Space Information Laboratories

VBIRS - AFTS and Space Based Range Technology

"Alternative to String of Pearls for T&E"

For Hypersonic Vehicles, Missiles, Strike Weapons and UAS

Vehicle Based Independent Range System (VBIRS)
USPTO Utility Patent Pending

SIL Aerospace Small Business

- AS9100 QMS for design, manufacture and test of Avionics and Li-Ion Battery Range Safety Environmentally Qualified flight units
- Primary business is Range Safety Space Qualified products for Aerospace Industry and Federal Agencies including the MDA, SMC, NASA, AFRL, DARPA, etc.
- Aerospace WO Small Business, Primary NAIC Codes 541712, 541333, 541380, 541690, 336419
- SIL is located in Santa Maria, CA 15 miles from Vandenberg AFB

DESIGNED AND MADE IN THE UNITED STATES

WHO IS SIL?

SIL accomplishments include:

- Enabled the transition from Radar to GPS tracking on ULA Atlas V and Delta IV Rockets for EWR using SIL's Vehicle Based Independent Tracking System (VBITS) technology

- Enabled the transition of MDA target missiles from Radar to GPS tracking for PMRF and RTS using VBITS technology

- First Range Safety Space Qualified Li-Ion Polymer batteries for MDA target missiles and reentry vehicles that significantly reduced battery weight **(saved over 150 lbs), volume (<1/3) and cost (1/2) over older Range Safety Space Qualified battery technologies (Silver Zinc, Ni-Cad)**

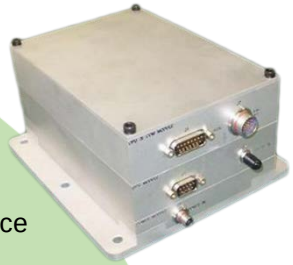
Space Qual Design and Flight Unit History & Experience

- SIL developed VBITS for MDA FTF Missile GPS Tracking Unit, 2006-2007. Flown eight times successfully 2010-2017 (FTG-06, FTG-06A, FTG-06B, etc)
- SIL developed Li-Ion Polymer common battery for MDA missiles and reentry vehicles – Range Safety Space Qualified and Production (LMSSC & Coleman MRBMs and Reentry Vehicles). Flown ten times successfully 2013-2017
- SIL developed VBITS for ULA Atlas/Delta Rocket GPS Tracking Unit (GTU), 2008-2011. Range Safety Space Qual and flown thirty plus times, 2012-2017
- SIL developed a low-cost VBITS AFTS Integral FailSafe Design for DARPA ALASA Phase I (2012-2013) and MDA SBIR Phase II (2016-2017)
- Vehicle Based Independent Tracking System (VBITS) USPTO patent, #5,739,787 (issued April 1998) for Rocket and MIssile GPS Tracking and Autonomous Flight Termination System (AFTS)---AFTS in Claim #1 and Common Bus Structure for Avionics and Satellites (CBSAS) Patent # 9,730,339 B2 (issued 8 August 2017) for Open, Modular, Scalable and Reconfigurable Avionics and Small Satellite Bus
- Vehicle Based Independent Range System (VBIRS) USPTO utility patent application #15/589,440 submitted 8 May 2017 for Vehicle Based AFTS and GEO/LEO Satellite High Data Rate Telemetry BVLOS Comm

Leveraging SIL Success's for MDA VBITS AFTS Unit

30%

VBITS GTU Successfully Range Safety Space Qualified and Flies on ULA Atlas V And Delta IV from EWR 2009-2017



10%

VBITS GTU Successfully Space Qualified and Flies on MDA target missiles from PMRF/RTS 2006-2017

15%*

SIL Li-Ion Polymer Battery Range Safety Space Qualified and flies on MDA target missiles and reentry vehicles 2013-2017

10%

VBITS AFTS DARPA Phase I Development 2012-2013

< 35%

MDA VBITS AFTS SBIR Phase II (2017-2018) and SIL USAF RIF (2018-2020) for Range Safety Space Qual and Flight Tests

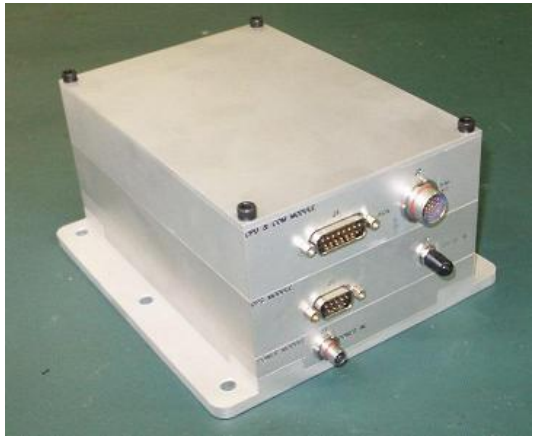
Green – *Leveraging past VBITS design to implement AFTS*
Blue – Remaining Work

* *2016-2017*

USAF Selected SIL Phase II SBIR: 2Ah FTS *Li-Ion* Battery will power VBITS *AFTS to reduce SWAP and further reduce work* Remaining.

VBITS MDA FTF GPS Tracking Unit

Space Qual (2008) and Eight Flights (2010-2017)



Size: 7.3” L x 6”W x 3.6”H
Weight: 5.5 lbs
Power: 28Vdc @ .4 Amps
Reliability: ≥ .9995

- Thermal Cycle and Vacuum: -35°C to +71°C
- Shock: 580 g’s from 1400-10,000 Hz
- Random Vib: 36.8 grms from 20-2000 Hz, 3 minutes per axis
- Sine Vibe: All LV2 variants
- EMI: RE101, RE102, RS101, CE102, CS101, CS104, CS114, CS115, CS116

VBITS Atlas/Delta GPS Tracking Units

Space Qual (2011) and 30 Plus Flights (2012-2017)

Size: 8” L x 8” W x 6”H
Weight: 10 lbs
Power: 28Vdc @ ½ Amp
Reliability: ≥ .9995

- Thermal Cycle and Vacuum: -34°C to +71°C
- Shock:

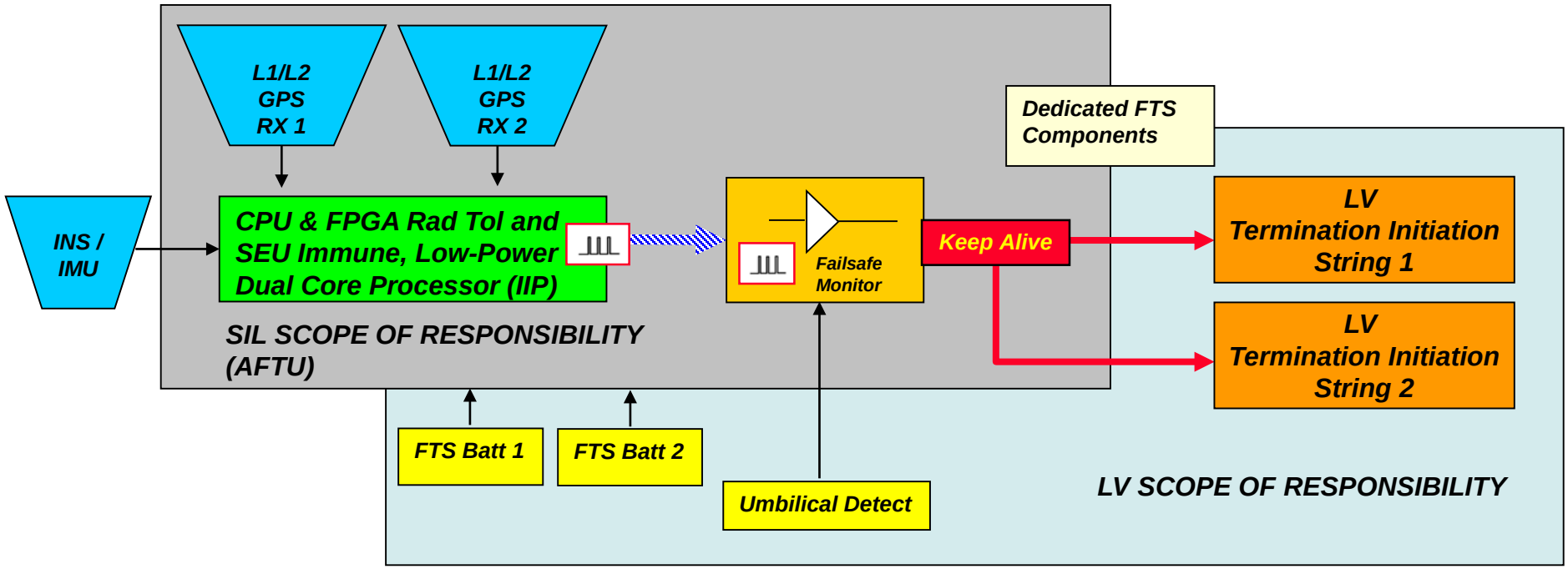
	Freq (Hz)	GPeak
	100Hz	200
	1000	1300
	10000	1300

- Random Vibration: 32.4 grms from 20-2000 Hz, 3 min per axis
- EMI: RE101, RE102, RE02, RS02, CE01, CE03, CE06, CE07, CEXX, CS-01 thru CS-07, CSXX—Lightning Strike

Representative VBITS AFTS Unit
Missiles, Hypersonic Vehicles & Strike Weapons

Size Estimate: 7.5” L x 6.5” W x 4” H
VBITS AFTS Weight Estimate: 7 lbs
Power Estimate: 28Vdc@ 1/2 Amp (Max)
AFTS Integral FailSafe Design Reliability (one unit): ≥ .9995 (1/2 hour mission)
AFTS Dual-String Design Reliability (two units): ≥ .99995 (1/2 hour mission)

VBITS AFTS System Diagram
Missiles, Hypersonic Vehicles & Strike Weapons



- Violation of two NAV sources after launch results in termination
- Failure of both Processors with heartbeat monitor results in termination
- Failure of a FTS battery results in termination
- Single point S/W failures are mitigated by using hardware based Failsafe Monitor
- Redundant *Missile* Termination Initiation Components (String 1, 2)
- VBITS AFTS Unit reliability $\geq$ .9995

SIL Li-Ion Intelli-Pack® Customer Batteries 2011 - Present

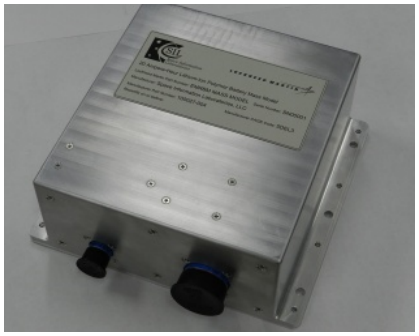
MMIII Missile FTS & GPS prototype Li-Ion Polymer Battery

33.6Vdc @ 3.8AH

Weight: 3.25 lbs

Customer ***Benefits****:*

- ***3x Energy Density (LiPo vs. Silver Zinc)***
- ***1/2 the Weight***
- *1/10 Life Cycle Cost*



MDA Missile & RV

20Ah Li-Ion Polymer Battery, 2011-Current

33.6Vdc @ 20AH

Weight: 14.5 lbs

Customer Benefits:

- *4x Energy Density (LiPo vs. NiCad)*
- *1/4 the Weight*
- *Saved 150 lbs on MDA missile*
- *1/5 Life Cycle Cost*

USAF SBIR Phase II

2Ah Li-Ion Polymer FTS Battery

33.6Vdc @ 2AH

Weight: 2.7 lbs

Customer Benefits:

- *3x Energy Density (LiPo vs.Silver Zinc or Ni-Cad)*
- *1/3 Weight*
- *1/10 Life Cycle Cost*

NASA JSC ISS

Li-Ion Battery

4.2Vdc@5.6AH

Weight: ½ lbs

Customer ***Benefits****:*

- *Astronauts recharge battery with Lenovo laptop computers on ISS*

Range Safety – AFTS Key Points

- *Range Safety requirements exist solely to protect people and property not the launch vehicle or payload*
- AFTS design is a tradeoff between cost / complexity and risk to mission success due to false negatives
- AFTS design is *never* a tradeoff between cost / complexity and risk to life – safety is paramount

So what does all this mean?

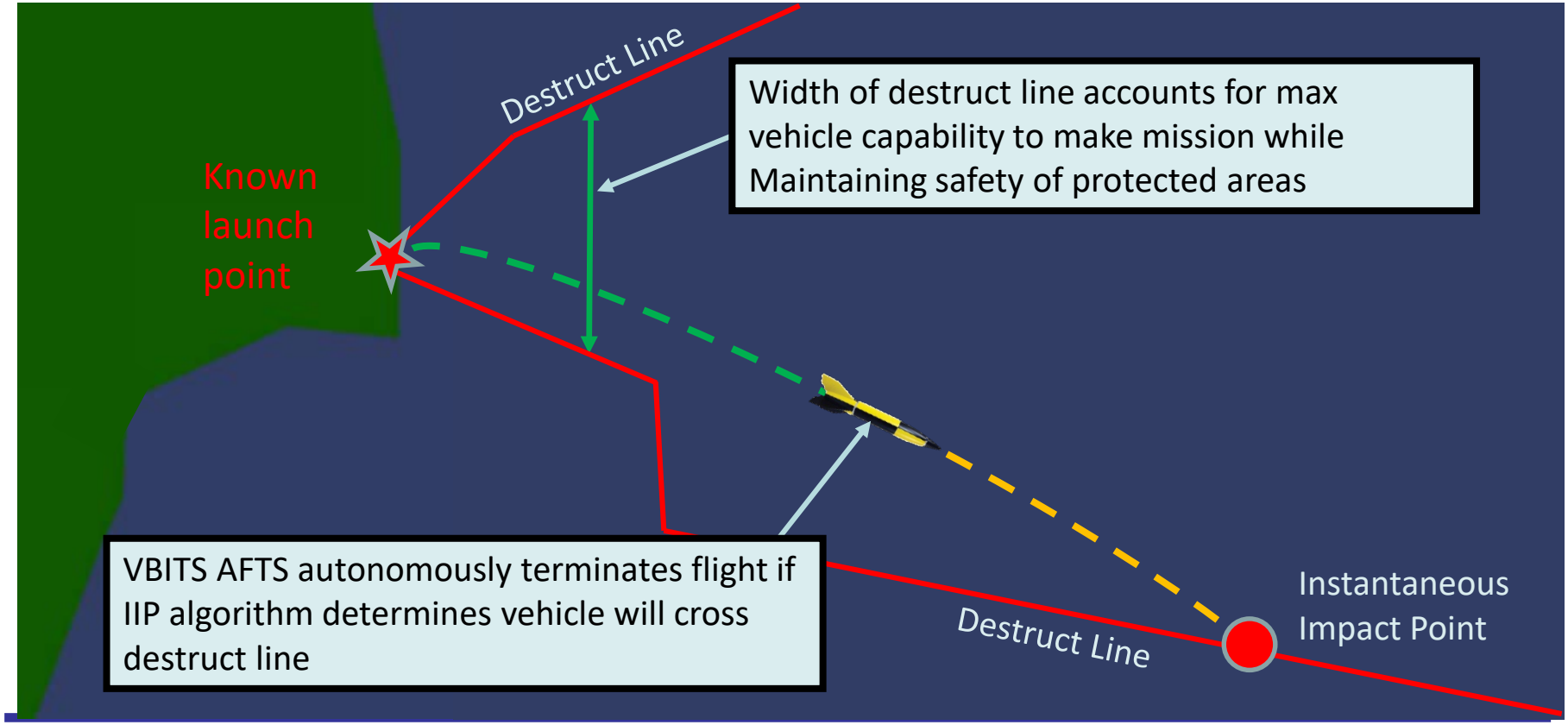
An AFTS system must not fail to terminate an off-course mission, but there is a possibility that it may terminate a nominal mission. Increased complexity / cost can only "buy" down risk to the payload

Range Safety – AFTS Overview

- Autonomous Flight Termination System (AFTS) uses on-board tracking and processing to terminate an errant launch vehicle
  - AFTS requirements are contained in RCC 319-07
  - AFTS tracking requirements are contained in RCC 324-01
  - AFTS software requirements are contained in AFSPCM 91-712
- AFTS may be stand-alone or be used with existing vehicle systems such as navigation sources (additional requirements may apply)
- Existing requirements are valid for the remainder of the FTS
  - AFTS only replaces command receivers, antennas and couplers
  - AFTS adds processing, independent navigation and performance sensors and associated supporting hardware
  - Requirements for the rest of FTS remain (e.g. ordnance, autodestruct & batteries)

AFTS IIP DESTRUCT LINE OPTIONS

- SIL's VBITS AFTU will integrate the 30SW Range Safety CASS OR2 IV&V Software
- Global responsibility to ensure missile, launch vehicle and payload debris lands safely



VBITS AFTS OPTIONS (HIGHEST AND LOWEST COST)

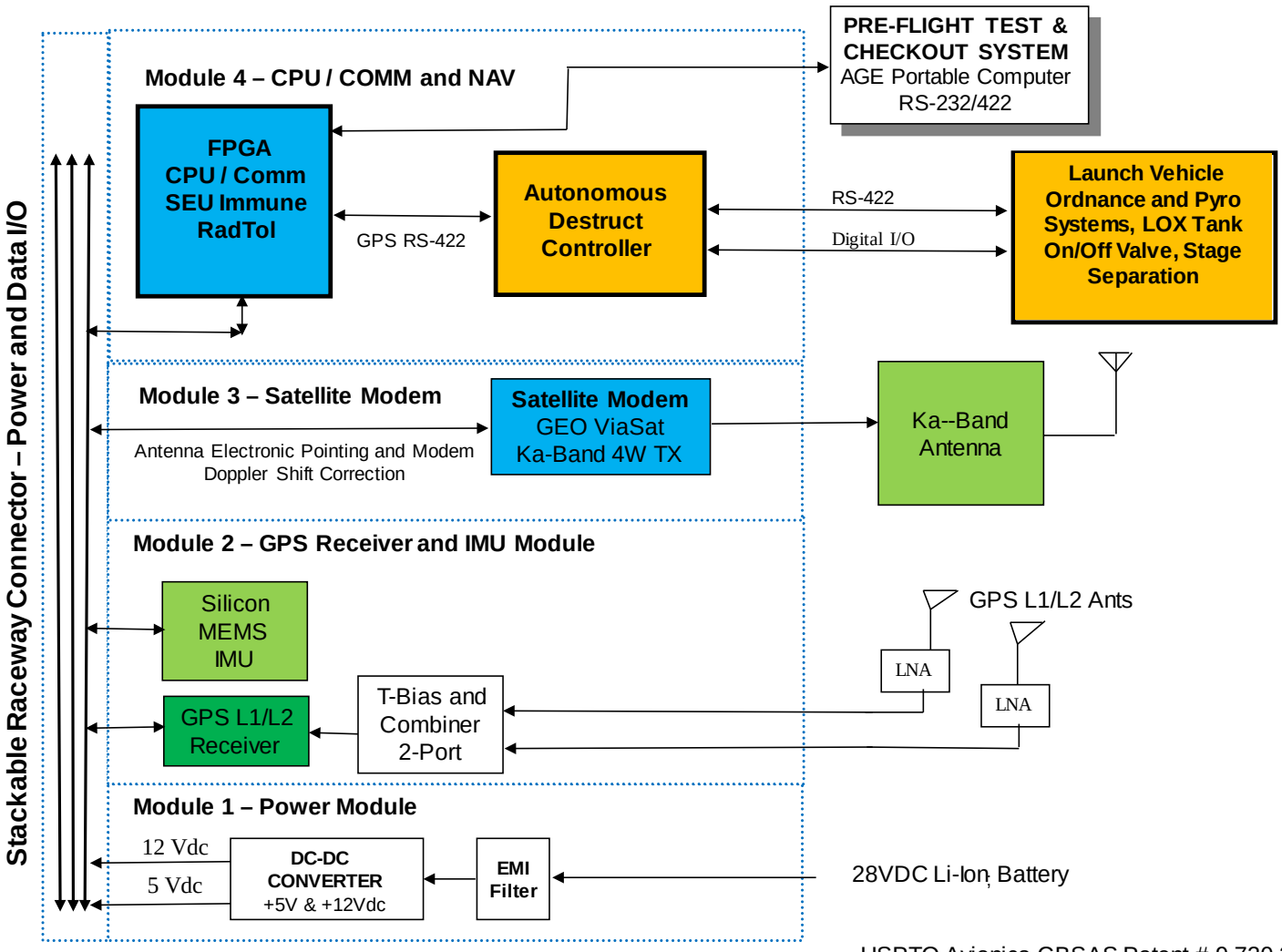
Potential options available based on highest to lowest cost:

- **Existing FTS requirement is ≥ .999 (1/2 hour mission)**
- **AFTS Dual String provides higher mission assurance that a good vehicle is not destroyed**
  - **AFTS Dual String Solution – Highest Cost**
    - Replaces Command Destruct Receiver Only
    - Dual String Architecture with cross strapping, two functionally identical units
    - Highest Cost, High complexity
    - Combination of dual GPS sensors and dual INS sensors
    - Focus on Mission Assurance in addition to Safety
    - Dual unit reliability estimate ≥ .999 (1/2 hour mission)

- **AFTS Single String Integral Failsafe Solution – Lowest Cost**
  - Dual GPS RX Sensors and LV NAV source input to make destruct decision
  - Dual Processor with heart beat monitors
  - Dual String Discrete Failsafe Monitor
  - Dual FTS Batteries (same as current FTS)
  - Dual Launch Termination Outputs (same as current FTS)
  - Highly reliable hardware ≥ .9995 (Based on VBITS FMECA and Flight history, ½ hour mission)
  - Use 30SW Range Safety provided IIP Algorithm to make destruct decision

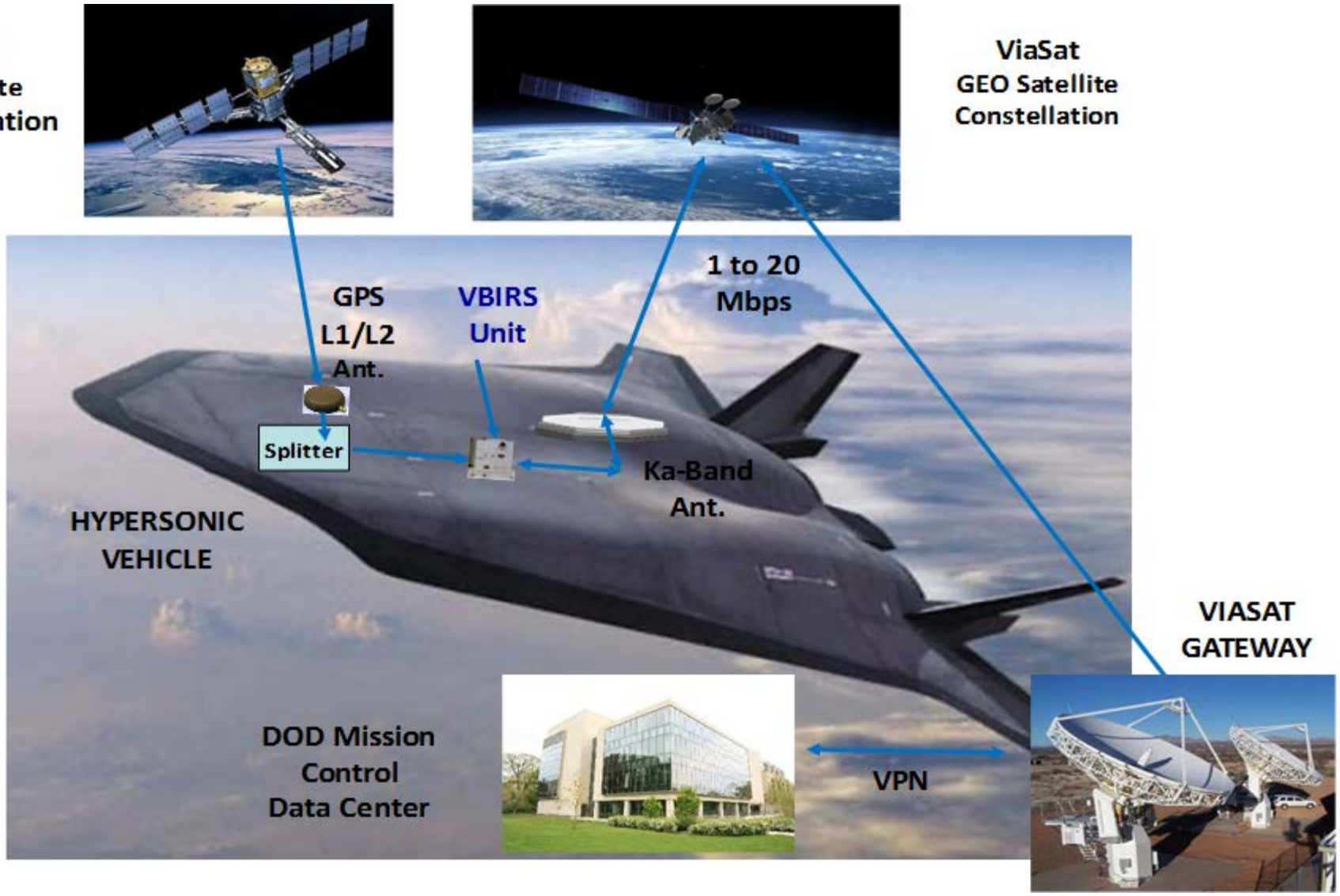
VBIRS OPEN & MODULAR AVIONICS

VBIRS Open, Modular, Scalable and Reconfigurable (OMSR) Avionics - AFTS and Space Based Range



USPTO Avionics CBSAS Patent # 9,730,339 B2

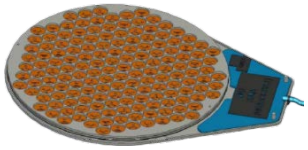
VBIRS - HYPERSONIC VEHICLES, MISSILES AND STRIKE WEAPONS BLOS COMM



Vehicle Based Independent Range System

LCD Metamaterial Antenna

Lens Antenna



MMIC Phased Array Antenna

Technical Challenge
Decrease Ka-Band Antenna Recurring Cost to < $20K each (Quantity 100)

Weapon System Antenna Options

Tx

Rx

Ka Amplifier (4 to 10W)_

Tx

Ka Modem

All Data, Comm, TT&C

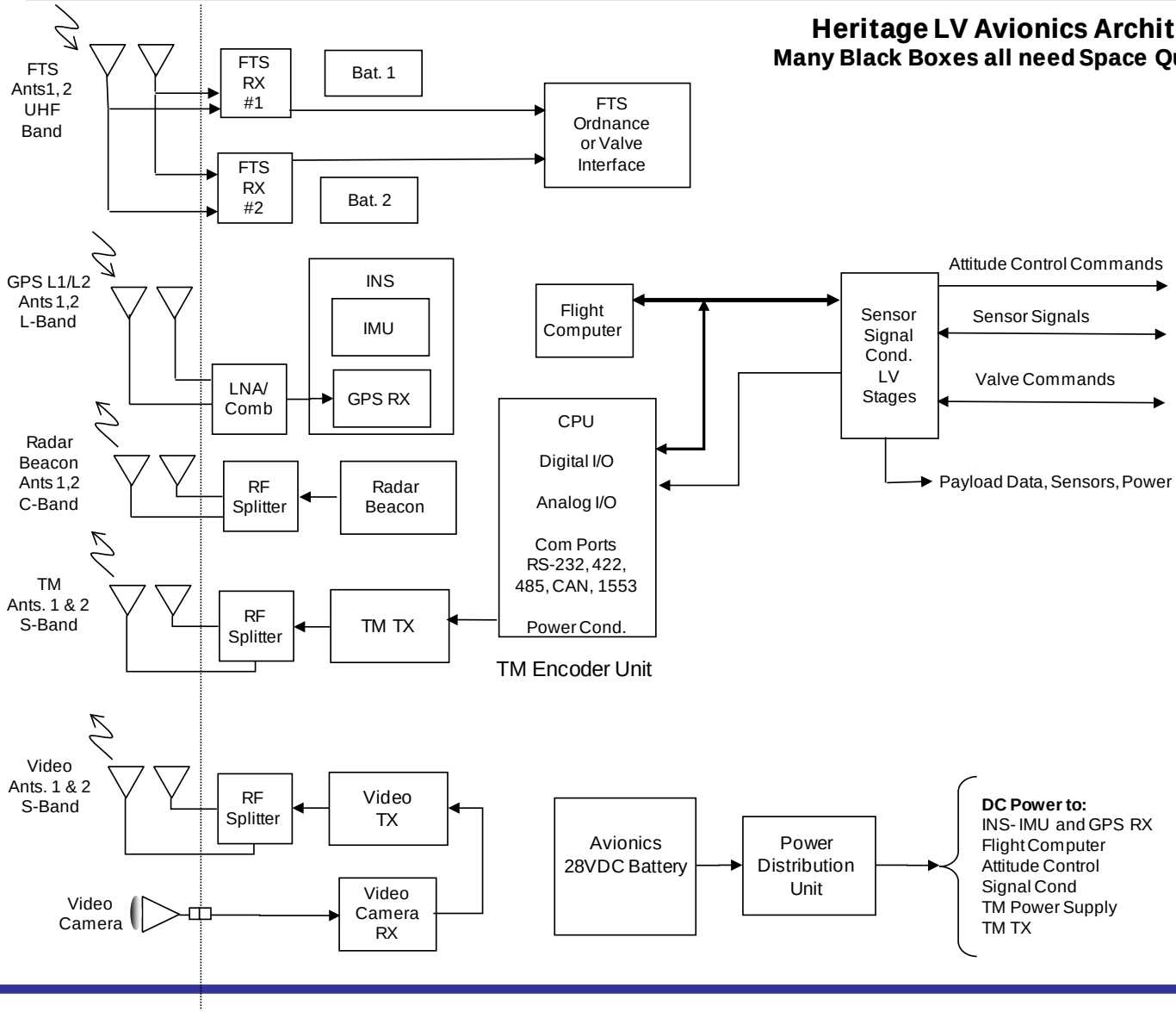
VBIRS GPS Rx and IMU data for electronics antenna pointing and Doppler Shift correction

SIL 8S1P @ 5Ah Li-Ion Battery

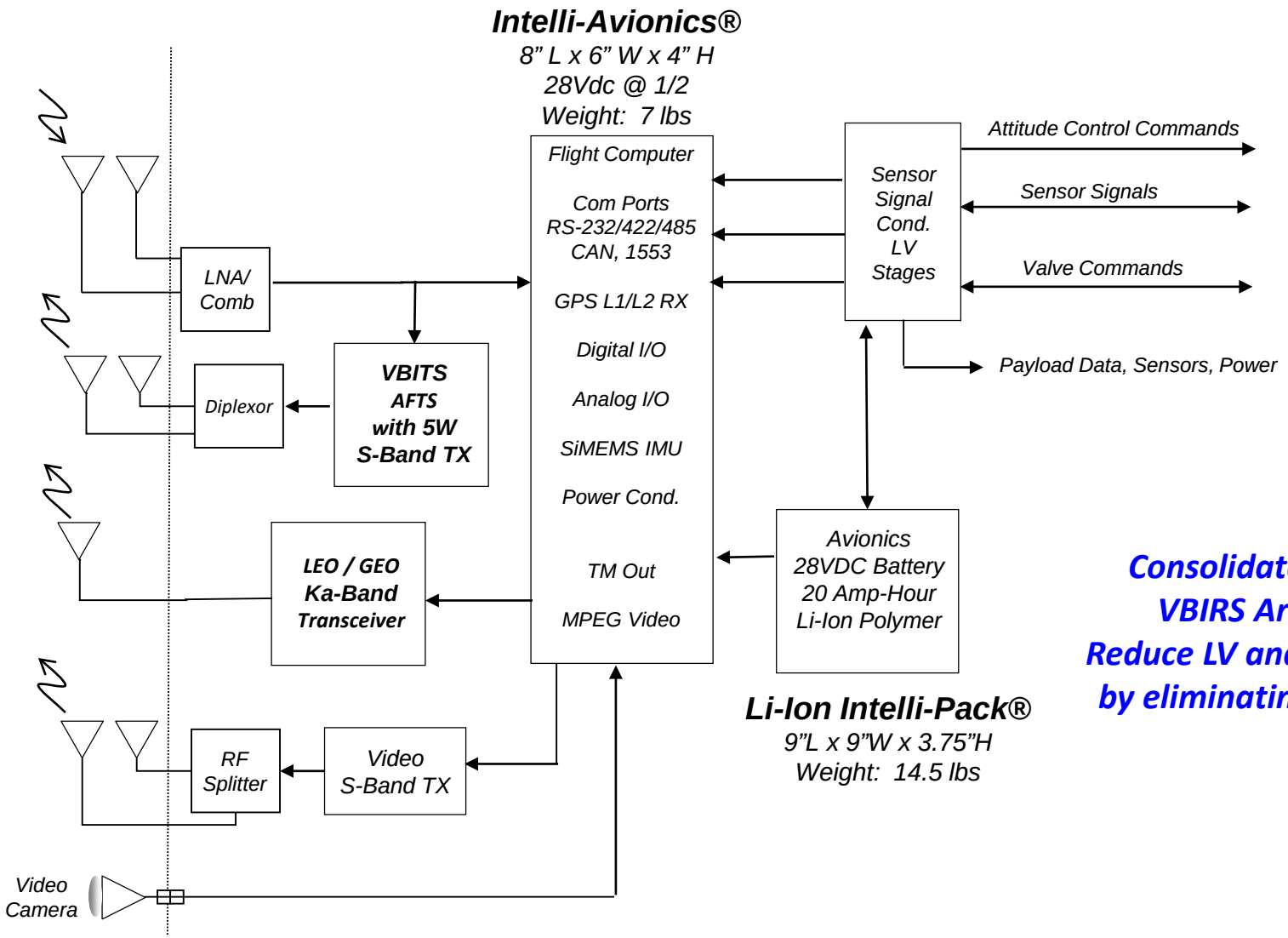
Powers All Active Systems

SIL VBIRS Missile Terminal

Heritage- LV Avionics Architecture



VBIRS – AFTS and Space Based Range NextGen LV Avionics Technology

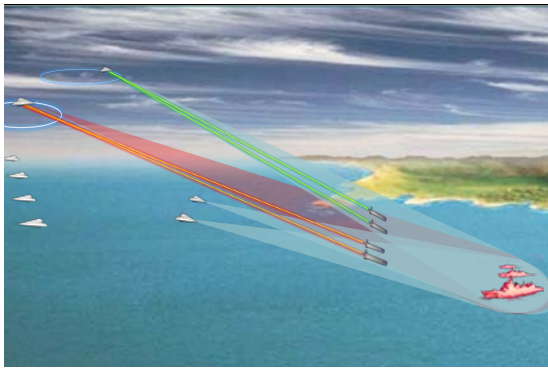


Consolidated Avionics®
VBIRS Architecture
Reduce LV and Lifecycle Cost
by eliminating Black Boxes

Vehicle Based Independent Range System Summary

- Implement BLOS High Data Rate Comm via GEO ViaSat Ka-Band
- Designed for future use with LEO Ka-Band Comm Constellations (2020-2025) with High Data Rate & Low Latency (< 100msec)
  - OneWeb, SpaceX, LEOSat, etc.
- VBIRS Open, Modular, Scalable and Reconfigurable (OMSR) Avionics is future proof through hardware, antenna pointing, machine language and automated decision for software upgrades
  - VBIRS OMSR hardware fully accommodates changing requirements
  - Fusion of PNT and Sensor Data Analytics, Machine Language Learning and Automated Decision Making
    - PNT, Sensors, Weapon System Characteristics, Environmental conditions used in Data Analytics
  - VBIRS OMR Avionics resistant to Technology Obsolescence thru stackable module upgrade and Delta Qual at economical price

Strike Weapon Kill Web



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