GPS World

GPS/PNT User Equipment Military/Civil/Commercial

A Guide to trends in GPS/PNT User Equipment

Presented By:
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GPS World

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Why GPS World and Not IDA?

- **21 years of Global PNT Receiver Survey Data**
  - ***Largest PNT receiver DB published annually***
  - ***Information from 55 global manufacturers***
  - ***Data on all aspects of 502 GPS, PNT (Multi-GNSS) receivers***
- **Largest known War Fighter PNT Requirements DB**
  - ***Thousands of war fighter responses over 10 years***
  - ***Wish List - What works and what does not***
  - ***Define the Perfect Handheld PNT Transceiver (PHPNTT)***
- **Using, testing, writing and speaking about GPS and PNT since 1978**

Top Ten War Fighter Requirements for the PHPNTT

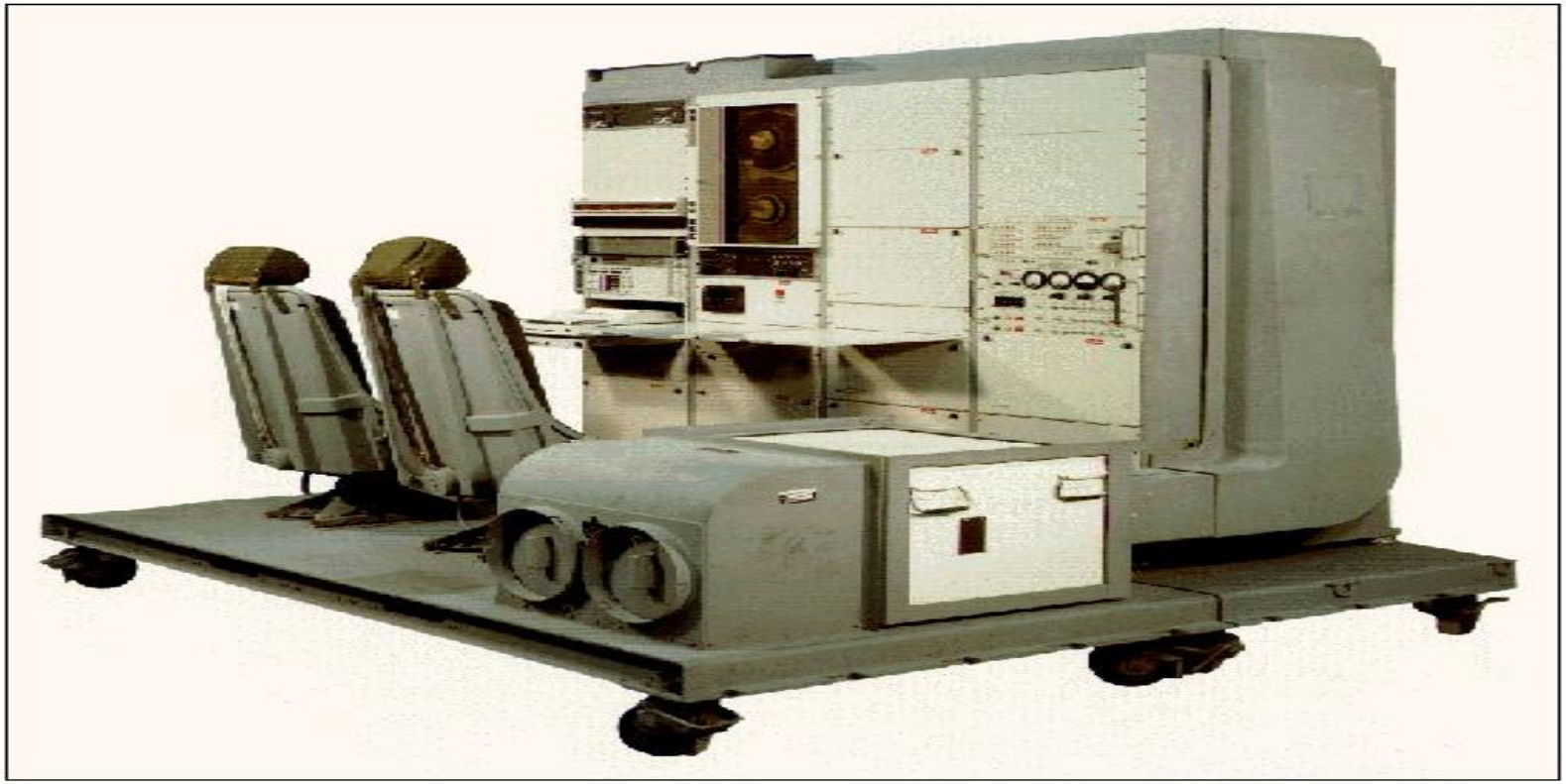
- **Mil Spec Rugged – Solid State Drive – No Moving Parts**
- **Friendly, Intuitive, Familiar Interface – Easy To Use**
- **Multi-GNSS – All signals available – Space & Terrestrial**
  - ***WiFi, eLORAN, Augmentations, Networks, Communications***
- **Wireless, portable, seamlessly networkable**
- **SWAP friendly, long battery life, with solar charger**
- **Real time 3D map data, NGA, Google, Satellite imagery**
- **Not a stand-alone device – embedded in a computer with multiple communication capabilities - secure**
- **Must be able to download and utilize new applications**
- **Software defined and expandable**
- **Act as a sensor with automatic reporting**

GPS User Equipment (MUE) Historical perspective

First GPS Military User Equipment (MUE)

Developed by Rockwell Collins in 1977

Initially utilized on orbit R&D SVs



GPS User Equipment (Commercial)
Historical perspective

First commercially viable GPS User Equipment

Developed by Phil Ward (GPS-IRT member)

For Texas Instruments in 1981

Evolution of Commercial GPS/PNT UE

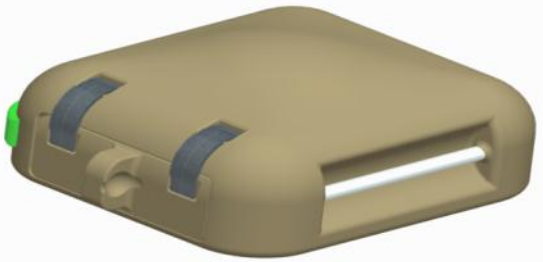
Garmin Wrist GPS Receiver

GPS Military User Equipment Historical and Current perspective CONT...

- **Rockwell Collins has been the primary GPS MUE provider - since 1977**

- Primarily with PLGR & DAGR
- 2012 = 500,000 + units fielded

2”x2”x1/2”
Future Army
Concept
“Puck”



MGUE – How not to build a PNT Device or Why War Fighters use Garmin's and iPhones

- Precision Lightweight GPS Receiver (PLGR) is **a single-frequency GPS** only receiver with a Security Module (PPS-SM) to access encrypted P(Y)-code.
- Fielded from 1990-2004. Replaced by (DAGR) Defense Advanced GPS Receiver
  - *Total of 165,000 PLGRs and 450,000 DAGRs fielded at a cost of more than $1B*
- Antiquated, proprietary OS and "extremely unfriendly – non-intuitive" user interface
- Not a functional handheld but functions well as embedded device - typically not networked
  - *Example: One STRYKER variant has nine separate DAGR's incorporated*
- PLGR decertified by US Marine Corp in 2010 due to friendly fire incidents
- DAGR used today primarily as embedded device only " horrible user interface"
  - *Monochrome screen, no active maps, navigation direct way-point only. Provides user with PNT information as coordinates – requires paper map to be an effective tool.*
  - *For other than straight line navigation - time, distance and ETA are incorrect.*
  - *Programming/mission planning require special cables, software and a laptop computer*
  - *Additional cables, radios and hardware required for PLGR or DAGR to communicate*
  - *Proprietary OS – no capability for additional programs to be added or utilized*
  - *SWAP issues – large, heavy, limited battery life (multiple batteries) for typical mission*
  - *TTFF – warm = 2+ minutes, cold with almanac download = 30+ minutes*
  - *Position accuracy expressed as PDOP (1-6) on separate screen from PNT data ~1m*
- **Advantages**: Anti-jam and legacy interface capabilities

Most Popular PNT Device in Theater Today – Over 250M sold

- Asst. GPS SBAS - WAAS (PNT)
- Asst. GLONASS (SBAS) (PNT)
- Digital Compass (PN)
- Wi-Fi (Comm-Data + PNT)
- Cellular (Comm-Data + PNT)
- Bluetooth (Comm-Data + PNT)
- Skyhook Wireless (PNT)
- Three Axis Gyro (PN)
- Accelerometer (PN)
- Pedometer (PN) – Application

All in 4 ounces

802.11n

Bluetooth

- Internet (Communications-Data) SKYPE- Application (PNT)
- Real Time accuracy and integrity representation (PN)
- 361+ Navigation applications designed for iPhone and iPad
- Real Time 3-D maps – Google maps - satellite imagery – updated continuously
- Automatic Location Based Services (LBS) – war fighter support
- BFT + other .mil App Store apps including multiple mil-GRID systems
- War Fighter discounts and mil spec hardened cases exist
- One button combat application

Most Popular COTS PNT Multi-GNSS Devices and Downloads

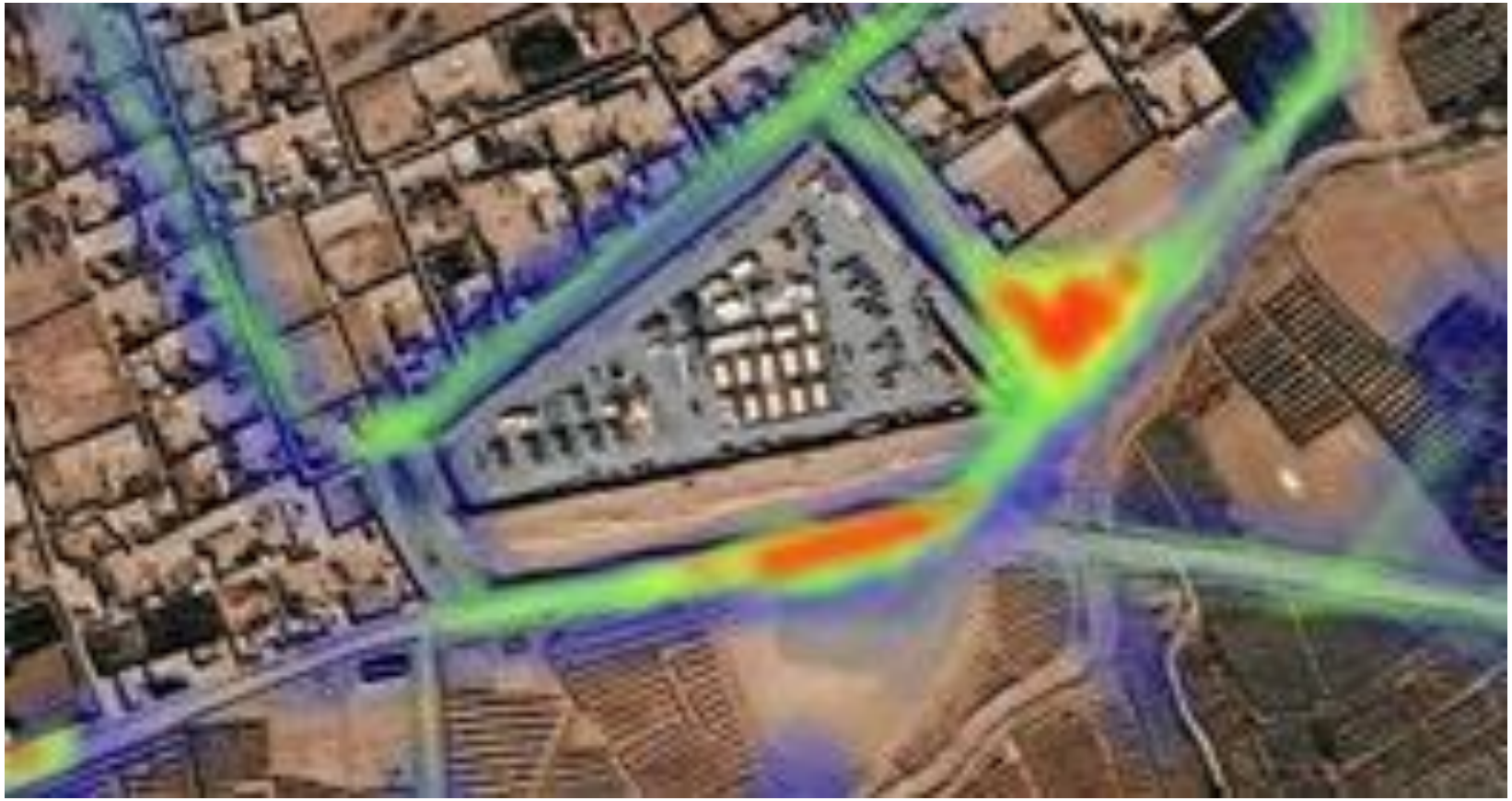
Products	Total Units Sold
☞ iPhone (2005)	250,600,000 (M)
☞ iPad (2010)	115,000,000 (M)
☞ iPhone/iPad App Store (2008) downloads (361 nav)	2,200,000,000+ (B)
◆ Garmin Sales (1989)	~100,000,000+ (M)

Future of PNT globally: Mobile devices capable of downloading and utilizing applications

DARPA & Smart COTS Devices on the Battlefield now!

- **DARPA, a DoD research arm, launched an effort recently called Transformative Apps. It developed a few dozen smart applications that work on a number of mobile devices. In addition to mapping, navigation and smart routes, the apps identify explosives, various weapons and help navigate and locate parachute drops.**
- **DARPA builds prototypes that are transferred to the Services and become official applications used by hundreds of thousands of war fighters.**
- **The challenge is to rapidly adapt COTS technology to the unique circumstances of the military, which often operates over large, hostile areas with little to no communications infrastructure.**
- **More than 1,000 war fighters in Afghanistan now use the technology as it continues to be rolled out to the Services.**

DARPA War Fighter Application



Garmin eTREX Saves Lives

"My name is SSG Kyle Dorsch…a Reconnaissance team leader in the 2-30 Infantry Battalion, 10th Mountain Division, deployed to the Logar province, Afghanistan**. I have used my Garmin eTrex Vista H throughout my deployment…it has been a lifesaver** in more than a literal sense. In fact, **there isn't a leader in our establishment without a Garmin product**…my Garmin guided me and my four-man team seamlessly through some of the toughest areas of Afghanistan…it also literally saved my life."

Pentagon Expected to Embrace Apple and Samsung Devices

- **The U.S. Department of Defense expects in coming weeks to grant two separate security approvals for Samsung's Galaxy smartphones, along with iPhones and iPads running Apple's latest operating system—moves that would boost the number of U.S. government agencies allowed to use those devices.**
  - ***WSJ - 1 May 2013***
- **Outstanding…but ten years late to need**

PNT User Equipment TRENDS
Space SIGNALS available

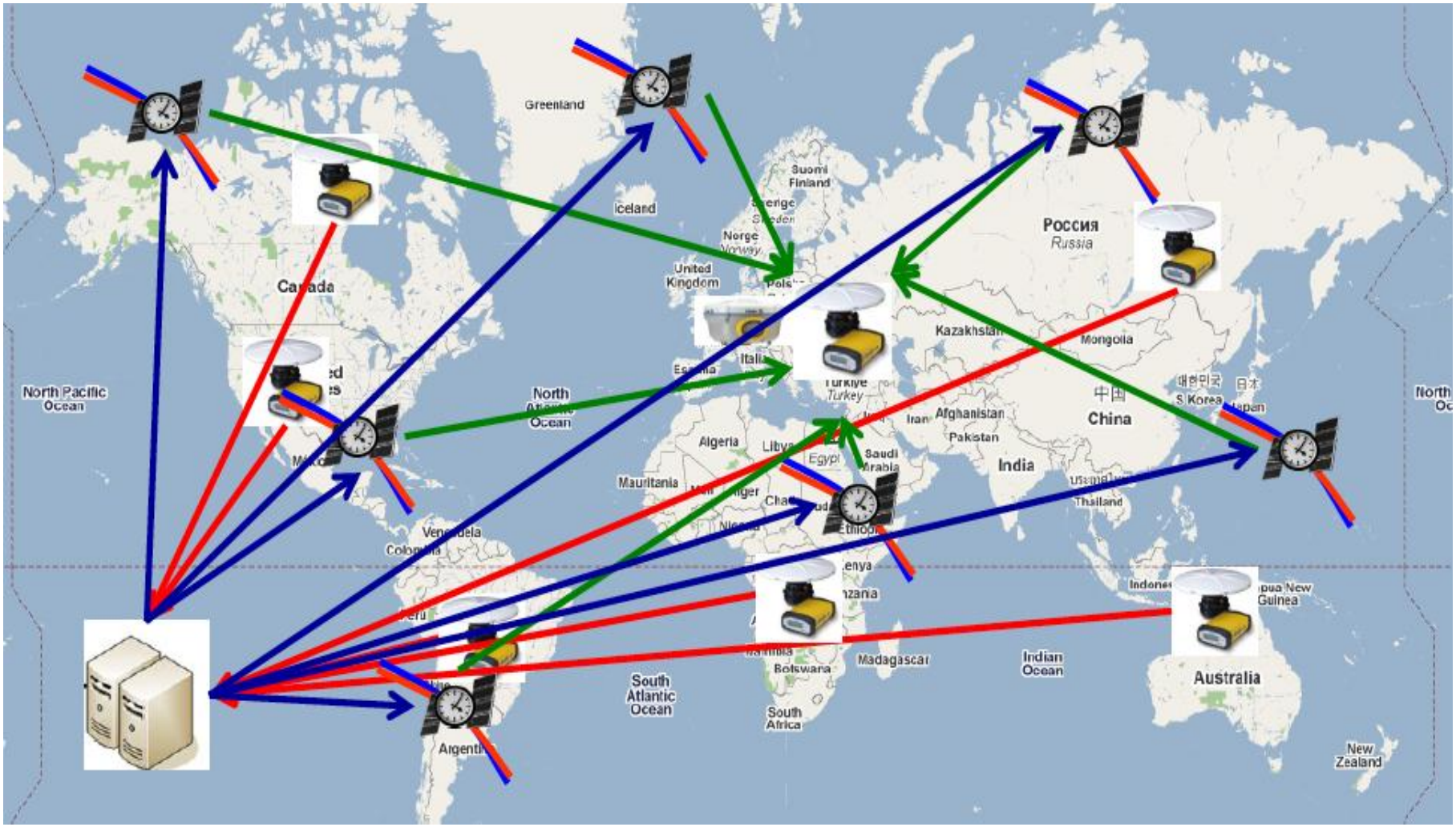
- **Civil-Commercial Multi-GNSS UE receives more space & terrestrial signals than US GPS MUE**
  - *GPS MUE 'officially' utilizes L1(CA), L2 P(Y) with SAASM (Selective Availability Anti-Spoofing Module)*
  - *No M-Code receivers today*
- **PNT UE philosophy: Track and Use All PNT Signals Available**
  - *GPS L1-CA/L2-codeless and ready for L2C, L5, L1C (GPS III & QZSS)*
  - *SBAS (WAAS, EGNOS, MSAS, GAGAN, SDCM) + DGPS & augmentations*
  - *GLONASS L1/L2/L5*
  - *Galileo E1/E5 (CBOC & Alt BOC)*
  - *Compass B1/B2/B3 (carrier signals only- no full signal specifications)*
  - *QZSS (Japanese GEO – highly elliptical) broadcasting L1 CA/C/SAIF, L2C, L5, LEX Pilot*
  - *WiFi, 3G-4G, Skyhook, eLORAN (UK), networks, CORS, VRS, GVRS*

Receive Everything – Trust Nothing

Multi-GNSS Technology Ready Today

- **GPS**
  - L1 C/A
  - L2C & L2 Enhanced Cross-correlation
    - L2C first shipped Q3 2003
  - L5
    - First shipped Q4 2005
- **GLONASS**
  - L1/L2 C/A & P
    - First shipped Q1 2006
- **SBAS**
  - DO-229D Compliant systems
  - WAAS/EGNOS/MSAS
- **Commercial SBAS**
  - OmniSTAR-HP/XP/VBS
  - L-band satellite link

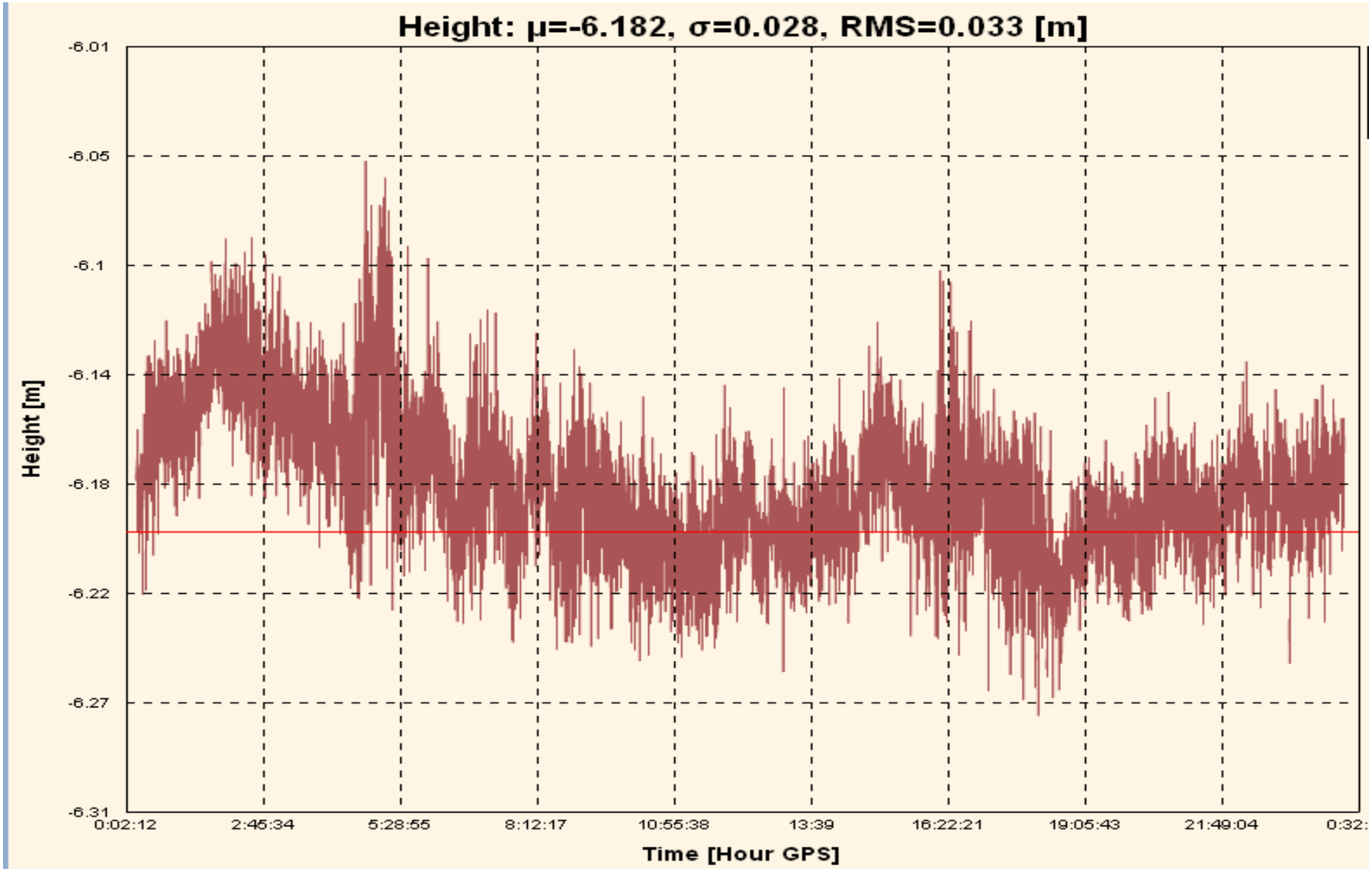
GVRS – Global Virtual Reference Stations



Multi-GNSS SVs in View – Commercial UE 40SVs/169 signals (MUE 10SVs/20 signals)

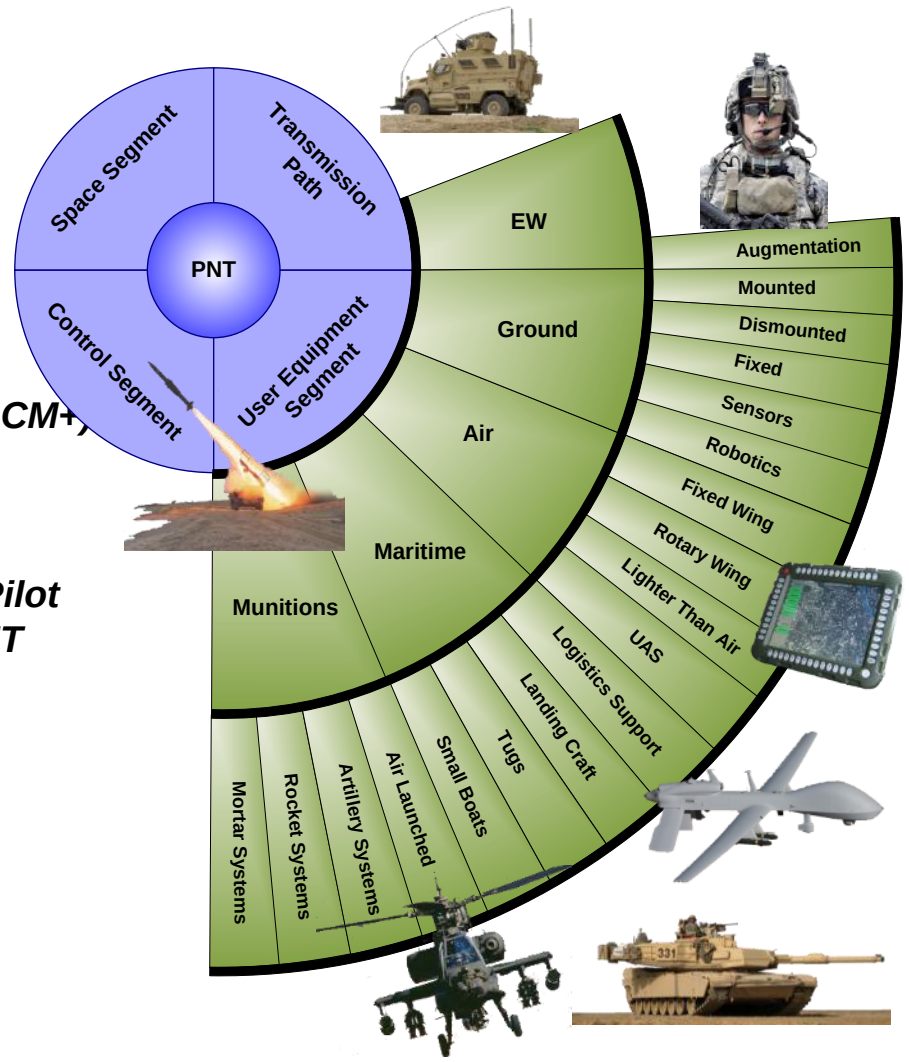
SV	Type	Elev. [Deg]	Azim. [Deg]	L1-C/No [dBHz]	L1	L2-C/No [dBHz]	L2	L5-C/No [dBHz]	L5	E6-C/No [dBHz]	E6
6	GPS	2.46	271.16	37.6	CA	13.9	E	-	-	-	-
9	GPS	16.05	29.93	41.1	CA	22.6	E	-	-	-	-
12	GPS	27.58	95.83	44.7	CA	31.1/39.2	E/CM+CL	-	-	-	-
14	GPS	28.36	309.16	43.7	CA	25.3	E	-	-	-	-
18	GPS	39.10	14.71	46.7	CA	33.2	E	-	-	-	-
21	GPS	78.78	214.21	45.5	CA	39.0	E	-	-	-	-
22	GPS	18.08	336.94	41.1	CA	22.9	E	-	-	-	-
25	GPS	38.83	139.81	46.7	CA	34.4/41.7	E/CM+CL	49.4	I+Q	-	-
27	GPS	3.91	31.67	-	-	-	-	-	-	-	-
29	GPS	18.81	168.74	42.2	CA	23.9/36.1	E/CM+CL	-	-	-	-
31	GPS	28.84	219.39	46.2	CA	32.5/39.2	E/CM+CL	-	-	-	-
1/G1	COMPASS	48.19	90.51	43.7	B1	-	-	42.3	B2	43.2	B3
3/G3	COMPASS	66.58	264.60	44.9	B1	-	-	43.0	B2	45.4	B3
4/G4	COMPASS	26.32	90.23	39.9	B1	-	-	36.1	B2	39.5	B3
5/G5	COMPASS	37.89	268.95	40.2	B1	-	-	38.6	B2	39.6	B3
6/I1	COMPASS	60.50	53.28	44.1	B1	-	-	42.4	B2	44.3	B3
7/I2	COMPASS	52.40	1.39	43.3	B1	-	-	41.7	B2	43.9	B3
8/I3	COMPASS	22.72	160.68	40.9	B1	-	-	37.6	B2	38.8	B3
9/I4	COMPASS	50.59	8.16	44.2	B1	-	-	42.5	B2	43.4	B3
10/I5	COMPASS	64.80	310.22	43.6	B1	-	-	42.3	B2	44.9	B3
11/M3	COMPASS	28.32	216.75	45.0	B1	-	-	43.8	B2	46.2	B3
12/M4	COMPASS	16.69	162.42	39.5	B1	-	-	37.8	B2	41.0	B3
14/M6	COMPASS	27.14	352.42	44.2	B1	-	-	42.3	B2	42.6	B3
11	GALILEO	10.59	282.38	41.9	CBOC	-	-	38.6/35.7/43.3	A/B/Alt	-	-
12	GALILEO	32.08	239.91	44.8	CBOC	-	-	42.3/39.1/46.8	A/B/Alt	-	-
4/6	GLONASS	11.03	92.27	42.4/40.5	CA/P	34.6/35.1	P/CA	-	-	-	-
5/1	GLONASS	23.54	40.84	44.9/42.2	CA/P	39.3/39.7	P/CA	-	-	-	-
6/-4	GLONASS	10.44	349.02	43.4/40.9	CA/P	38.6/39.2	P/CA	-	-	-	-
9/-2	GLONASS	53.73	195.44	47.3/45.9	CA/P	40.4/41.7	P/CA	-	-	-	-
10/-7	GLONASS	5.75	202.50	40.7/38.8	CA/P	27.9/30.5	P/CA	-	-	-	-
15/0	GLONASS	16.42	26.56	38.4/36.2	CA/P	37.6/38.8	P/CA	-	-	-	-
16/-1	GLONASS	66.50	40.40	49.2/47.2	CA/P	43.1/43.9	P/CA	-	-	-	-
19/3	GLONASS	13.15	177.77	42.6/40.8	CA/P	36.9/37.7	P/CA	-	-	-	-
20/2	GLONASS	28.72	231.99	36.8/35.1	CA/P	35.7/36.9	P/CA	-	-	-	-
21/4	GLONASS	15.00	281.98	40.6/38.9	CA/P	33.5/34.5	P/CA	-	-	-	-
193	QZSS	63.55	123.08	46.6/50.0/46.8	CA/BOC/SAIF	44.1	CM+CL	50.5	I+Q	44.3	LEX
125	SBAS	-45.00	0.00	-	-	-	-	-	-	-	-
126	SBAS	2.59	269.74	-	-	-	-	-	-	-	-
127	SBAS	33.98	268.81	42.0	CA	-	-	-	-	-	-
129	SBAS	48.12	91.74	40.6	CA	-	-	-	-	-	-
137	SBAS	42.46	91.45	41.3	CA	-	-	-	-	-	-

Commercial Multi-GNSS PNT VRS receiver Performance Over 24 HRS (3 cm)

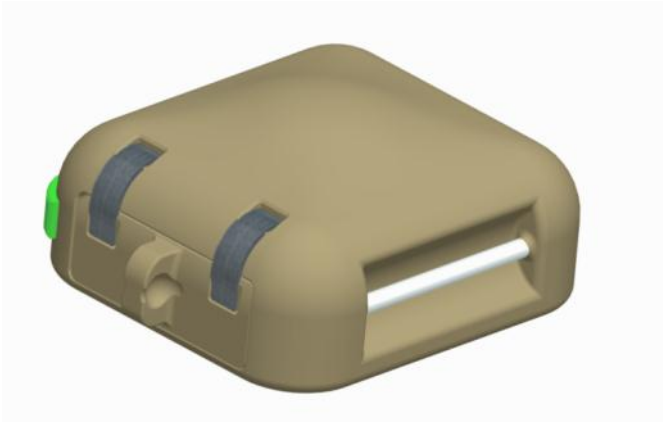


Assured PNT - Impacts and Capabilities

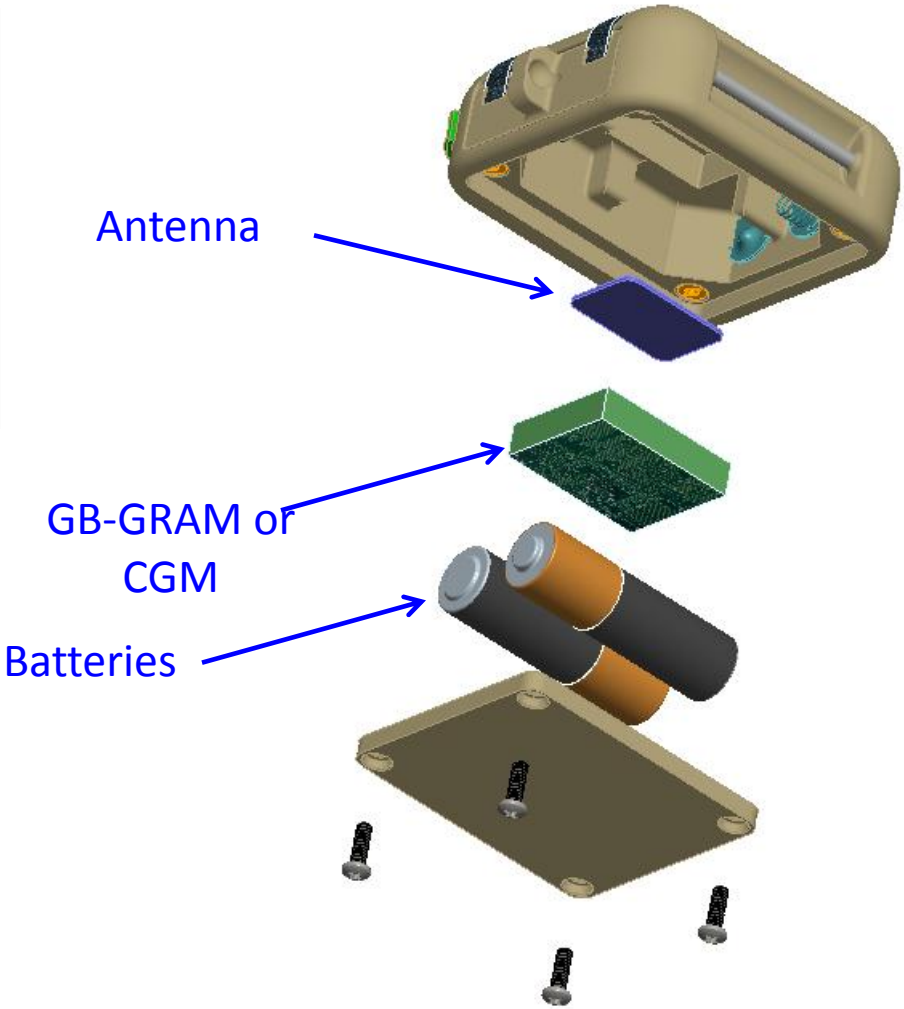
- **PNT impacts all platforms across all domains**
- **Assured MUE PNT Today**
  - *L1(C/A), L2 P(Y), SAASM (Future M-Code)*
  - *Accuracy ~ 1m*
- **Assured MUE PNT with all signals available**
  - *GPS L1/L2/L5/L1C/L2C/M-Code/SAASM*
  - *SBAS (WAAS, EGNOS, MSAS, GAGAN, SDCM+)*
  - *GLONASS L1/L2/L5*
  - *Galileo E1/E5 (CBOC & Alt BOC)*
  - *Compass B1/B2/B3*
  - *QZSS GEO – L1 CA/C/SAIF, L2C, L5, LEX Pilot*
  - *Two way communications, Networking, PNT servers, each PNT device with unique IP address and each PNT device serves as a sensor*
  - *Software definable devices*
  - *Multiple software applications (Apps)*
  - *Accuracy ~ 3 cm*



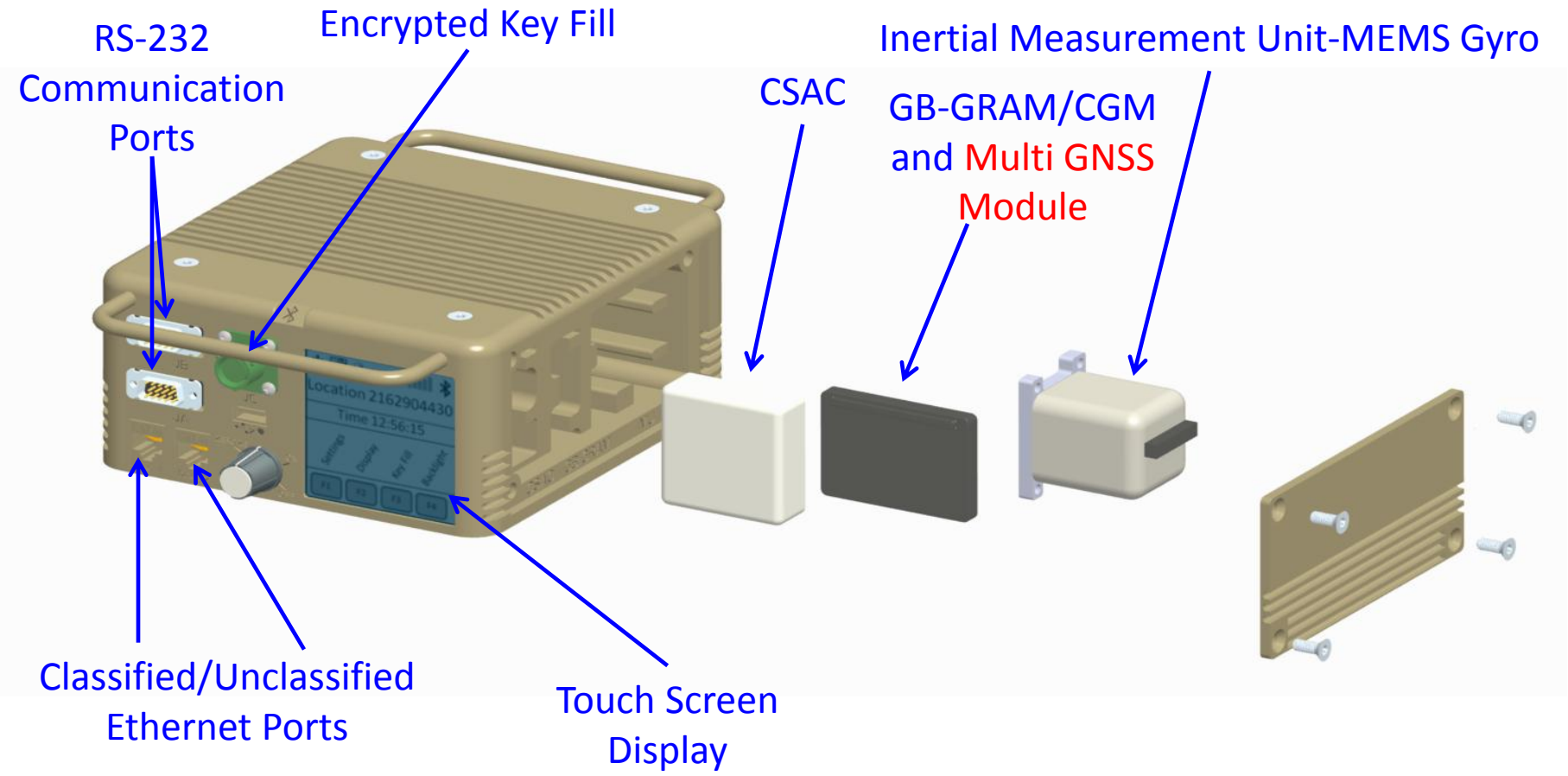
GPS Only MUE Puck



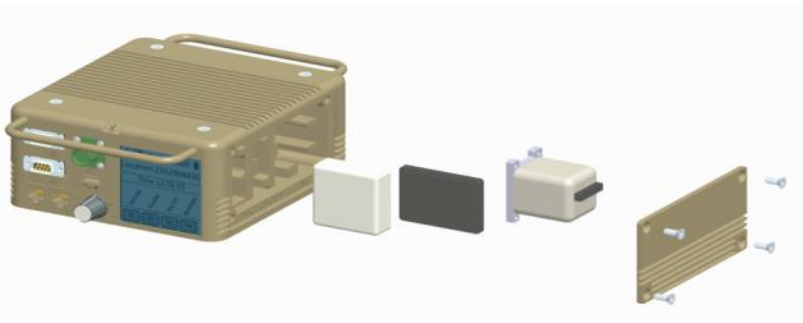
L1(C/A), L2 P(Y) & SAASM only



GPS/PNT/Multi-GNSS-All Signals Available Hub



YUMA 2 or Hub or Both



- Rugged **Windows computer** - touchscreen – daylight viewable – warrior mode
- All the capabilities of the DAGR including **SAASM + M-Code capable**
- WiFi, 4G, CDMA, GSM, Network and Skype communications
- Multi-GNSS plus WiFi, Network and SkyHook Wireless PNT capabilities
- Hundreds of PNT applications
- Military Mission Planning Platform - MilSpec certified and ruggedized
- RTK software with 2-4 cm accuracy capability built-in
- Program exist to incorporate all PUCK capabilities (CSAC, MEMS etc.)
- Military Service(s) ordered thousands of units

Conclusion
Services PNT UE Trends

- **Army has a Way Ahead with Assured PNT program**
  - ***Includes end of PLGR & DAGR and adding new networkable devices***
  - ***Plans for 4th Generation HH devices and embedded PNT devices as sensors to include the Puck and Hub***
- **Marine Corps: Decertified PLGRs (2009) and limits use of DAGRs**
  - ***DAGRs used primarily as embedded devices***
  - ***Purchasing approved SAASM devices from commercial vendors***
- **USAF: Outfitted 70% of aircraft with modern, integrated, networkable and upgradeable PNT devices**
- **Navy: More than 60% of the fleet outfitted with modern PNT networked devices**

One Size Does Not Fit All

Future of PNT

- **Multi-GNSS - Utilizing all PNT signals available**
  - ***Space and Terrestrial (GPS, GLONASS, eLORAN)***
  - ***Traditional and non-traditional (WiFi, GVRS, carrier signals)***
- **Multi-function COTS devices with non-proprietary OS, intuitive interfaces and Mil Spec ruggedized**
  - ***Multiple methods of communications***
    (WiFi, Skype, 4G, Text, Auto-text, satellite)
- **Software Downloads – Applications**
  - ***COTS applications plus .mil apps store***
- **Networked Devices for SA, updates and PNT**
  - ***Real time satellite imagery and mission data injects***
  - ***Defense and intelligence LBS***
- **Each device will be a sensor on a network**
  - ***Automatically report jamming, interference and location data***
- **Utilize SAASM & anti-jam military signals only as required**

Questions

- **Contact Information**
- **Don Jewell**  **djewell@gpsworld.com**
- **Phone:**

Commercial Coda for MUE

- **For commercial methods to work completely, as a MUE acquirer you must:**
  - ***Decentralize, so that decision-making is spread widely***
    - **Services and Agencies vice DoD wide procurement that results in one size fits all**
  - ***Shun procurements leading to supplier monopolies***
    - **Do not award every contract to a single supplier i.e. Rockwell Collins**
  - ***Take 80% of the capability you want along with capabilities you don't think you need***
  - ***Tolerate small scale failures***
    - **Cannot be 100% risk averse – historically DAGR failure rate exceeds most commercial and civil UE failure rates**
  - ***Always consider the user and the man-machine user interface***