National Position Navigation
and Timing Architecture

APEC GNSS Innovation Summit

Karen Van Dyke, DOT/RITA/Volpe Center

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Overview

• PNT Architecture Background
• Architecture Development
• Vision, Strategy, and Vectors
• Way Forward
PNT Architecture Background

• Study requested by
  – Assistant Secretary of Defense for Networks and Information Integration
  – Under Secretary of Transportation for Policy
  – National Space-based PNT Executive Committee

• Justification - PNT Strategic Landscape is Changing
  – Gaps in current capabilities
  – Insufficient unity of effort towards future PNT capabilities

• Products
  – 20 year strategic outlook to guide near and mid-term decisions on PNT capabilities
National PNT Strategy Needed

- **Develop a Comprehensive PNT Architecture**
  - DSB Task Force on GPS Oct-2005
  - JROCM 187-06 Sep-2006
  - NSS Program Assessment Mar-2005
  - DoD PNT S&T Roadmap Apr-2006

- **Develop a Comprehensive National PNT Architecture**
  - Volpe GPS Vulnerability Sep-2001
  - Nat’l Approach to Aug. GPS Dec-1994
  - Civil AoA Briefing May-2005
  - Radionav Sys. Task Force Jan-2004

- **Conduct a Comprehensive Analysis of GPS Backup Navigation & Precision Timing Options**
  - DoD PNT S&T Roadmap Apr-2006
  - NSS Program Assessment Mar-2005

- **JROC Approves the PNT JCD & Validates the Five Gaps Identified**
  - DSB Task Force on GPS Oct-2005
  - JROCM 187-06 Sep-2006

- **Develop a Comprehensive PNT Architecture**
  - NSS Program Assessment Mar-2005

- **Determines the optimal integrated system for meeting requirements of Federal users**
  - JROCM 187-06 Sep-2006

- **Periodically Evaluate Radionavigation System Contributions to the Overall Mix**
  - NSS Program Assessment Mar-2005

- **Validate GPS Requirements vs. PNT Requirements**
  - JROCM 187-06 Sep-2006

- **Conduct a Comprehensive Analysis of GPS Backup Navigation & Precision Timing Options**
  - NSS Program Assessment Mar-2005

- **JROC Approves the PNT JCD & Validates the Five Gaps Identified**
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- **Determine the optimal integrated system for meeting requirements of Federal users**
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Foundations

RITA
FAA
JPDO
FHWA
FRA
DOC
NIST
DHS
USCG
DOI
State
NASA
NCO

ASD/NII Memo 23-Jan-2006

“NSSO develop a National PNT Architecture”

DOT/RITA Memo 14-Mar-2006

“RITA will lead effort on behalf of DOT for the civil community”

NPEC Action Items 26-Jan-2006

“NPCO will initiate an effort with NSSO”

PNT Architecture TOR 11-Jul-2006

More Effective & Efficient PNT and an Evolutionary Path for Government Provided Systems & Services
## National PNT Architecture Scope

<table>
<thead>
<tr>
<th>USERS</th>
<th>DOMAIN</th>
<th>MISSIONS</th>
<th>SOURCES</th>
<th>PROVIDERS</th>
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<tbody>
<tr>
<td>Military</td>
<td>Space</td>
<td>Location Based Services, Tracking, Survey, Scientific, Recreation, Transportation, Machine Control, Agriculture, Weapons, Orientation, Communications and Timing</td>
<td>GNSS, GNSS Augmentation</td>
<td>Military</td>
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<td>Homeland Security</td>
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<td>Terrestrial NAVAIDS</td>
<td>Civil</td>
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<tr>
<td>Civil</td>
<td>Surface</td>
<td></td>
<td>Onboard / User Equip Networks</td>
<td>Commercial</td>
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<tr>
<td>Commercial</td>
<td>Sub-Surface</td>
<td></td>
<td></td>
<td>International</td>
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<tr>
<td>Individual</td>
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Broad Scope Requires Innovative Approaches and Focused Analysis Efforts
"As-Is" PNT Architecture Graphic (2008)
Primary PNT Gaps

• Gaps primarily drawn from military’s PNT Joint Capabilities Document, with additions and modifications from parallel civil community documents and discussions
  – Physically Impeded Environments
  – Electromagnetically Impeded Environments
  – Higher accuracy with integrity
  – Hazardously Misleading Info (Integrity)
  – High Altitude/Space Position and Orientation
  – Geospatial information - access to improved GIS data (regarding intended path of travel)
  – Insufficient modeling capability
Primary Objective of the Architecture

“…provide more effective and efficient PNT capabilities focused on the 2025 timeframe and an evolutionary path for government provided systems and services.” -- Terms of Reference
Framework to describe user needs & environments, and which users are affected by each capability gap
Cumulative Process

Data Gathering

- PNT User Perspectives (2020)
- PNT User Perspectives (2020)

Needs & Gaps

- Functional Reference Model
- Environment, Technology & Evolved Baseline
- PNT Evolved Baseline (2020)

Concept Development

- Guiding Principles
  - VISION: US Leadership in Global PNT
  - STRATEGY: Greater Common Denominator
  - PRIMARY VECTOR: Multiple Phenomenologies
  - PRIMARY VECTOR: Interoperability Solutions
  - SUPPORTING VECTOR: Fusion of PNT with Communications
  - SUPPORTING VECTOR: Cooperative Organizational Structures

Trade Space, Features & Architectures

- Example RA: Dependent Terrestrial
- Example RA: PNT Architecture Example

Analysis & Assessment

- Analytical Framework

Community Involvement

- Architecture Development Team, Subject Matter Experts, Small Working Groups & Industry

Environment, Technology & Evolved Baseline

- Community Involvement
  - Architecture Development Team, Subject Matter Experts, Small Working Groups & Industry

Analytical Framework
Related Efforts & National Decisions

- Recent & Upcoming Decisions
  - Future of eLORAN
  - Future of NDGPS and High Accuracy NDGPS
  - Backup SATNAV Tasking
  - Backup PNT Needs (ADS-B, NGATS, Timing Infrastructure)
  - GPS III and OCX Acquisition Strategies

National PNT Architecture

- Joint Planning & Development Office
  - Next Generation Air Transportation System
  - SatNav Backup Study

- DOT and FAA
  - Aviation Navigation Evolution Roadmap
  - GPS Evolutionary Architecture Study

- National Space-Based PNT Coordination Office
  - 5-Year Plan & Assessment

- USSTRATCOM
  - PNT Joint Capabilities Document
  - PNT Functional Solutions Analysis

- DARPA
  - Focused PNT Technical Challenges

- RAND
  - Ensuring Effective PNT

- DHS/USCG
  - Timing Criticality Study

- NSSO
  - NSS Program Assessment
  - NSS Plan

- DOD
  - DOD PNT S&T Roadmap update

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MAINTAIN SHARED SITUATIONAL AWARENESS
Guiding Principles

**VISION**
US Leadership in Global PNT

**STRATEGY**
Greater Common Denominator

**PRIMARY VECTOR**
Multiple Phenomenologies

**PRIMARY VECTOR**
Interchangeable Solutions

**SUPPORTING VECTOR**
Synergy of PNT with Communications

**SUPPORTING VECTOR**
Cooperative Organizational Structures
National PNT Architecture Vision

US Leadership in Global PNT

• National PNT Architecture based on policy foundation set by 2004 Presidential Policy Directive on Space-Based PNT
• Efficiently (cost, schedule, acceptable risks, user impact) develop and field the best technologies and systems
• Promulgate stable policies (commitment to funding, commitment to performance, advanced notice of change, etc)
• Foster innovation through competition within the commercial sector
• Ensure robust and enduring inter-agency coordination and cooperation
• Maximize the practical use of military, civil, commercial and foreign systems and technologies
• Judiciously develop and apply standards and best practices
National PNT Architecture Strategy

The US can Best Achieve Efficiency and Effectiveness through a Greater Common Denominator Approach

• Satisfy common needs with common solutions
• Promulgate a predominantly “dependent” architecture where users rely upon external sources
• Leverage ongoing US GNSS modernization to assure global service and support national interests
• Promote adoption of low-burden “autonomous” features for robustness
• Specialized needs still require specialized solutions
• Balance provided or enabled capabilities with the need for a military PNT advantage
“Should-Be” PNT Architecture Graphic (2025)

Synergy of PNT and Communications

Interchangeable Solutions

Multiple Phenomenologies

ENABLERS & INFRASTRUCTURE

Standards Reference Frames Cryptography Science & Technology USNO NIST NGA NGS
Star Catalogs Launch Modeling Mapping/Charting/Geodesy Laser Ranging Network

Cleared for public release, distribution unlimited; SAF/PA case 2007-0613, 20 Sep 07
Next Steps

• NSSO, RITA & NII oversee development of detailed transition and implementation planning

• Hold Workshop to Obtain Industry Feedback on Recommendations When Publicly Released

• Architecture Implementation Memorandum
  – Approved event-based implementation timeline

• Influence update to PNT planning documents
  – Federal Radionavigation Plan
  – Five-Year National Space-Based PNT Plan
BACKUPS
Purpose of NSSO Architectures

• Enterprise Level Guidance
  – High Level Capabilities
  – Fundamental Processes
  – Organizations
  – Infrastructure

• Similar to City Planning
  – Considerations for how people, buildings, transportation, utilities work together
  – Effect of External Factors (e.g., weather, state jurisdiction, etc.)
  – Objective is not to design all the buildings
  – May conduct detailed design of some elements, primarily to gain understanding of higher level issues
Functional Reference Model

PTO: Position, Time and/or Orientation (including the time derivatives)
Concept Development

PNT Architecture Trade Space

- **Source Location** (of the service provider)
  - **Terrestrial**: concept provides service from, near, or beneath the surface of the earth
  - **Space**: concept provides service from space

- **Service Volume** (of the service provided)
  - **Local**: concept provides a meaningful service only at a fixed point
  - **Interplanetary**: concept provides a meaningful service throughout the solar system

- **Autonomy** (of the user)
  - **Dependent**: concept requires frequent refresh of information from external sources to provide a meaningful service
  - **Autonomous**: concept, once initialized, is self-contained and requires no refresh of information from external sources to provide a meaningful service
PNT Representative Architectures (RA)

0: Evolved Baseline
1: Dependent Terrestrial
2A: Combined GNSS Constellations
4: Network Aiding of GNSS
5: Aided Autonomous Sensors and Aiding Sources
6: Highly Autonomous

RA0 = EBL (Point of Departure)

RAs ARE NOT FINAL SOLUTIONS – THEY ARE USED TO GAIN INSIGHTS TOWARDS FINAL RECOMMENDATIONS
From Representative Architectures … to Recommendations

- Preliminary Analysis (Feb - Mar 07)
- Cost and Performance Analysis (Apr - Jul 07)

Representative Architectures

Hybrid Architectures

Should Be Architecture
- Recommendations
- Guidance
- Decision Criteria
Three Themes (Hybrid Architectures)

**Hybrid A**
- Common solutions for many users
- Horizontal integration
- Greatest common denominator
- Emphasis on global and long range broadcasts direct to users

**Hybrid B**
- Common solutions for many users
- Horizontal integration
- Greatest common denominator
- Emphasis on networks

**Hybrid C**
- Specialized solutions for each user group
- Vertical integration
- Least common denominator
- Emphasis on autonomous solutions
These features should be hybrid cornerstones:

- EBL Enablers
- GIS Data
- US GNSS
- Ground Based PNT
- Network

- INS
- Clock
- Stars
- Accuracy Augment
- Integrity Augment

These features/systems can contribute to covering primary PNT gaps; those which help the most, or which help to cover multiple gaps, should be included in hybrids:

- More Power
- Reduced Age of Data
- More Satellites
- LF/ELF PNT
- Network Aiding
- INS
- Multi Sensor Integration
- Topo Sensors
- “Here” Beacons
- Signal Diversity
- Redundancy
- Comm
- Higher Freq
- Cell Network
- Clock
- Signals of Opportunity
- Frequent Calibration
- MultiLat Beacons
- Stars

Version 18 Jul 07
Cornerstone Features:

Primary Gaps

<table>
<thead>
<tr>
<th>Category</th>
<th>Features</th>
<th>Gaps</th>
</tr>
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<tbody>
<tr>
<td>EM Impeded–Unintentional</td>
<td>EBL Enablers, Signal Diversity, More Power</td>
<td>LF/ELF PNT, Network Aiding, Cell Network, INS Clock, Multi Sensor Integration, Signs Of Opportunity, &quot;Here&quot; Beacon, MultiLat Beacon</td>
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</tr>
<tr>
<td>Higher Accuracy with Integrity</td>
<td>EBL Enablers, Reduced Age of Data, Redundancy</td>
<td>LF/ELF PNT, Network Aiding, Cell Network, INS Clock, Multi Sensor Integration, Signs Of Opportunity, &quot;Here&quot; Beacon, MultiLat Beacon</td>
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</tr>
<tr>
<td>Hi-Altitude Pos. &amp; Orientation</td>
<td>EBL Enablers, More Satellites</td>
<td>LF/ELF PNT, Network Aiding, Cell Network, INS Clock, Multi Sensor Integration, Signs Of Opportunity, &quot;Here&quot; Beacon, MultiLat Beacon</td>
</tr>
<tr>
<td>Access to Geospatial Data</td>
<td>EBL Enablers, GIS Data, More Satellites</td>
<td>LF/ELF PNT, Network Aiding, Cell Network, INS Clock, Multi Sensor Integration, Signs Of Opportunity, &quot;Here&quot; Beacon, MultiLat Beacon</td>
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**Selected features that can contribute to covering gaps**

- EBL Enablers
- GIS Data
- More Satellites
- LF/ELF PNT
- Network Aiding
- Cell Network
- INS Clock
- Multi Sensor Integration
- Signs Of Opportunity
- "Here" Beacon
- MultiLat Beacon
- More Power
- Signal Diversity
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- Higher Freq
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