2008

NASA Range Safety Annual Report

This 2008 Range Safety Annual Report
is produced by virtue of
support from the following:

Shannon D. Bartell
Director, Safety and Mission Assurance

Humberto Garrido
Deputy Director, Safety and Mission Assurance

Bryan O'Connor, Chief Safety and Mission Assurance
NASA Headquarters

Robert D. Cabana
Director,
Kennedy Space Center

IV. EMERGING TECHNOLOGY

For more background and information on Emerging Technology, *click here.*

A. RADIO FREQUENCY MONITORING AT KSC

Radio Frequency (RF) Monitoring at Kennedy Space Center (KSC) is a vital function to guarantee a non-interference electromagnetic environment, especially during launch and landing operations, and is identified as one of the 2008 KSC High Priority Technology Needs. NASA and Soneticom, Inc, Melbourne, FL, with funding from the Innovative Partnerships Program (IPP), are installing and field testing a system at KSC to provide enhanced RF monitoring capabilities. The IPP established the Partnership Seed Fund to address barriers and initiate cost-shared, joint-development partnerships. The goals of this KSC/Soneticom partnership include:

- Evaluating a commercial precision geolocation system that will continuously monitor RF activity in the KSC environment.
- Identifying areas that might be detrimental to sensitive payloads and/or equipment.
- Characterizing patterns of RF activity at KSC.
- Evaluating the system's ability to identify and locate long-range/off-shore RF emissions.

This project began in August 2008 with an IPP grant to install a three-sensor test system at KSC (Figure 11) with a team comprised of NASA KT-C and IT-D2-A, Soneticom, and the KSC Electromagnetics Effects Laboratory run by Boeing. The sensors are located at 520 feet on the roof of the Vehicle Assembly Building (VAB), at 45 feet on the roof of the Central Instrumentation Building (CIF), and at 18 feet on the Fire Rescue Training Building. These sensors can monitor frequencies from 30 MHz to 3 GHz in the shaded area shown in Figure 12.

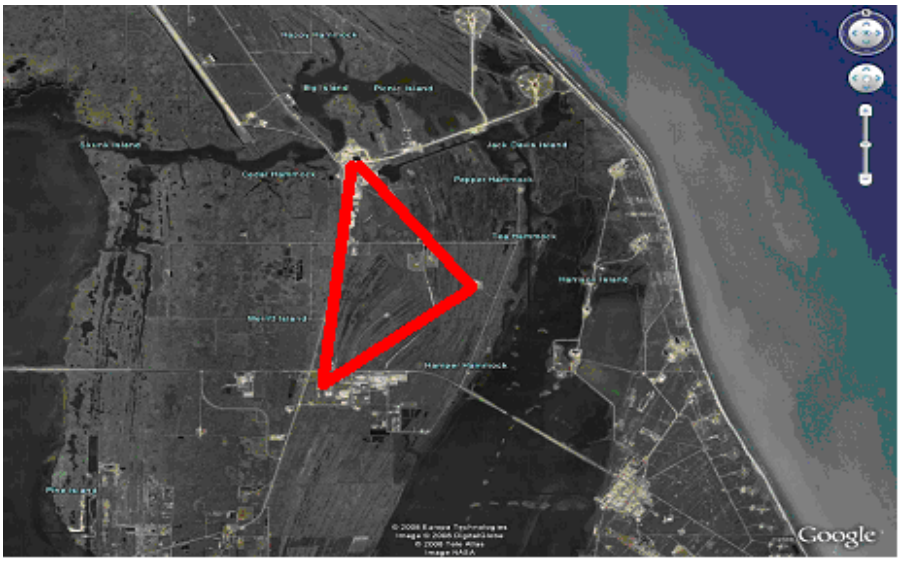

FIGURE 11: SENSOR LOCATIONS

This test system will support a variety of coordinated tests and experiments and will allow different teams at KSC an opportunity to become familiar with the function and capabilities of the precision geolocation system. If funding is available, the long-term goal of this project is to cover all of KSC and Cape Canaveral Air Force Station.

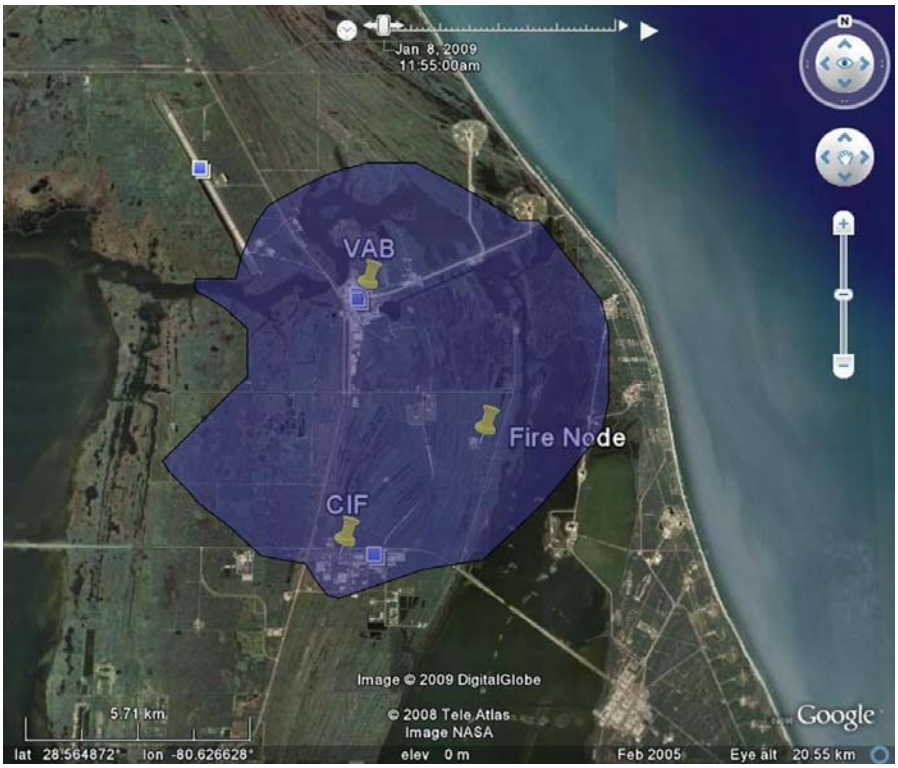

FIGURE 12: THREE-SENSOR COVERAGE AREA

Soneticom currently has two Phase II Small Business Initiative Research projects to provide specialized algorithms and advanced component designs to enhance the RF Monitoring at KSC.

B. GPS METRIC TRACKING UNIT (GMTU)

As the access of space by commercial vehicles continues to be explored and the number of vehicles launching into space increases, the need to incorporate the latest tracking technology becomes a necessity. The tracking technology is the Global Positioning System (GPS), and although it is used in aerospace vehicles today, it has not become mainstream in space vehicles. Instead, technology developed over 50 years ago using ground-based radars is still being used today to track flight vehicles during the launch phase. In response to this need, NASA and the Air Force have agreed to use GPS on all flight vehicles starting in 2011. Therefore, the development and testing of the GPS capability is critical to support the agreement and to support the transition of the GPS capability into future operational systems.

The Applied Technology Directorate of Kennedy Space Center has developed a lightweight, low cost GPS unit called the GPS Metric Tracking Unit (GMTU) (Figure 13) that will move forward the use of GPS systems on space vehicles in the future. This unit was developed under the Space-Based Range Demonstration and Certification (SBRDC) project (formerly known as the STARS project) with a primary goal of advancing range technologies in the area of Range Safety systems.

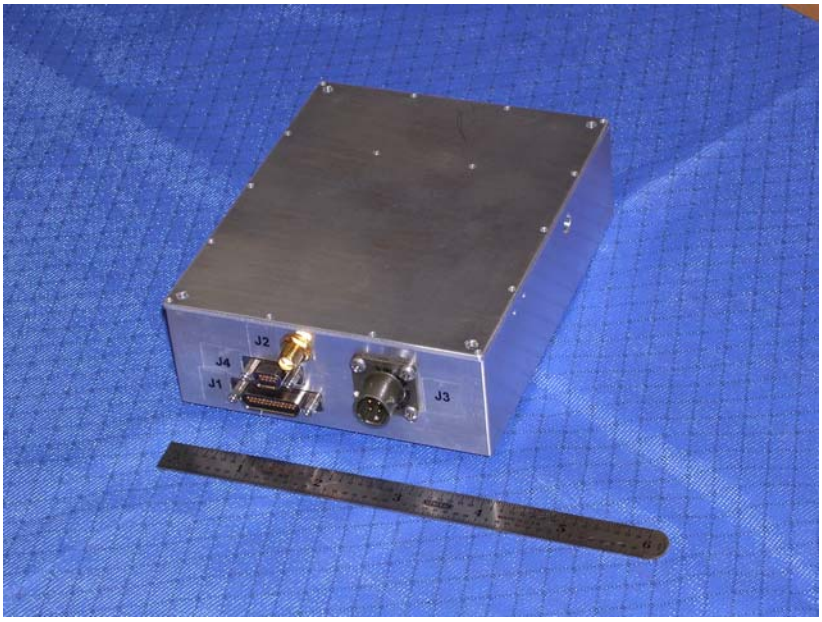

FIGURE 13: GPS METRIC TRACKING UNIT (GMTU)

The GMTU was the first step in a spiral development effort to develop a light weight, low cost. Space-Based Telemetry, Tracking, and Command Subsystem (STTACS) that provides expanded tracking capabilities for the space vehicle community and enhances Range Safety operations. The second step in the spiral development was the Low Cost TDRSS Transceiver (LCT2) developed by the Wallops Flight Facility (WFF). This LCT2 is a light weight, low cost transceiver that can transmit directly to the ground or to a geosynchronous relay satellite.

FIGURE 14: GMTU FLIGHT TEST ONBOARD A SOUNDING ROCKET

Although the GMTU and LCT2 were independently implemented and tested, KSC and WFF engineers collaborated during the development efforts to allow the hardware to be integrated into a single enclosure leading to the final STTACS subsystem.

On 14 July, 2008, the GMTU was successfully flight tested onboard a sounding rocket on a suborbital flight from the WFF (Figure 14). The mission, named Sub-TEC II 41.075/Smith, used a two-stage sounding rocket consisting of a Terrier/Orion booster combination (see Figure 2). The flight was a suborbital flight where the payload parachuted into the ocean and was recovered.

This was the first flight test for the GMTU onboard a sounding rocket.

A second flight test of the GMTU occurred on 7 November, 2008, this time successfully flying onboard an F-104 fighter jet from KSC (Figure 15 and 16).

FIGURE 15: GMTU FLIGHT TEST ONBOARD A F-104 FIGHTER JET

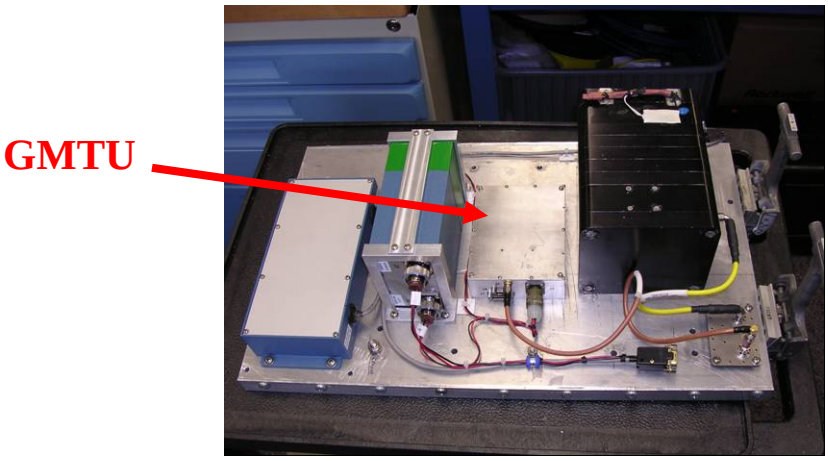

FIGURE 16: GMTU MOUNTED ON THE F-104'S EXPERIMENT PLATE

The GMTU consists of two boards: the KSC designed Command and Telemetry Processor (CTP) board (Figure 17), and the commercially available GPS receiver board. The CTP is the processor board for the GMTU that inputs commands, receives GPS data from the GPS receiver board, and outputs metric tracking data. The CTP was developed using state-of-the-art technologies that allowed a reduction in size from similar previous implementations.

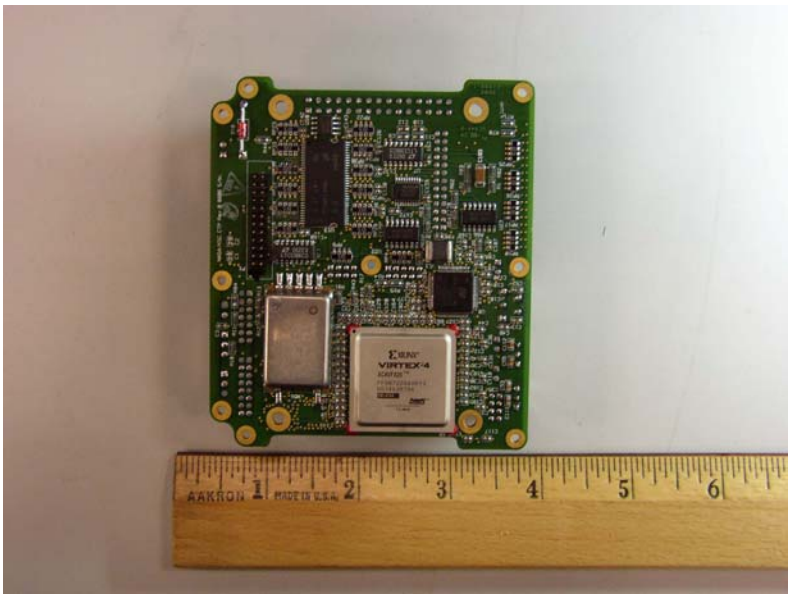

FIGURE 17: COMMAND AND TELEMETRY PROCESSOR (CTP) BOARD DEVELOPED AT KSC

The CTP is a highly versatile, small, lightweight processor board designed for rugged applications and was developed to provide specific functions (namely, the command processing, telemetry processing, and GPS metric tracking of a flight vehicle). It can also be used as a general purpose processor board to perform numerous functions implemented in either hardware or software using the Field Programmable Gate Arrays (FPGAs) two PowerPC processors and/or its logic cells. The CTPs processors run the real-time VxWorks operating system.

Functionally, the CTP was designed for range safety applications that would ultimately be part of a vehicle's flight termination system. Subsequently, the major functions of the CTP are to perform the forward link command processing, GPS metric tracking, return link telemetry data processing, error detection and correction, data encryption/decryption, and flight termination action command processing. Additionally, the CTP can be used in many applications performing different functions and is not limited to range safety applications. The CTP is a programmable, configurable general purpose processor board that can survive and operate in a launch environment.

The final step of the spiral development will be to integrate and test the GMTU and the LCT2 into one unit. This integrated unit called the STTACS can provide a space-based capability to the flight vehicle to track the vehicle, receive commands, and send telemetry data to the ground directly or through the space-based relay satellite. The STTACS capability onboard a flight vehicle eliminates the need for down range ground stations. The STTACS was designed to

meet Range Safety's link margin and latency requirements for vehicle flight termination commands and telemetry.

The GMTU is controlled and configured through a serial or Ethernet interface. For the sounding rocket flight, the serial and Ethernet connections were available in the blockhouse using the vehicle's umbilical interface. Prior to launch, the Ethernet interface was used to verify that the GMTU was functioning properly. Once in flight, the GMTU sent its data to the vehicle's telemetry system which was downlinked to the ground.

The resulting GMTU flight test results will continue to advance aerospace GPS system technologies and architectures. Such technologies help to reduce launch operations costs and provide the flexibility to launch from different areas and for different launch trajectories.

Key accomplishments:

- Successful sounding rocket flight test on 14 July, 2008
- Successfully demonstrated the GMTU in a launch environment
- Successful F-104 flight test on 7 November, 2008
- Successfully demonstrated the GMTU in an aircraft environment
- Continued to increase in TRL and confidence of incorporating GPS technology in aerospace vehicles

Future Plans:

- Integrate and test the GMTU and the LCT2 into one unit called the STTACS
- Pursue efforts to transfer the system into operational use

C. AUTONOMOUS FLIGHT SAFETY SYSTEM

The Autonomous Flight Safety System (AFSS) is a joint Kennedy Space Center (KSC) and Wallops Flight Facility (WFF) project intended for use as an independent and autonomous flight termination subsystem for expendable launch vehicles. It uses tracking and attitude data from onboard Global Positioning System (GPS) and Inertial Measurement Unit (IMU) sensors and configurable rule-based algorithms to make flight termination decisions.

The objectives of the AFSS are to increase capabilities by allowing launches from locations that do not have existing range safety infrastructure, to reduce costs by eliminating downrange tracking and communications assets, and to reduce the reaction time for flight termination decisions.

Previous flight tests have been reported in the annual KSC Range Safety Report. This year the team has been preparing for the flight test of Test Article #3—the third prototype system of the overall AFSS program—on a Terrier Improved Orion sounding rocket at WFF in 2009. The flight test of Test Article #3 will be a demonstration of improvements from Test Article #2 that flew on the SpaceX Falcon at the Kwajalein/Reagan Test Site on 21 March, 2007.

1. Test Article #3

Although Test Article #3 will have a similar hardware configuration as Test Article #2, many improvements and modifications have been made to advance toward the final system. Some of these improvements include:

- A loosely coupled GPS/INS Kalman-filtered navigation solution has been added.
- An improved ground support computer will be used to input the configuration and mission rules files, initialize the system, provide uplinked commands, and monitor the system's performance and software function indications.
- The termination signal output will have a dummy ordnance load that will be monitored instead of only a software flag.
- The team has taken steps to initiate an Independent Verification and Validation (IV&V) of the software including the consolidation of key software design artifacts.
- The AFSS team has been working with the WFF Range Safety office to tailor the Range Commanders Council *Flight Termination Systems Commonality Standard*, RCC 319.
- There are additional input/output ports to the hardware chassis.
- An external lanyard will provide first motion detection.
- The low cost TDRSS Transceiver (LCT2) will provide a forward link to safe the system after the mission is finished and a return link to view the system's performance during the mission.
- An automated test facility has been built at WFF to test GPS receivers, IMUs, and the AFSS.

2. F-104 Flights

The GPS/INS navigation hardware and software was flight tested on an F-104 at the KSC Shuttle Landing Facility (SLF) on 8 November, 2007 and 28 February, 2008. Data was also collected during a flight from Clearwater to KSC on 27 February, 2008. No flight rules were tested. The combined filtered position, velocity, and attitude data as functions of time were compared to the outputs from a GPS receiver and a separate Attitude Heading and Reference System.

A Reimbursable Space Act Agreement, KCA-4143, between NASA KSC and Starfighters, Inc. provided the flight opportunity. NASA-KSC and Starfighters established the partnership to demonstrate the use of the SLF and the F-104 aircraft as a research platform to support NASA's plan for expanding the use of the SLF and to support NASA's project development. Starfighters had an additional partnership with Florida Institute of Technology (FIT) and its Florida Commercial Sub-orbital Research and Training Center. FIT was responsible for the design and fabrication of hardware required for payload installation and interface to the F-104.

The flights provided the opportunity to find and correct several software problems before the upcoming sounding rocket flight of Test Article#3.

FIGURE 18: STARFIGHTERS F104

D. JOINT ADVANCED RANGE SAFETY SYSTEM

The Joint Advanced Range Safety System (JARRS) is a collaborative effort between Dryden Flight Research Center and the Air Force Flight Test Center at Edwards Air Force Base to develop a state-of-the-art mission planning, risk analysis, and risk management tool for range safety. The Range Safety organizations from all Major Range and Test Facility Bases (MRTFB) are being asked to support the development, testing, and operation of Unmanned Aerial

System (UAS) and Reusable Launch Vehicles (RLVs). It is the vision of JARRS to provide range safety support for these missions.

JARRS consists of two primary elements: a Mission Analysis Software Tool and the Real-Time Operations Tool. The Mission Analysis Software Tool will quantify the range safety risk for a given flight path and its associated vehicle parameters using a computerized method. This method will streamline the range safety analysis by providing a consistent, high fidelity solution in less time than required by present methods of analysis.

Additionally, the Real-Time Operations Tool will provide the Range Safety Officer with near real-time assessment of the range safety risks during flight. This capability has many possible applications to the UAV or RLV operator, including assessment of UAV overflight of populated areas, allowing extended flight of an anomalous vehicle, recovery of an off-nominal vehicle at an alternate landing site, or selection of an alternate flight or entry path.

Major accomplishments this year include a study comparing the probability of impact output from JARSS MP with data from a real-world case, improvements to population/asset management, added the ability to input a simple turn model, and the code was updated to MATLAB 2008a.