IPT on other instrumentation development programs, it was decided that HSTSS should be developed as a modular/component system. The modular/component design is a building block design so systems can be configured to fit the different space requirements (from .5 cubic inches to 13 cubic inches). This way we could develop individual building blocks to allow HSTSS to be geometrically flexible and easily adaptable to latest technology, as it became available. The modular/component design makes HSTSS more adaptable to meet the different configurations needed by the three Services.

DEVELOPMENT STRATEGY

The strategy for HSTSS is to contract out the development of the individual technologies or building blocks. After the delivery of these building blocks the Government would prototype instrumentation systems to meet a number of different requirements. The prototypes would be limited to quantities no greater than fifty. When test quantities grew large enough, an integration/production contract would be competed. The component cost is greatly reduced because the technology is commercially available and the components could be fabricated with very little development. As stated previously the technology driving parameters of the system are the requirement for high-g and microminiature size. The HSTSS has led the way using acquisition reform and streamlining in our acquisition process. The IPT has been innovative and works hard to reduce the award time and utilize the electronic media.

PROGRAM MANAGEMENT

With the increasing sophistication of munitions and small missiles, instrumented flight tests are necessary to reduce development costs. However, in the case of small or relatively inexpensive systems, instrumented flight tests are often not made due to anticipated or presumed high cost of measurement systems. Because the cost of instrumentation is high and in most cases the instrumentation is not recoverable, the cost of testing can be high. The DoD and the Army provide the funding for this project. The project is to develop and demonstrate a new generation of high-g (100,000 g's) telemetry technologies. In the beginning the HSTSS strategy was to have a prime contractor as the integrator for the HSTSS components. Because it did not work out that way in the initial request for proposal (RFP), the IPT decided that the building block approach at the component level would be the most effective strategy. The IPT had based this decision on the past experience from projects where the components could not be separated and therefore the project succumbed to obsolescence, could not be maintained, and was not used. The building blocks were divided into the transmitter, power source, encoder, and sensors. Contracts were awarded for the building blocks. When the building blocks are delivered the Government will integrate them into prototype systems for specific test instrumentation needs. During the development of the building blocks, HSTSS has been able to take advantage of the latest technology and incorporate this technology into the building blocks. These products will be made available to the test community (Ref 1). The acquisition strategy is obviously driven by the need for inexpensive, microminiature and high-g instrumentation modules/components. If instrumentation is to be inexpensive it needs to come from commercial technology. Transmitters that cost $5,000 will be less than $1,000. If program costs are to be reduced we need to leverage other programs and work the three Services as a super IPT. Managing programs to develop test and evaluation instrumentation is a challenge today because the Government does not buy sufficient quantities to control the market. This is an important reason the Government must not duplicate effort and why the three Services have to work together so we leverage the quantities and combine them into one market. This still does not create a market as large as the commercial market, but it will help. We need to utilize commercial technology. Companies will not invest resources in a program that does not have a future market place to make them sufficient profits. It is the commercial technology that controls the market place and is highly profitable because of the quantities sold. Automobiles, cell phones and wireless internet are a few examples where the quantities being purchased are high and the profits are also high. These are also the industries that have products similar to our instrumentation needs, such as sensors and transmitters. There are two paths we can take to be able to work with industry and make it profitable for them. First, we can take existing commercial technology and adapt it to our needs. Second we can develop something to meet our needs and show industry that there can be a commercial market for that technology. In our case, the transmitter manufacturer is adapting his cell phone technology to meet our needs because he feels when our product is developed he can use this same technology for other commercial applications. The HSTSS can only be a success if commercial technology is considered in the modules/components being developed under this program. The critical aspect of

HSTSS, which was stated before, is that the instrumentation is not recoverable and therefore the cost must be kept at a minimum.

Key management tools, which have been used successfully, are the IPT, leveraging technology being developed by other activities, and searching out and using commercial technology. In today's market a Program Manager has to be smart enough to follow the trends in the commercial market and utilize that technology to meet the needs of the program.

COMMERCIAL TECHNOLOGY

Under the HSTSS program, commercial technologies are needed to meet the tri-Service requirements. In some cases commercial technologies would not fulfill the needs, such as in size, power requirement or high-g environment. It was concluded early that the commercially packaged transmitters available would not fit the requirements for many of the HSTSS integration efforts. Components were not available from the commercial transmitters to meet our requirements. Because the components were not available the HSTSS IPT awarded a contract to develop a transmitter chipset. The chip sets include voltage controlled oscillators (VCO), amplifiers, and phase locked loops (PLL). This product is being delivered with various levels of packaging, allowing greatest flexibility. The various levels include bare die, packaged integrated circuits, and complete modules. Ultimately this offers the designer the latitude to use the product in small or large volumetric applications. When this contract was awarded there were no commercially available components to meet the size and power requirements. Now there are components, such as VCO, amplifiers, and PLL on the commercial market that will meet the majority of the HSTSS requirements. Because we took the building block approach we can integrate the HSTSS components with any of the components on the market. The market expansion into the 2.4 GHz frequency has helped HSTSS since the frequency for the HSTSS transmitter is very close to the commercial frequency.

In the past on many programs, including HSTSS, the only way to meet the size and power requirements were to go to a traditional application specific integrated circuit (ASIC) development solution. Recent advancements in commercially available programmable chips are allowing non-development ASIC solutions to be achieved. Technology driven markets, such as the wireless handset, have given light to new chip developments. Many new programmable logic device chips are being made available that contain digital and analog circuitry. This new circuitry potentially eliminates the need for separate blocks of analog and digital circuits. Traditional ASIC development is time consuming and is not flexible in terms of modifying the design after the ASIC has been fabricated at the foundry (Ref 2). Significant reductions in encoder development time and cost are being realized by utilizing programmable technologies in lieu of traditional ASIC developments (Ref 3). The HSTSS has looked at several commercially available programmable chips to meet a PCM encoder requirement.

It is important to ensure that the ASIC design is properly implemented, because it will save both time and money. Performing simulations on the circuitry to check electrical and layout characteristics is usually the only method to verify the design. However, knowing the parameters to model, selecting tools, model generation, and validation is time consuming by itself. After performing this phase, the designer may find out that some of the assumptions were not correct, causing a modification or simulation redesign. Another way to validate the design would be to use programmable chips to implement a design and provide confidence that the ASIC design will function as expected. The commercial market is recognizing the cost effectiveness of using programmable devices to meet small quantity needs, and also to verify ASIC designs for large quantity needs. Because of this, the market has expanded in the area of programmable devices.

The HSTSS has evaluated a 4-channel PCM encoder on a projectile and an 8-channel PCM encoder on a missile/rocket; both based on a field programmable gate array (FPGA) chip. The encoder modules were developed as risk mitigation efforts under HSTSS, but were soon found to be very practical and useable. The encoders were used as an example to see how the FPGA chips would survive and operate in high-g applications. To meet the size requirement the FPGA chip was required to be packaged on the module as a bare die. Additional HSTSS IPT efforts are being based on complex programmable logic devices (CPLD) and peripheral interface control (PIC) processor chips. These chips are small enough to meet the packaging requirements needed for small volumetric applications and enhanced performance. Several designs are being investigated using both CPLD and PIC processor chips. Initial PIC design concepts have shown that the chip is well suited for lower PCM bit rates, and is capable for implementation of serial data streams. The initial testing of the PIC output PCM bit stream was at a bit rate of approximately 625 Kbit/s, but the PIC is believed to support higher rates. Inputs supported include analog data and digital data (SPI, RS-232, RS-422). Initial CPLD design concepts have shown that the chip is well suited for higher PCM bit rate, and achieving bandwidths of up to 5 Mbit/second. The number of channels and throughput obtained in the PIC and CPLD designs are limited by the selection of A/D converters that meet HSTSS size requirement.

The goal of the HSTSS IPT is to have a family of encoders based on commercially available programmable chips. With the continued expansion of programmable chips in the commercial market, the HSTSS IPT goals will be met.

The HSTSS developed a power source that would exist in the harsh launch environment using the commercial technology that was available. Solid polymer electrolyte, lithium-ion power cells from Ultralife Batteries (UK) were evaluated (Ref 4). The solid-state polymer batteries (nominal 4 V) are rechargeable, lightweight, physically configurable, and environmentally friendly. Cells can be made to almost any user shape or configuration. They can be layered together and connected in parallel and/or series to provide a complete battery system. Ultralife was contracted to modify its commercial cells for the gun-launched environment. Single-cell configurations have survived shock accelerations of more than 110,000 g’s and centrifugal tests at 300 rev/sec, yielding radial accelerations of 24,000 g’s. Primary power cells, available from Ultralife Batteries (US), offer similar form factor characteristics with even higher energy density and have been evaluated for high-g applications (Ref 5).

INTEGRATED PRODUCT TEAM

The major factor contributing to the success of the HSTSS program is the effective way that the IPT has worked together. Because HSTSS is such a large program, it was decided more than just a single IPT was needed. There are six active contracts totaling almost $10 M. There are two universities doing studies for HSTSS. Because of this large consortium, there is not just a single IPT. The IPT process is a valuable asset to HSTSS helping to manage the work. The team is constantly considering the cost and the affects on cost of any change in requirement, and yet they strive for a superior product that can be used by the majority of the participants. Teams are formed as additional projects are added to cover individual applications. It is very rewarding to see the cooperation and unity the HSTSS program has between Services, various activities, industry, and other governments.

The IPT is effective because it brings together a great variety of talent and experience. It also by nature produces a greater networking capability than can be done alone. This process has been responsible for the progress the HSTSS project has made over the past four years. The IPT has been able to make technical decisions and still keep cost and schedule well under control. Everyone is focused on the requirements and how these can be met with the latest technology. The team and HSTSS are continually growing.

CONCLUSION

The HSTSS is a low cost, flexible instrumentation system that will be used on a variety of projects. This is happening because we have a great IPT; we are leveraging other programs, and making full use of commercial technology. Some of the HSTSS components can meet the commercial needs allowing the manufacturer to expand the market, which eventually reduces the unit cost and gives the manufacturer a reason to produce the component. Commercial applications from the cell phone industry has made it possible to design a transmitter around the latest miniature VCOs, power amplifiers PLLs, and crystal oscillators. The use of commercial technology such as FPGAs, CPLDs and PIC processors have made it possible to design encoders with tremendous flexibility. In order to be able to find this technology we must be looking. It has been a total team effort and it has required leveraging other programs and sharing with programs working the same or similar issues. The way to have a successful instrumentation development in today’s arena requires leveraging, IPTs, partnering, and commercial technology.

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