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

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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. Actual testing data will be compared with the original system design requirements. Integration of the JAMI components into weapon systems is now underway. This paper discusses the progress of the program during the past year and the efforts planned for the final year of 2005.

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 development of sophisticated post mission processing to obtain End Game Scoring (EGS) quality measurements as well as enhancements to Flight Termination including a programmable Safe and Arm (FTSA) device and extended environment Flight Termination Receivers were included.

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 weapons 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.

2004 PROGRESS

Significant progress has been made during the past year in the areas of high dynamic GPS development and ground processing. Actual flight testing of the JAMI components have demonstrated that the original design requirements of the project are attainable including time to first fix (TTFF) of the GPS tracking hardware, position and attitude accuracy, flight dynamics and packaging constraints. During the past year a contract was awarded for the JTU, the final GPS sensor design was delivered and tested, the safe and arm design was transitioned to production and an improved ground station filter was integrated. These successes were not without their setbacks however and a Test Analyze and Fix workshop was held that brought all of the disciplines together to work on system interface problems.

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 and other system related requirements. Other stringent requirements include the environmental vibration environment, and the production cost goals. The JAMI TSPI requirements were divided into real-time (RT) and post mission (PM) processing.

JAMI Design Goals	**Threshold**	**Objective**	**Demonstrated Results**
GPS Acquisition Time	3 sec max		< 2 sec
Attitude Accuracy	5 degree (RT)	2 degree	~ 5 deg (PM)
Velocity	1500 m/s	2000 m/s	> 2500 m/s
Acceleration	40 G	50 G	> 100 G
Jerk	400 G/s @ 100 ms		> 500 G/s @ 100 ms
Position Accuracy	80 meters (RT)	0.5 meters	< 40 meters
Velocity Accuracy	8 m/s (RT)	0.1 m/s	~ 20 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 JAMI project funded the development of an Application Specific Integrated Circuit (ASIC) that combined the functionality of four GPS receiver ASICS into a single chip. This chip is now fabricated by Samsung and is also used commercially in production GPS receivers. The controller ASIC was combined with an RF ASIC manufactured by Maxim into the JAMI GPS Sensor Unit (GSU) which was delivered in March 2004 and has been tested extensively at Eglin AFB, Florida. Currently the GSU-II, as shown in Figure 1, has demonstrated the ability to acquire more than four satellites from a cold start in less than 2 seconds. It can track to over 100 G in acceleration, 400 G/s for 300 ms in jerk, and track under acceleration down to –167 dBW with a C/No or 33 dB-Hz after acquiring at –162 dBW, C/No at 38 dB-Hz. The unit has been tested to velocities of over 2500 m/s. It consumes about 0.7 watts of power. As opposed to the original HSTSS Position Location Sensor (PLS technology, the GSU-II has two modes of operation, a GPS sensor mode and a navigation or receiver mode. In the sensor mode this unit requires a ground processor unit that completes the GPS receiver function. The low cost ground processor is implemented on a PCI format card to allow for easy integration into the JAMI ground station computer. One ground processor card is required for each airborne sensor so four cards will be needed to meet the JAMI requirement to track four missiles simultaneously. The navigation mode, if selected, allows the GSU-II to operate as an autonomous GPS receiver. In this mode the unit will phase track to at least 25 G of dynamics but requires up to 40 seconds to acquire satellites and download the ephemeris message needed for full navigation. The same ASIC devices used in the GSU have been packaged into a commercial receiver measuring less than 25 mm square compared with the JAMI size of 61 mm square demonstrating the future potential of the technology.

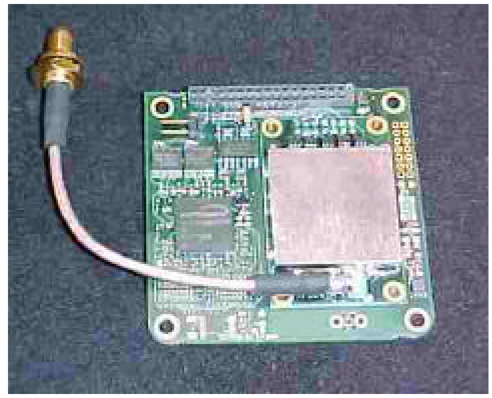

Figure 1 GPS Sensor Unit

JAMI TSPI Unit- A contract was awarded to Herley Industries for the design and development of the high dynamic TSPI unit. The first unit delivered for missile integration is scheduled for July 2004. One of the biggest challenges for the JTU design during the past year has been the optimization of the IMU sensors. Several improvements to the IMU signal conditioning including reduction of sensor noise and scale factor and bias corrections over temperature have significantly improved the performance. The IMU samples are collected at a 1 KHz rate, averaged for 8 ms and added to a running accumulation of delta velocities and delta thetas that have been converted into a single quaternion. The accumulations are samples every 8 ms and combined into a downlink message that is input into the missile PCM encoder at a rate of less than 150 kb/s. The message structure was defined by a separate JAMI specification. The on board accumulation of sensor data was developed to allow the Kalman filter on the ground to track through telemetry dropouts. The technique works very well as demonstrated during several captive carry test events of the system.

The JTU was designed to be easily integrated into a weapon telemetry system using either an asynchronous serial port or a 16 bit parallel port. The maximum bandwidth required is less than

150 kb/s. One of the weapons to use the JTU is also using the event marker inputs to critically time tag events in the missile such as rocket motor fire or fuze arm enable. The JTU is slightly over 13 cubic inches in volume and consumes less than 5 watts.

JAMI Test Bed- The 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 TSPI Unit Message Structure (TUMS) format. The Advanced Range Datalink System (ARDS) pods were selected as the independent tracking "Truth" source since they were readily available and were useful for accuracies higher than the JAMI TSPI real-time requirements. ARDS has a position accuracy of about 1 meter and an attitude accuracy of better than 0.1 degree. Several test bed flights were conducted during the past year. The GPS/IMU data from these flights was processed using the real-time filter and the TSPI solution was output to the range display system at NAVAIR, China Lake. The archived data files were also processed post mission to evaluate the ultimate performance of the sensor. The flight test consisted of nine runs using an F/A-18 aircraft. The runs included a combination of rolls, weaves, loops and turns that generated up to 20 G of acceleration and about 360 degrees per second of angular rate.

JAMI Data Processor- The JAMI Data Processor supports both real-time and post mission data processing and analysis. The JDP consists of a standard PC computer, processing software developed for the JAMI project by the range development department at Edwards, AFB, and up to four ground processor cards provided as part of the GSU GPS solution by Ceva-DSP. The cost goal for the JDP is still $12K per range including the four GSU ground processor cards. The government owned data processing software should significantly reduce the range out-year support costs. The JDP has already been installed and integrated into the range at Point Mugu and will be integrated at Tyndall, AFB in 2004.

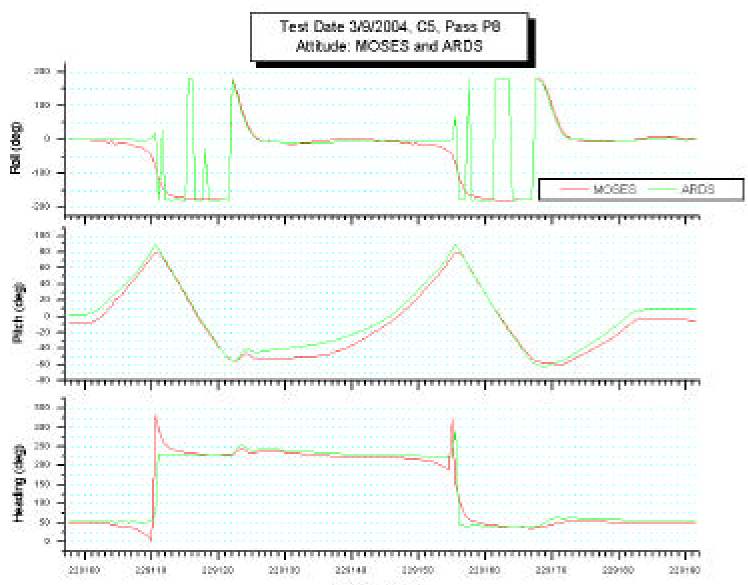

Figure 2. JAMI JDP vs ARDS Raw Attitude

The post mission software used for JAMI analysis is based on the Multi-Optimal Sensor Estimation Software (MOSES) developed for flight analysis at Edwards AFB. This year the MOSES-7 tools were validated and released for production analysis. MOSES-7 has two significant improvements over previous versions. First was the addition of carrier phase tracking to improve GPS position accuracy. The second improvement and big advantage for JAMI was that the MOSES implementation does not require the measurements in the air to be time synchronized with the measurement from the reference receiver on the ground. This was significant for JAMI since the reference receiver has a 100 ms update rate while the GSU is outputting data every 64 ms.

Figure 2 shows the output of the JDP post mission processor attitude verses ARDS for pass 8 of the test flight. This pass is a Cuban-8 maneuver. There is a real 4 degree pitch offset between the test bed plot and the ARDS pod. This plot demonstrates that the goal of attitude accuracy of less than 2 degrees is possible but the filter time delay characteristics between the JDP and the ARDS post processor makes precisely timed comparisons difficult.

Flight Termination Component Development- The primary goals of the JAMI project in the area of flight termination technology were the development of a programmable Flight Termination Safe and Arm (FTSA) and the extended qualification of existing flight termination receiver hardware to the JAMI composite environmental levels. The receiver delta qualification was completed in 2003 and resulted in both the Herley HFTR-60 and L-3 FRT-925 units successfully completing the testing.

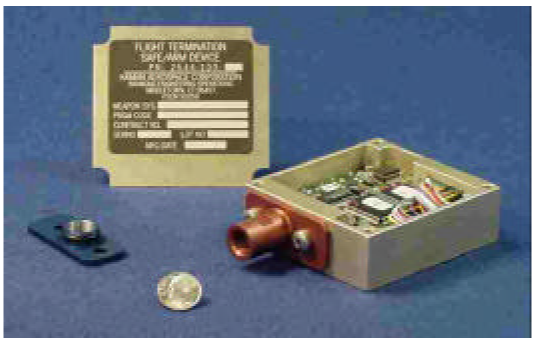

Figure 3 JAMI FTSA

The FTSA development was delayed by a requirement to perform an extensive system safety analysis in March 2004. A production readiness review was held in January and proof of design units were assembled in March but the qualification unit assembly was held up pending the approval of both Navy and Air Force system safety analysis of the design. Explosive interface testing is scheduled for the summer 2004. Several weapon programs have decided to use the JAMI FTSA design in improved telemetry systems now under development.

The JAMI FTSA provides the user with the ability to program the arming conditions into the unit at the factory. Parameters that are available for selection include the safe separation time, the launch valid time, the acceleration level of launch, and whether failsafe conditions of loss of power or loss of tone are used. The FTSA design was optimized to all its use in almost any weapon requiring flight termination.

Weapon Integration- The JAMI project attempted to define all of the JAMI components completely using specifications and Interface Control Drawings (ICD). A problem encountered during the past year is that the original specifications were written as development documents. As the hardware designs matured, these development specifications should have been converted to performance specifications but for a variety of reasons this has not happened. When actual weapon integration began, specific interface information was required and had to be generated.

Another problem with missile integration was the testability of the JAMI components once installed in the weapon. In some cases, a final test of the TSPI system was required during missile all-up-round testing. This presented the need for a GPS satellite simulator to be included as part of the test set. In addition, a streaming PCM decommutator was required to feed continuous real-time data to the GSU ground processor unit. Several tradeoffs were made between the complexity and cost of the system and the value of validating the JTU performance at final checkout. In most cases a decision was made to do extensive JTU testing at the telemeter level and then just make sure that the unit was functional at final missile checkout. Actual missile flight testing is not scheduled until 2005.

CONCLUSIONS

The JAMI GPS sensor technology testing results exceeded expectations and resulted in a GPS sensor with significant Test And Evaluation potential. The JAMI Data Processor demonstrated the capability of processing both real-time and post mission data from the JDP that meets the JAMI performance requirements in most cases. Integration of the JAMI components into weapon systems is progressing with performance testing at missile level one of the more challenging issues to resolve. The flight termination component qualification should be completed in 2004 with several projects ready to use the units. In the next year the JAMI components will be integrated into at least three weapon systems with the JDP integrated at three ranges.