A STATUS REPORT OF THE JOINT ADVANCED MISSILE INSTRUMENTATION PROJECT THE JAMI SYSTEM TAKES SHAPE

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ABSTRACT

Joint Advanced Missile Instrumentation (JAMI), a Central Test and Evaluation Investment Program (CTEIP) initiative, is developing advanced telemetry system components that can be used in an integrated instrumentation package for tri-service small missile test and training applications. JAMI demonstrated significant improvement in the performance of low-cost Global Positioning System (GPS) based Time-Space-Position Information (TSPI) tracking hardware that can be used for world-wide test and training. Acquisition times of less than 3 seconds from a cold start and tracking dynamics to over 60 Gs were demonstrated. The design of a programmable Flight Termination Safe and Arm device has been completed. High dynamic testing results of GPS and Inertial measurement Unit (IMU) devices and problems encountered are discussed. Initial flight-testing of the JAMI components used on the missile and target and the ground processing of the data have been completed. This paper discusses the progress of the program during the past year and the efforts planned for fiscal year 2004.

KEY WORDS

GPS, TSPI, telemetry, flight termination

INTRODUCTION

The JAMI project was initiated in 1997 to address enhancements in missile instrumentation primarily through the introduction of GPS as an improved and worldwide tracking source. The concept of a programmable Flight Termination Safe and Arm (FTSA) device was included as well as the development of sophisticated post mission processing to obtain End Game Scoring (EGS) quality measurements.

JAMI has progressed from a concept, through demonstrated and working hardware, to an operational system and has been integrated onto national ranges in support of missiles and targets.

BACKGROUND

The JAMI system was developed under a spiral development concept in an effort to reduce risk, take advantage of the latest technology available, and in response to the planned project funding allocation. Since the JAMI project included elements of flight safety, TSPI, multiple-band telemetry antennas, and EGS, the government was designated as the system integrator to reduce risk. This approach has its risk however in that the JAMI team is responsible for many of the milestones in supporting weapon programs.

The JAMI program leveraged off technology developed under other CTEIP programs such as the Hardened Subminiature Telemetry and Sensor Systems (HSTSS) project for the high dynamic GPS concept and the IMU sensors needed for the JAMI TSPI Unit (JTU). In addition, the JAMI program investigated the capability of existing flight termination receivers and identified shortfalls in their applications to many weapons.

2003 PROGRESS

The JAMI progress during the past year has been primarily in the area of defining a complete system and integrating all or parts of that system into weapons and ranges. Actual flight hardware was developed to supplement the test bed hardware that had been developed to validate the component specifications. A JAMI System Description and Interface Guide was published that defined all of the range user interfaces between various JAMI components. Range surveys were conducted at White Sands Missile Range (WSMR), Tyndall AFB, and Point Mugu to define range equipment capabilities and interfaces. Extensive testing was done at both the component and integrated system levels.

The JAMI project has some challenging technical goals covering several technologies. The most challenging are shown in Table 1 and include the dynamics and acquisition time of the GPS, the environmental vibration environment, and the production cost goals. The JAMI TSPI requirements were divided into real-time (RT) and post mission processing.

JAMI Design Goals	Threshold	Objective
GPS Acquisition Time	3 sec max	
Attitude Accuracy	5 degree (RT)	2 degree
Velocity	1500 m/s	2000 m/s
Acceleration	40 G	50 G
Position Accuracy	8 meters (RT)	0.5 meters
Velocity Accuracy	1 m/s (RT)	0.1 m/s
Altitude	30,000 meters	60,000 meters
Participants (missile/target)	Four on four	

Table 1 JAMI Design Goals

GPS Tracking Technology- Work continued on the high dynamic GPS tracking technology developed by ParthusCeva. The GPS sensor demonstrated a capability of tracking much higher that the 40 G JAMI objective. The original GPS sensor dubbed the Position Location Sensor (PLS) was refined. Testing revealed that half of the receiver channels were reporting out a psudorange time that was offset form the other channels. This inter-channel bias resulted in several problems. 1- The channels exhibited tracking noise of over 9 meters RMS, 2- Usable carrier phase recovery was not possible using post mission software tools, and 3- very large position biases were observed during simulator testing on the order of 50 meters. These problems were corrected and a new GPS sensor was developed and designated the GPS Sensor Unit (GSU). Testing of the new units indicate that carrier phase recovery is now possible but further tests are needed. A contract was awarded ParthusCeva to develop a custom Application Specific Integrated Circuit (ASIC) to replace the four existing GPS ASICs. This device which is due for delivery in August 2003 will improve performance by reducing the initial acquisition time to less than 3 seconds, reduce the code tracking noise by implementing adaptive tracking loops and reduce power by at least 50% compared to the PLS. As with the PLS, the high dynamic GSU requires a ground processor unit to complete the GPS receiver function and form the GPS output message. This unit has been called either the ParthusCeva ground segment or the ground processor and is the second half of the GPS receiver hybrid concept. A separate ground unit is required for each participant and is part of the JAMI ground processing system.

JAMI TSPI Unit- The JAMI program identified the need for a low dynamic TSPI unit for target applications and a high dynamic TSPI unit for missile applications. The development of the low dynamic unit was considered low technical risk but since the investigation into IMU sensors and processing was still underway, a Creative Research And Development Agreement (CRADA) partnership was solicited between the government and industry to co-develop the unit. After an open advertisement and evaluation of proposed cooperation, Herley Industries was selected as the industry partner responsible for the mechanical design and power design of the unit. The pre-qualification unit is shown in Figure 1. Initial testing indicated the need for some vibration damping material which has been added. Prequalification testing has been completed and qualification testing is planned for summer 2003.

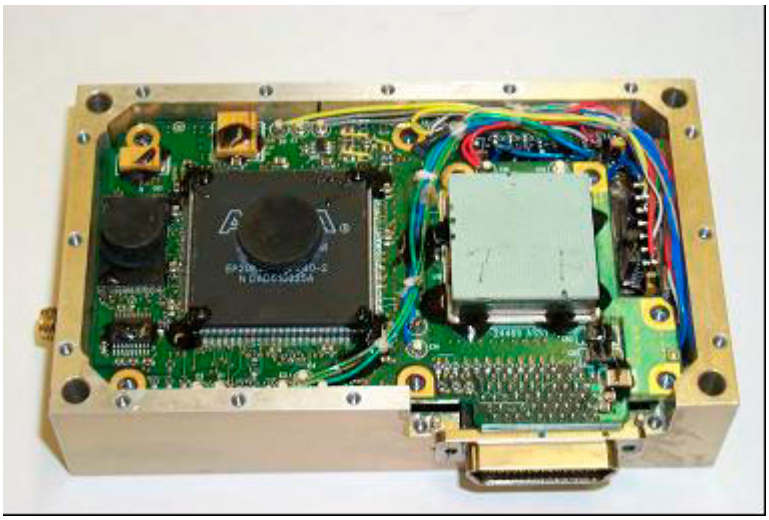

Figure 1 Low Dynamic TSPI Unit

Another goal of the CRADA was the validation of the on-board IMU processing algorithms which process the raw IMU sensor inputs and create accumulated delta velocity and quaternion solutions that are combined with the GPS data and sent to the ground processor in a JAMI developed message structure. The IMU accumulations were designed for robustness of the system in high noise environments where

telemetry dropouts are common. This IMU processing technique appears to be quite robust based on the analysis of the test bed flight data.

Based on the results of design and testing on the high dynamic GSU and the low dynamic JTU, a contract was awarded in May 2003 for a high dynamic TSPI unit for high dynamic applications. The contract is expected to provide flight hardware for missile integration and testing by the summer 2004. Additional improvements to the ability of the high dynamic GSU are planned to increase the carrier phase tracking capability of the unit up to 40 G by creating an aiding file based on the real-time position data and using this file during post mission phase recovery.

JAMI Test Bed- The JTU test bed pods were developed as a way to validate the IMU signal processing and the complete TSPI unit functionality. They provide real flight data to the JAMI Data Processor in the JTU TUMS format. The Advanced Range Data System (ARDS) pods were selected as the independent tracking "Truth" source since they were readily available and were useful for accuracies similar to the JAMI TSPI real-time requirements. Four configurations of test beds were flown, each with carefully selected variations from the previous version. In August 2002, test bed #2 was flown and demonstrated that position and attitude accuracies equivalent to the ARDS system were possible using low cost, miniature components. The test beds also demonstrated the utility of the IMU accumulation algorithms by processing the data during periods of high telemetry noise or drop-out conditions. An example of the JAMI IMU reported roll angle during a GPS dropout verses ADRS data is shown in figure 2.

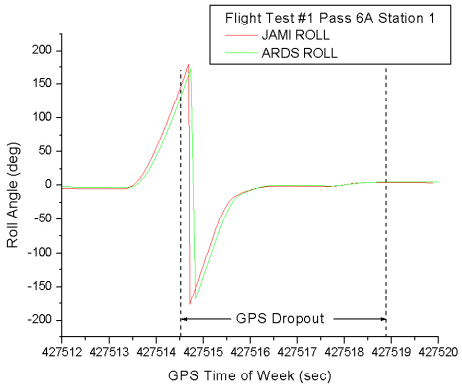

Figure 2 IMU roll verses ARDS

JAMI Data Processor- One of the goals of the JAMI project was to develop low cost components for weapon applications. The goal of the TSPI unit was to be less than the cost of a C-band radar transponder. For the ground station, the original JAMI goal was to field a system that could be installed on a range with a hardware cost of under $12K total for a system that could track four targets and four missiles. For this goal to be met, the unique ground station hardware had to be minimized. Although the final configuration is still under development, it looks like the original cost goal is attainable in that only the ParthusCeva ground processor is required to perform the GPS sensor function on the ground. The ParthusCeva ground processor is a single card that processes the GPS sensor message into a standard GPS message structure. The rest of the JDP hardware consist of a standard rack mount computer with removable hard drive, CD ROM, and standard computer accessories. All of the real-time and post mission software are government owned and controlled and will be made available to the ranges at no cost.

The JDP software supports both real-time TSPI processing and post mission analysis although it is assumed that most post mission analysis will be done on a separate standard Windows PC. A Graphical Users Interface was design for the range operator that displays a large variety of

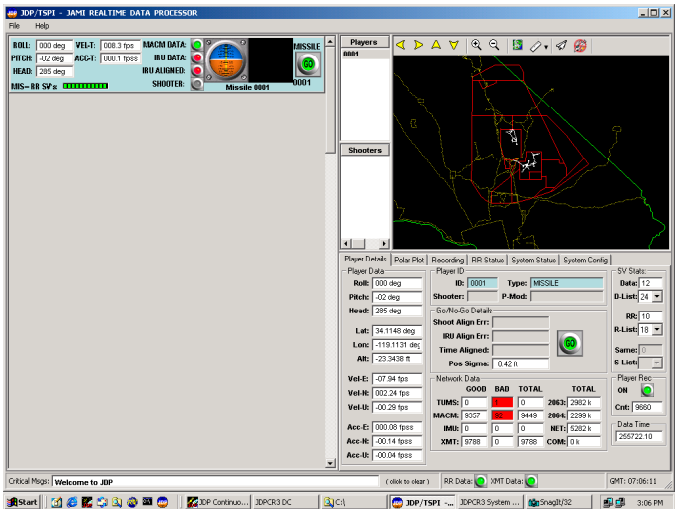

Figure 3 JDP User Screen

information used for setup, operation, and troubleshooting functions. An operator can easily monitor for TSPI quality, vehicle heading and attitude, the number of satellites tracked, etc through the graphics display. A typical display is shown in Figure 3 with only one participant selected as seen in the left box.

The first JDP was installed at NAVAIR Point Mugu to support missile flight testing in December 2002 and used for the first time in March. The second JDP was installed at Tyndall AFB in June 2003. The first end-to-end test of the JAMI system came in March 2003 when both a low dynamic test bed and high dynamic test bed configuration were flown on an F-18. Although several test bed hardware failures were noted that prevented complete data analysis of the TSPI data, the complete system did provide tracking data to the range display boards at China Lake and indicated that the specified range interfaces worked as planned.

Flight Termination Component Development- The JAMI project partnered with industry to increase the capability of existing flight termination hardware during the past year. The JAMI status report in 2002 reported that an effort was underway at the White Sands Missile Range (WSMR) to extend the testing on existing flight termination receiver hardware. This effort is now complete and both the Herley Industries HFTR-060 and the L-3 Conic FTR-925 have completed qualification testing to the JAMI environmental levels. These level are substantially higher than the original qualification levels and demonstrate the rugged packaging technology available in the smallest flight termination receiver technology commercially available. A qualification test report is available from the range safety office at WSMR.

The JAMI project also proposed a Flight Termination Safe and Arm (FTSA) device with the capability of setting the arming conditions at the factory using programmable logic. The qualification testing of this device has been delayed but should be completed by the end of 2003. The unit is less than 10 cubic inches in volume and is shown in Figure 3. Due to the small number of parts required to implement the design, the free flight reliability prediction is greater than .9999 for a 30 minute flight which easily meets the RCC-319 requirements for flight safety equipment. The FTSA design incorporates Low Energy Explosive Foil Initiator technology to reduce the high voltage requirement on the firing circuit.

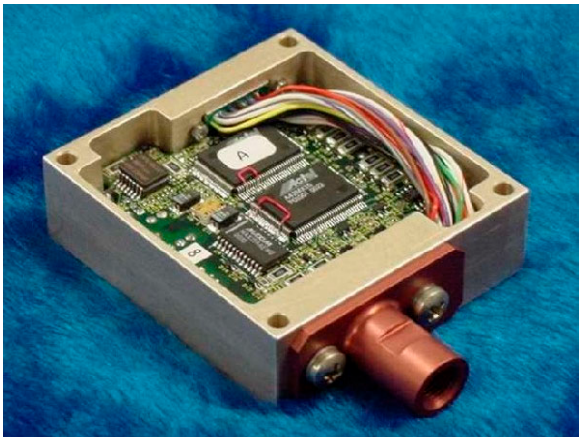

Figure 4 JAMI FTSA

The JAMI project was expanded during the past year to enhance the flight safety operational capability at Tyndall AFB. An automated over-the-horizon UHF uplink will be added to the E-9 range support aircraft. This upgrade will provide the capability to automatically link 400 MHz flight safety signals through the E-9 and on to a missile and is needed on many of the new missiles that are planned for testing at Tyndall AFB. A flight safety upgrade is also planned for the Navy as part of an effort to shift the P-3 range support aircraft capability into the C-130 aircraft platforms.

CONCLUSIONS

All of the major components and modules of the JAMI concept have been demonstrated during the past year. An end-to-end system consisting of the low and high dynamic JTU devices, JAMI Data Processor, range interfaces, GPS reference receiver, range telemetry, Local Area Network infrastructure, and range display boards were demonstrated during missile launches and captive carry flights. Contracts for all of the final JAMI deliverables are now in place with production costs well in line with the JAMI life cycle goals. Further refinement of the ground processing software and validation that specified requirements can be met are the goals for the next year. JAMI has supported flight safety range upgrades both in the air and on the ground. Plans and initial work in support of integrating JAMI components into weapons and targets is underway. The productions cost goals for both flight hardware and range integration are attainable.