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# Aerospace Vehicle Scalable, Modular, and Reconfigurable Technologies to bring innovation and affordability

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## ABSTRACT

The Space Information Laboratories (SIL) Intelli-Avionics®(patent pending) and VBITS GPS Tracking and AFTS (patent # 5,739,787) technologies are being developed, Space Qualified and manufactured to eliminate the Aerospace "Black Box Syndrome". What is the Aerospace "Black Box Syndrome", and why does it continue in many aerospace applications? In last few decades, many Aerospace companies designed and manufactured hardware/software engineering systems to meet a specific requirement but all of these systems did not have the virtues of being open, modular, stackable and reconfigurable (OMSR) to meet new and evolving requirements. Yes, they work but the cost is generally too high and not easily upgradable once they are manufactured for a specific application. In the current economic environment in the United States, reinventing Aerospace to eliminate the "Aerospace Black Box Syndrome" must become a system engineering challenge to all prime contractors and technology suppliers for use on current and future Aerospace vehicle systems. The Aerospace vehicles (missiles, launch vehicles, RLVs, and satellites) subsequently have many separate black boxes that cannot be upgraded without a complete redesign in many cases to meet additional engineering requirements. This unnecessary and costly reality in the DOD, NASA and Aerospace industry requires customers to pay for engineering redesign and full Space Qualification testing for each of the black boxes.

With great advancement in processor, communication, FPGA, digital signal processing, power and microwave electronics in the 21st century, the "Black Box Syndrome" paradigm in Aerospace can be changed so more advanced requirements can be accomplished with upgradeable and flexible engineering systems, thus greatly reducing unit cost (1/2) for development and life-cycle cost (1/10). There is no reason that the many black boxes being flown on Aerospace vehicles cannot also be consolidated into fewer black box units (C&DH, TT&C, Sensor and Power subsystems in Aerospace vehicles). By reducing the number black boxes that need to be Space qualified for future Aerospace vehicles, the engineering development and life cycle cost will be reduced greatly. This technical paper will highlight system engineering and design approaches to bring innovation and affordability for multiple Aerospace vehicles, and DOD/NASA Ranges (WR, ER, PMRF, NASA Wallops, etc.).

## INTRODUCTION

SIL is developing next generation open, modular, stackable and reconfigurable (OMSR) avionics technology to bring innovation and reduce cost for multiple aerospace platforms.

Intelli-Avionics® is a transformational technology that enables consolidation of multiple avionics black boxes into a single or few units. Typical avionics systems have multiple black boxes including the following: Processor, GPS Receiver, INS and/or IMU, Communication Ports (RS-232, RS-422, 1553, CAN, I2C, etc.), Analog and Digital I/O, A/D and D/A, Ordnance Interface and Switches/Relays. Each one of these functions are separate black boxes that all need to be Space Qualified that drives significant development and recurring life cycle costs. By consolidating these functions into a few units, a significant cost savings can be realized on multiple Aerospace vehicles.

## INTELLI-AVIONICS® CONCEPT OF OPERATIONS

Intelli-Avionics® is an OMSR plug-n-play avionics technology (patent pending) that allows users to select many different modules to meet multiple aerospace

vehicle avionics application requirements (GPS and INS/IMU navigation, satellite bus, payload sensors, rocket/missile interfaces, autonomous flight and destruct systems, LEO/GEO satellite communication, power and switching, etc.). The Intelli-Avionics® open modular technology can easily be adapted to meet multiple aerospace vehicle requirements to include launch vehicles (LVs), reusable launch vehicles (RLVs), UAS, and satellites with new hard real-time VxWorks software suites. The Intelli-Avionics® modular package is robust and environmentally qualified to worst case rocket and missile EWR 127-1 and RCC 324-01 range safety requirements successfully (Table 2 below).

The system level diagram in Figure 1 below a typical avionics architecture on rockets and missiles with the many black boxes for flight termination, telemetry, INS/IMU navigation, Radar tracking, attitude control, sensors, and launch vehicle on-board camera. All these black boxes need to be Space Qualified and the overall unit and life cycle costs are very expensive. In order to reduce cost it's very important to reduce the number of black boxes and consolidate the avionics architecture.

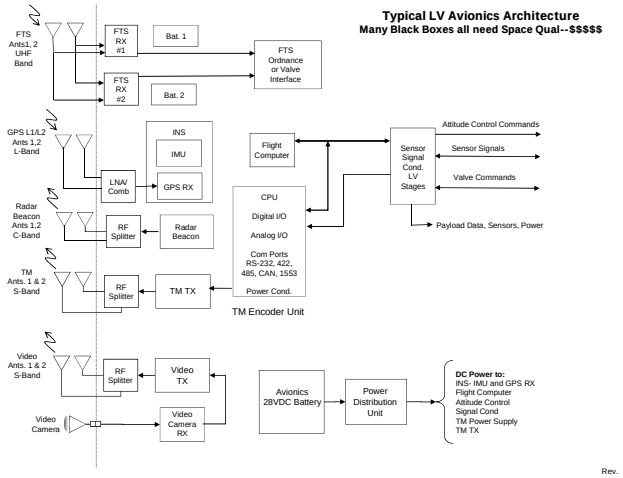


**Figure 1- Typical LV Avionics Architecture**

The Intelli-Avionics® concept of operations is to consolidate the number of black boxes into one or a few, only using AFTS, GPS Tracking, Space Based Range and consolidated avionics boxes (flight computer, INS, comm ports, etc. in one unit), and connect directly to multi-use patch antennas (GPS/S-Band--two summed or RF split, 180 degrees apart) on the outside of the launch vehicle to be ready to support global test range capability at a very cost efficient and responsive manner. Intelli-Avionics® can be tested remotely prior to flight via a RS-422 (hard-wired) and/or satellite communication RF link from an aerospace vehicle to a DoD/NASA range safety center. The launch vehicle requires a ground/mobile telemetry system and a computer to receive GPS metric tracking and telemetry data using a secure IP address. The Intelli-Avionics® S-Band downlink provides GPS metric track data (ECEF PVT at 20Hz) which can be directly inserted into the range safety display of the Instantaneous Impact Point (IIP) algorithm. No range ground radars are required for real-time range safety metric tracking of the launch vehicle.

The Intelli-Avionics® is a space qualified Plug and Play (PnP) technology that allows processor, communication (RS-232/422/485, 1553, CAN, and Ethernet), and RF devices (GPS Receiver, S/L-Band transmitter, LEO/GEO satellite transceivers, software defined radio, etc.) to reside within the same modular stackable unit and meet stringent environmental qualification requirements for missiles, rockets, airplanes, and satellites. The versatility of the Intelli-Avionics® unit can be used to meet many requirements that are envisioned for any launch vehicle.

For example, one application being discussed by DoD and NASA is an Autonomous Flight Termination System (AFTS) on the launch vehicle. If DoD decides to employ an autonomous flight termination system architecture, ground command destruct transmitters will no longer be required to provide adequate range safety services while saving the customer very significant money. DARPA selected VBITS AFTS and Space Based Range technology enabling for the DARPA ALASA Phase I program (2012-2013). In Phase II (2014-2016), it will be Space Qualified and flown on the Boeing ALASA nano/micro satellite launch vehicle

The Intelli-Avionics® uses plug-n-play GPS Rx/L or S-Band TX multiple function patch antenna that is mateable to any size aerospace vehicle with high-temperature RF transparent coating if required. The patch antenna pre-amp and bandpass filter is powered through the RF cable, so they can be mounted to any launch vehicle diameter.

The Intelli-Avionics® units can be constructed to satisfy GPS L1 or L1/L2 metric tracking unit for range safety with or without an S-Band transmitter and/or space based range LEO/GEO satellite transceiver. A Intelli-Avionics® unit can also be configured as a consolidated avionics unit with flight computer, GPS receiver and silicon MEMS IMU providing independent uncorrelated 6DOF, ECEF PVT and attitude rates for navigation and guidance of the launch vehicle. Currently, SIL's VBITS GPS Tracking, AFTS and Space Based Range unit was selected as enabling

technology for the DARPA ALASA program. This work includes selecting a robust hardware/software architecture approach that would provide the best solution for range safety qualification of an AFTS unit based on EWR 127-1, RCC 324-01 and RCC 319-10 range safety requirements. A VBITS AFTS unit and IIP algorithm (30SW Range Safety provided) will be HWIL tested with a GPS simulator running the LV 6DOF trajectory with antenna gain and phase patterns loaded to test nominal and off-nominal trajectories. The VBITS AFTS failsafe technology shown in Figure 5 will be Space Qualified and fly on the Boeing ALASA launch vehicle in late 2015.

## CONSOLIDATED AVIONICS ARCHITECTURE

How do we reduce cost for launch vehicle avionics systems? You must reduce the number of black boxes and do the same navigation and guidance functions. Secondly, the small launch vehicles carrying nano/micro/small satellites should use GPS Tracking, Autonomous Flight Termination System and Space Based Range (LEO GlobalStar/Iridium and/or GEO TDRSS/InMarSat) architectures to reduce the number of boxes on the launch vehicle and reduce range ground instrumentation to support launches that can cost up to $1M a day.

Figure 2 below shows a launch vehicle avionics using a GPS MT, AFTS and Space Based Range architecture and when comparing this with figure1 above, you can notice a significant reduction of black boxes on the launch vehicle to stop the "Black Box Syndrome" in Aerospace. With current state-of-the-art PC104 Plus/Express CPU and communication technology (efficient line of site and satellite beyond line of site transceiver technology), multi-function patch antennas and FPGA reconfigurable technologies, the number of black boxes on Aerospace vehicles can be greatly reduced for significant unit (1/2) and life cycle cost savings (1/10).

So why hasn't this been done? Once the black boxes have been Space Qualified, there is a large NRE investment the DOD, NASA and Aerospace industry are reluctant to consider changing to this technology. Subsequently, there are Launch Vehicles, Missiles and Satellites using 20-30 year old technology in the Aerospace enterprise. In order for a small business innovator to replace the old technology, it requires a DOD or Aerospace prime sponsor willing to make the one time NRE investment and assume some risk to change the old technology. The business case must be made on the technical value proposition and cost savings to convince the DOD, NASA and/or Aerospace prime contractor program office to make the technology change. DOD and NASA are now starting to demand lower cost in the Aerospace business due to budget constraints and the small business innovators with new technology are now being viewed as a proactive partner instead of a threat to the establishment. Aerospace prime contractors are now starting to include small business on their team on new projects to meet the 25% government mandate now to include small business innovators to lower cost in the Aerospace enterprise, which is a recent positive development.

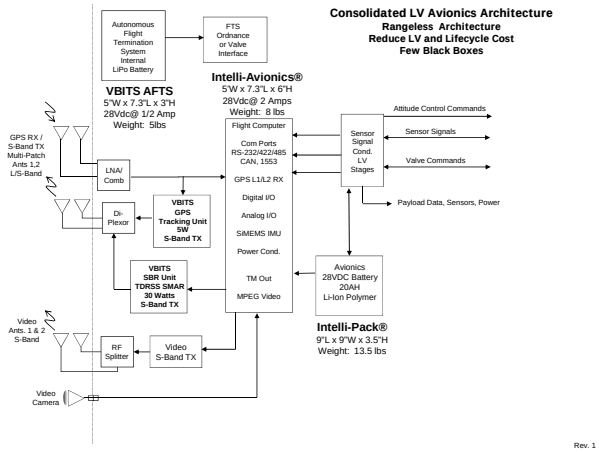


**Figure 2: Consolidated LV Avionics Architecture**

## ENVIRONMENTAL QUALIFICATION

For a new Avionics system for use on any DoD test range (WR, ER, PMRF, WSMR, etc.), the GPS RCC 324-01 environmental test requirements must be followed. A tailored RCC 324-01 document was must be written in coordination with Range Safety office personnel (30SW, 45SW, PMRF, etc.). For AFTS, both the RCC 324-01 and RCC 319-10 requirement guidelines are required for development (hardware and software) and range safety Space Qual certification.

VBITS GPS Tracking Units has successfully passed environmental qualification the test levels, shown in table 1 below, MDA LM Flexible Target Family (Figure 4) and ULA Atlas/Delta rocket GPS metric tracking unit programs. The VBITS tracking unit has flown eight times on ULA rockets and four time on MDA missiles and flawless record of maintaining continuous rocket and missile metric tracking.

In the latest round of SIL development, theIntelli-Avionics® GPS receiver ECEF PVT data can update the INS at 100Hz thus allowing for a lower cost

SiMEMS IMU and maintain ECEF XYZ position accuracy of < 5 meters and velocity accuracy of < 1 m/sec, 1 sigma throughout flight.

| Environmental Qualification Tests | Test Levels |
|---|---|
| **Thermal Humidity** | -40C to +85C (24 cycles, 1 hour dwells at each temperature extreme |
| **Thermal Vacuum** | 400,000 Ft. (2 x 10-7 psia), -34C to +85 |
| **Random Vibration** | 26.4 grms, 3-Axis, 0-2000Hz |
| **Sine Vibration** | 14.14 gpk, 0-300Hz 21.21 gpk, 301Hz to 2000 Hz, 3 Axis |
| **Shock** | 40g, 11msec, 3-Axis, bi-directional, 12 Shocks |
| **Acceleration** | 30g, 3-Axis bi-directional |
| **Outgassing** | Space Shuttle, all NASA Codes |
| **EMIC** | CE102, CS101, CS114, CS115, CS116, RE102, RE103 |

**Table 1: Intelli-Avionics® Environmental Tests and Levels**

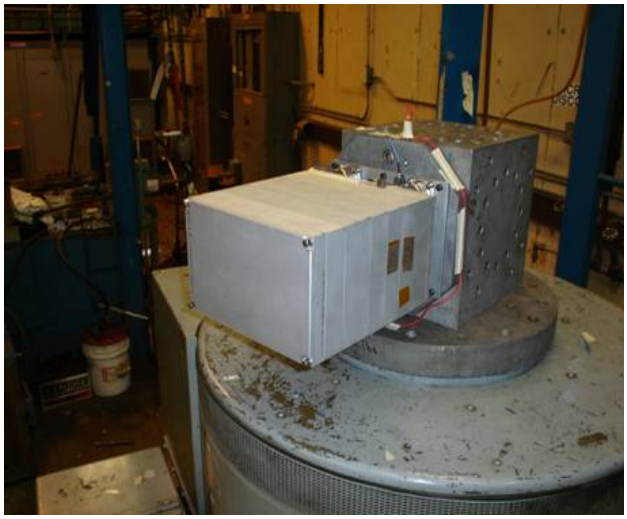

**Figure 3 - X-Axis Random Vibration Test**

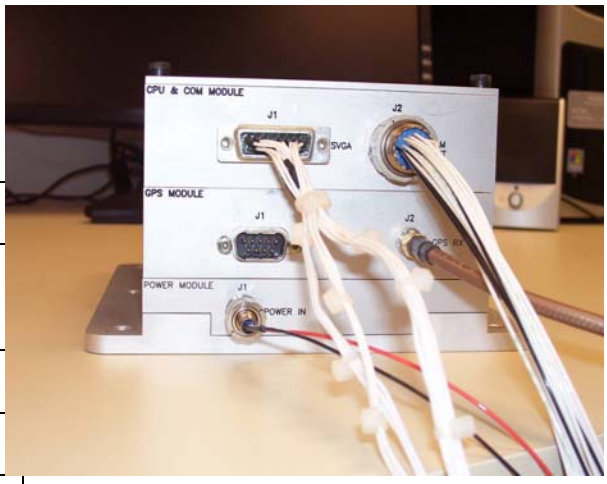


**Figure 4 - VBITS MDA FTF GPS Metric Track Engineering Unit**

**Figure 5 - VBITS AFTS for DARPA ALASA**

## CONCLUSIONS

SIL's Intelli-Avionics® and VBITS enabling patented technologies are important to transition LV avionics to state-of-the-art technology (Processor, Communication, Navigation, Tracking and Power systems) that is available to upgrade the old legacy avionics systems flown on the majority of launch vehicle and missile systems today. The life cycle cost saving (1/10) can be realized by employing the consolidated avionics architecture outlined in this paper.

For many decades the DoD and NASA have discussed transition to GPS metric tracking, autonomous safety and space-based range architecture. The progress has been very slow in transitioning to these architectures. Transitioning to on-board systems would greatly reduce range operational and maintenance costs compared to current ground based architectures (radar, command destruct transmitters and optics) and would make the test ranges more responsive to customers (DoD, civil and commercial). For decades, the FAA has also discussed moving away from the radar ground architecture toward GPS and satellite based technologies for aircraft tracking and data retrieval. The DoD, NASA, and the FAA continue to spend billions of O&M dollars on ground range instrumentation O&M technology based in the 1950-1960s technologies.

The Intelli-Avionics® is a pioneering disruptive technology that enables the new launch range architectures envisioned with minimal ground-based infrastructure and would drastically decrease DoD, NASA and user costs. It can also support consolidated avionics on rockets, missiles and small satellites where there is many black boxes performing various functions (Processor, Communication, Data I/O, A/D, D/A, INS/IMU, GPS Receiver, pyro firing, video processing, etc.). It would also improve responsiveness in supporting missile launches anywhere on the globe.

## REFERENCES


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