Multi-Mode Position Navigation & Time (MM-PNT)

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Dan Leaf
Sector Vice President, Strategic Initiatives
Northrop Grumman Mission Systems
What Do We Mean by Multi-Mode PNT?

Synthesized Multi-Mode Position Navigation and/or Time solution(s) optimized for specific mission requirements

- GPS
- INS/IMU (eg, Gyro, Accelerometer)
- Other GNSS
- Altimetry
- EO/IR Imagery
- LIDAR
- Range Finding

FUSION

INTER-OPERATION
Why Multi-Mode PNT?

• MM-PNT can deliver:
  – Mission assurance despite GPS denial
  – Improved accuracy & timeliness
  – Exploitation of other mission capabilities for PNT

• Enabling:
  – Dismounted situational awareness and C2
    • Ground Forces Firefighters, other emergency services
  – Absolute or relative PNT
    • Proximity operations for unmanned vehicles in air, land, and sea
    • Sense and avoid
  – Precise, tailored target geolocation
Making Multi-Mode PNT Work

- **The Key:** data fusion & interoperation of disparate PNT-relevant sensors.

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<th>Trivial Selection</th>
<th>State of Practice</th>
<th>Emerging</th>
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<td>Selection of “best measure” at each sample point</td>
<td>INS + GPS</td>
<td>Improved accuracy &amp; timeliness</td>
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<td>Sensors Meet Mission</td>
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<td>Platform Reqs</td>
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<td>Functions Effectively</td>
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- **Emerging architecture:**
  - Networked multifunction assets contributing to PNT solution
  - Real-time filtering framework to optimally fuse sensor data

- **Examples of Emerging PNT Work:**
  - On-board sensors (e.g. EO/IR, SAR) used as navigation aids.
  - Comms system enables
    - Networked time maintenance, to facilitate satellite acquisition in GPS receiver
    - RF ranging to aid navigation system in fashion similar to GPS
    - GBAS / SBAS augmentation over networks

- **Key technical challenges:**
  - **Accuracy:** Achieving accuracy of fused solution exceeding the accuracy of underlying measurements. Today’s instruments are still challenged to meet most demanding PNT requirements.
  - **Availability:** Ensuring high availability of PNT when solution comes from a suite of sensors, each with limited availability.
  - **Integrity:** Real-time PNT solutions are fragile with respect to unmodeled errors in input data. Difficult to recover from a corrupted solution.
• Personal Navigation and Situational Awareness (Beacon)
  – Positions and status of dismounted soldiers, firefighters, civilian emergency personnel automatically networked to HQ/team leader
  – Adaptable referencing - for indoor ops, floor number may be the critical metric. MM-PNT overlaid against an alternative datum such as a CAD DB of building yielding relative position and altitude and convert to floor number and area to meet mission requirements

• Embedded GPS/Inertial (EGI) User Equipment for Dynamic Platforms
  – Tight/ultratight coupling of GPS with mature Gyro and Accelerometer-based INS/IMU solutions for improved accuracy and timeliness. EGI technologies enable popular GPS augmentations, e.g,
  – Space Based Augmentation System (SBAS): Global availability; provides better than 0.5M accuracy in real time; used in global, commercially available subscription services, including StarFire & Omnistar
  – LAAS, Local Area SCAT 1 Systems: Compatible with deployed Ground Stations
Existing / Emergent MM-PNT Implementations

• **Precision Dynamic Relative Navigation**
  High integrity coordinated navigation of multiple platforms in motion. Integrates sensors to provide predictive and reactive coordinated trajectories under physical kinematic constraints:
  – Aircraft carrier ops including arrested UAV landing
  – Automated Aircraft In-flight Refueling
  – Automated collision avoidance

• **Geolocation and coordinated surveillance of Time-Critical Targets**
  Geolocation capabilities from single platform vs. moving target to distributed multiple platform collaboration persistent surveillance. GPS + INS + imagery sensors + DTED + other databases = precision relative navigation and timing solutions

• **Major Size Weight And Power (SWAP) reduction for man-portable and small UAV platform applications**
Leveraging Multi-Mode PNT

- **SWAP Reduction for Nav Grade IMU:**
  Miniaturizing a Nav Grade IMU would enable MM PNT benefits to be realized for personal navigation and for miniaturized unmanned vehicles (UAV swarms, etc.), even when in GPS-challenged environments. And it would call for new MM-PNT techniques for GPS integration. Micro Nuclear Magnetic Resonance Gyro [\(\mu\text{NMRG}\)] in 1CC/5mW form factor, and Precision Micro Accelerometer [PMA] in 0.2CC/5mW form factor are now being pursued to achieve such IMU miniaturization.

- **Personal Navigation Advances:**
  - **Personal navigation, including Beacon.** A series of possible options for future products include: Miniaturization to reduce SWAP and extend battery refresh cycle to achieve Cigarette pack form factor, employing such technologies as MEMS IMU fusing non-traditional sensors, including comms, and reduced form factor radio & battery; UWB, other RF technologies for Ranging, network connectivity; Network-assisted GPS / navigation; Vision-aided personal navigation; LADAR aiding of IMU; Pedometry: human motion modeling of pedestrian navigation.
  - **Multi-phenomenological GPS devices.** Man-portable device exploiting such sources as alternate space-based PNT sources beyond GNSS; local PNT sources (e.g., local radio stations, radars, emitters); precision internal clock; ground altimetry; topology, magnetic/gravity maps/database. Also providing, e.g., manual laser rangefinder/illuminator; validation logic...
Future Multi-Mode PNT Possibilities

- **Expansion of usable space-based PNT sources:**
  - Leverage comm and other satellites with secondary GPS payloads – imbed the GPS “signal” in their data/comm stream
  - Add a Ground Based Laser Ephemeris Update System (GBLEU), a series of Earth stations with full space visibility, rapidly and autonomously determine the precise ephemeris of all GPS and GPS support spacecraft (GEO and LEO spacecraft carrying back-up GPS payloads (clocks/transmitters))
Closing Thoughts

• **Multi-mode PNT may be the next great leap in positional and chronological situational awareness**
  - Adapt “where and when” to meet very specific purposes by referencing platforms or facilities/fixtures
  - Dramatically expand PNT proliferation through size, weight and power improvements
  - Eliminate need for all capabilities need to reside in a single PNT source to achieve real PNT improvement
  - Enhance mission assurance by cross-referencing and multi-source integration including non-traditional PNT sources like networks

• **Maximizing the value of PNT is not just a technology matter; it requires domain knowledge of the mission space**