July 28, 2010

MEMORANDUM FOR DISTRIBUTION

SUBJECT: National Positioning, Navigation, and Timing Architecture Implementation Memorandum

An interagency team led by the Office of the Assistant Secretary of Defense for Networks and Information Integration and the Department of Transportation's Research and Innovative Technology Administration recently concluded the National Positioning, Navigation, and Timing (PNT) Architecture transition planning activity pursuant to the 16 June 2008 Architecture Guidance Memorandum. The effort resulted in a National PNT Architecture Implementation Plan (Attachment 2).

As co-sponsors of this study, and in accordance with its Terms of Reference, we approve the National PNT Architecture Implementation Plan and provide it for participating agencies' consideration to inform their subsequent planning, programming, budgeting, and execution activities.

All objectives of the Terms of Reference have either been satisfied or are hereby relieved. As a result, the effort has been successfully concluded.

Questions regarding this action should be directed to Captain Kevin Andersen, USN (571-432-1433, NSSO.PNT@osd.mil).

Cheryl J. Roby
Acting Assistant Secretary of Defense for Networks and Information Integration/ DoD Chief Information Officer

Roy W. Kienitz
Under Secretary of Transportation for Policy

Attachments

1. Distribution
2. National PNT Architecture Implementation Plan

National Positioning, Navigation, and Timing Architecture

Implementation Plan

April 2010

Approved for Public Release

SAF/PA Case Number: 2010-0494

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EXECUTIVE SUMMARY

Background

The Assistant Secretary of Defense for Networks and Information Integration (ASD/NII) and the Under Secretary of Transportation for Policy (UST/P) sponsored a National Positioning, Navigation, and Timing (PNT) Architecture Study to "provide more effective and efficient PNT capabilities focused on the 2025 timeframe and an evolutionary path for government-provided systems and services." The co-sponsors approved that architecture and issued an Architecture Guidance Memorandum (AGM) on June 16, 2008. The implementation plan identifies the activities the PNT stakeholders' will need to undertake to implement the National PNT Architecture recommendations and provides essential supplementary guidance.

Rationale

PNT is integral to the infrastructure on which the U.S. economy and national security rely. Absence of a coordinated National PNT Architecture may result in greater operational risks, uncoordinated research efforts, potentially wasteful procurements, and could possibly impact architectures or other systems depending on PNT.

"As-Is" PNT Architecture

The current *de facto* PNT Architecture consists of an *ad hoc* mix of externally-provided and autonomous PNT sources as well as PNT augmentations that provide PNT to a wide array of civil and military users operating in space, air, land, and maritime environments. The U.S. government has identified a number of gaps in PNT capabilities that the current PNT architecture is unlikely to resolve.

"Should Be" National PNT Architecture

The National PNT Architecture Implementation Plan provides the architectural vision for U.S. leadership in global PNT by promoting a Greater Common Denominator Strategy, where the core needs of many users are efficiently met through externally-provided, commonly-available solutions, rather than by numerous, individually-customized systems. The vision and strategy are described by four vectors, which together support the complete guiding principles of the National PNT Architecture:

1. Multiple Phenomenologies – Use multiple phenomenologies to ensure robust availability.
2. Interchangeable Solutions – Strive for interchangeable solutions to enhance efficiency and exploit source diversity.
3. Synergy of PNT and Communications – Pursue fusion of PNT with new and evolving communications capabilities.
4. Cooperative Organizational Structures – Promote interagency coordination and cooperation to ensure the necessary levels of information sharing.

The relationship between the "As-Is" and "Should Be" architectures is illustrated in Figure 1. Note the "Evolved Baseline" Architecture that represents future PNT capabilities if actions are not initiated now to improve future capabilities.

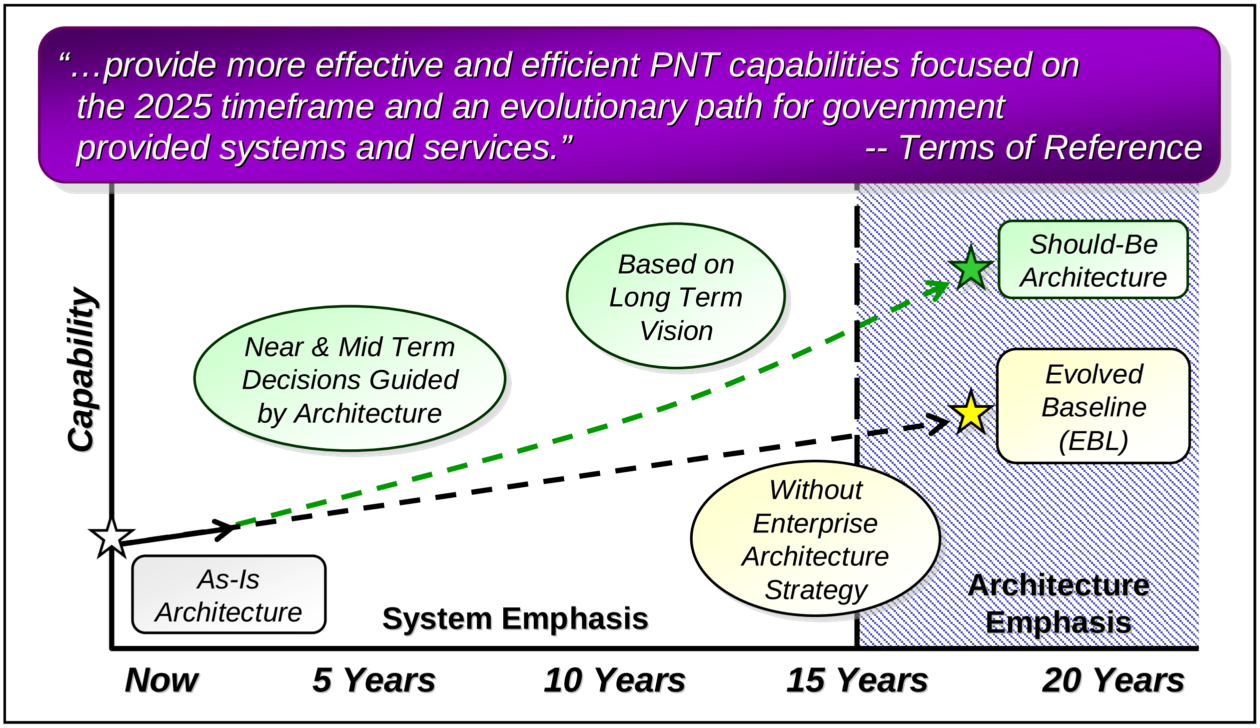

Figure 1: "As-Is" and "Should Be" Architectures in context

Implementation Strategy

The overall implementation strategy is to make focused and coordinated incremental investments to systematically change PNT capabilities and infrastructure in order to eliminate capability gaps and bring about significant efficiencies in acquisition and operation. This will involve analyzing and maturing PNT provider capabilities, user equipment, technology, management structures, and policies consistent with the National PNT Architecture strategy and vectors. Implementation of the PNT architecture implementation plan will require coordinated research, development, test, and evaluation to maintain U.S. leadership in global PNT.

Implementation Overview

This Implementation Plan is an interagency action plan consisting of transition elements that address the PNT Architecture strategy and vectors. PNT Architecture transition elements are the necessary, near-term, and executable tasks that must be implemented by interagency partners to transition the "As-Is" Architecture to a developing and more capable "Should Be" Architecture of 2025. Transition elements that start in the near-term are identified for stakeholder organizations to begin detailed planning; tasks that begin in the mid- to far-term are outlined more broadly since the specifics of their implementation depend on results which have not yet occurred. The Plan will be updated approximately every two years to take into account accomplishments or setbacks from previous versions and will also reflect changes in the PNT environment.

1 INTRODUCTION

The Assistant Secretary of Defense for Networks and Information Integration (ASD/NII) and the Under Secretary of Transportation for Policy (UST/P) sponsored a National Positioning, Navigation, and Timing (PNT) Architecture study to “provide more effective and efficient PNT capabilities focused on the 2025 timeframe and an evolutionary path for government-provided systems and services.” ASD/NII and UST/P co-sponsored the study in response to multiple Department of Defense (DoD) and civil agency recommendations to develop a comprehensive National PNT Architecture as a framework for developing future PNT capabilities and supporting infrastructure.

The co-sponsors approved the Architecture recommendations and issued an Architecture Guidance Memorandum (AGM), provided in Appendix A, on June 16, 2008. The AGM established a PNT Architecture Transition Team (ATT), consisting of PNT stakeholders and facilitated by the National Security Space Office (NSSO), to develop a PNT Architecture Implementation Plan defining the time-phased, fiscally-informed roadmap to guide implementation.

This document is the PNT stakeholders’ plan supporting the implementation of the National PNT Architecture recommendations and provides essential implementation information and guidance. Relevant acronyms and abbreviations are included in Appendix B; and reference documents are identified in Appendix C.

1.1 The Need for a National PNT Architecture

PNT is integral to U.S. national security, infrastructure, and prosperity; however, in most cases its role is not obvious. In terms of national security, PNT is vital to command, control, and communications capabilities and to all forms of precision operations such as locating targets, delivering weapons on target, and providing logistical support. From a national economic perspective, PNT plays a critical role in the operation of transportation, communications, power distribution networks, emergency response operations, and other critical infrastructures.

There is no existing architecture with a national perspective to guide U.S. government (USG) decisions for implementing PNT services or capabilities. For example, the Federal Radionavigation Plan (FRP) and the National Space-based PNT 5-year Plan address only the portion of the PNT Architecture related to radionavigation. It is an important part, but only one part, of the PNT Architecture, and does not guide other PNT capabilities. Absence of a coordinated PNT architecture may result in operational risks, uncoordinated research efforts, lack of clear developmental paths, potentially wasteful procurements, inefficient deployment of resources, and serious impacts to architectures, systems, and infrastructures depending on PNT.

The National PNT Architecture Implementation Plan highlights the importance of the supporting infrastructure necessary to implement and maintain future PNT services, addresses capability gaps projected to exist in the 2025 timeframe, and articulates recommended initiatives to close those gaps (or mitigate their effects). It does this by guiding future PNT capabilities that will sustain U.S. military, civil, and scientific activities through the mid-21st century or longer; motivating studies, analyses, and assessments for the development, demonstration, and implementation of PNT technology; and providing a coordinated framework to inform USG investment decisions regarding PNT.

1.2 "As Is" PNT Architecture

The "As Is" PNT Architecture is the current *de facto* architecture consisting of an *ad hoc* mix of dependent and autonomous PNT sources as well as augmentations that provide PNT to civil and military users operating in space, air, land, and maritime environments. PNT services are supported by a large number of PNT-enabling capabilities and infrastructure, and are provided in environments with spectrum, weather, fiscal, and geo-political challenges.

The "As-Is" PNT Architecture is characterized by widespread use of the Global Positioning System (GPS), government-provided GPS augmentations optimized for different user groups, for-profit commercial GPS augmentations, and non-space based systems that provide PNT services. These developments have greatly improved PNT capability over the past several decades, but the USG believes significant capability gaps are developing and will continue to grow since they are not fully addressed by the "As Is" PNT Architecture.

1.3 "Should Be" PNT Architecture

The "Should Be" National PNT Architecture implementation plan enhances U.S. leadership in global PNT by promoting a Greater Common Denominator Strategy, where the core needs of many users are efficiently met through commonly-available solutions, rather than by numerous, individually-customized systems. The strategy will be implemented through four vectors: PNT sources based on multiple phenomenologies; the ability to integrate data from different PNT sources into a single, common PNT solution; the synergy of communications and PNT capabilities; and the development of cooperative organizational structures.

The relationship between the "As-Is" and "Should Be" Architectures is illustrated in Figure 2. Note the "Evolved Baseline" Architecture that represents future PNT capabilities if actions are not initiated now to improve future capabilities.

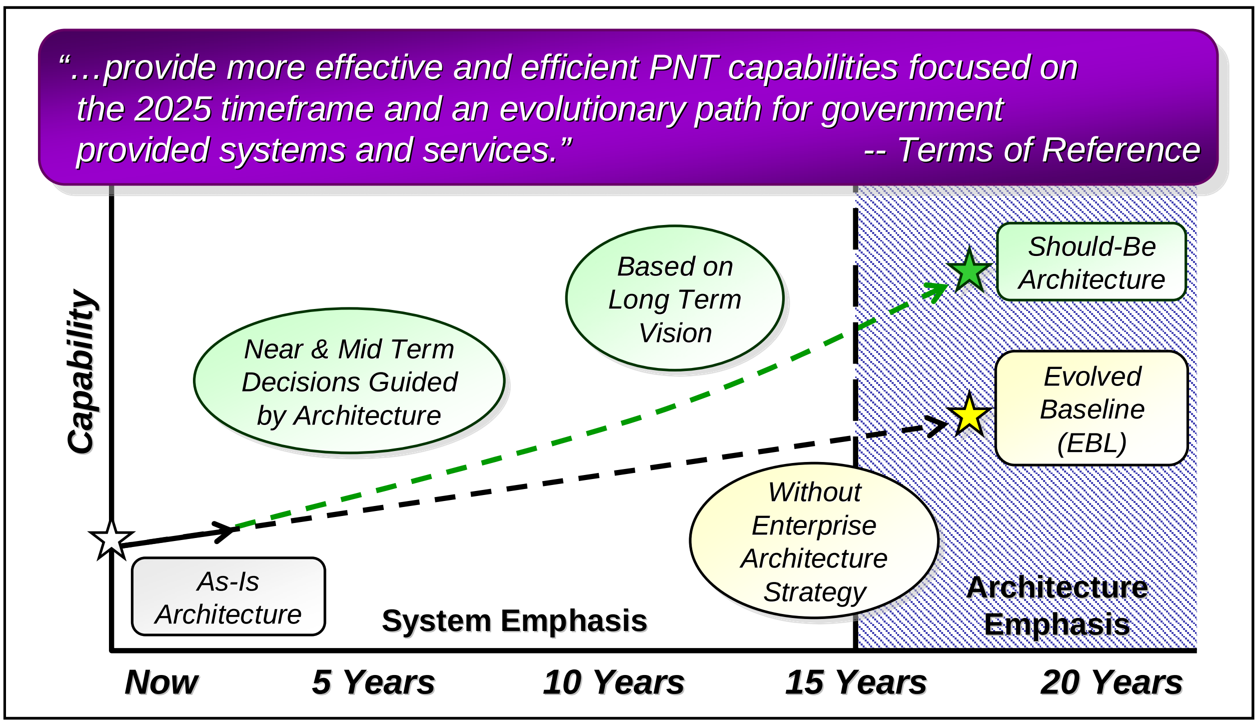

Figure 2: "As-Is" and "Should-Be" Architectures in context

The “Should Be” architecture is an enterprise architecture, with more work required to fully identify the needed and available capabilities to define a system-of-systems architecture. The tasks identified in Section 3 will result in information and investment guidance to advance the system-of-systems definition.

1.3.1 Vision

The National PNT Architecture Vision anticipates that the United States will maintain leadership in global PNT by efficiently developing and fielding effective PNT capabilities and making them available worldwide. The U.S. can achieve this vision by implementing the following practices:

- Enabling commercial sector innovation and advancement of government-provided PNT capabilities by developing and adhering to stable policies that will build domestic and international credibility with respect to commitments to funding, performance, advanced notice of change, *etc*.
- Providing PNT capabilities in a coordinated manner, sharing information, and presenting a unified view of national objectives by promoting interagency cooperation across the full scope of PNT activities.
- Maximizing the practical use of military, civil, commercial and foreign systems and technologies, and leading the effort to integrate available signals to achieve assured higher-performing PNT solutions.
- Developing and applying comprehensive standards and best practices, while encouraging others to adopt or align with U.S. capabilities.
- Encourage the adoption of U.S. developed standards and best practices through comprehensive development and application.

1.3.2 Strategy

The Greater Common Denominator Strategy is expected to make greater common core capabilities available to an unlimited number of users around the globe while addressing the uniquely stressing needs of a few users through custom solutions. The strategy therefore calls for the development of autonomous capabilities that balance the need for a national security advantage with the advantages inherent in providing greater common capabilities, in accordance with national policies.

1.3.3 Architectural Vectors

The vision and strategy are supported by four vectors, which together constitute the guiding principles of the National PNT Architecture Implementation Plan:

1. Multiple Phenomenologies – Use multiple phenomenologies to the maximum extent practical to ensure robust availability.
2. Interchangeable Solutions – Strive for interchangeable solutions to enhance efficiency and exploit source diversity.
3. Synergy of PNT and Communications – Pursue, where appropriate, fusion of PNT with new and evolving communications capabilities.

4. Cooperative Organizational Structures – Promote interagency coordination and cooperation to ensure the necessary levels of information sharing.

Multiple Phenomenologies

Multiple phenomenologies refer to diverse physical phenomena such as radio frequencies, inertial sensors, and scene mapping, as well as diverse sources and data paths using those physical phenomena (*e.g.,* multiple radio frequencies) to provide interchangeable solutions to the user; it also addresses issues related to standards, criteria of use (especially when incorporating foreign data sources), and mixing ground-, air-, space-based, and internal data sources for a single solution. The National PNT Architecture Implementation Plan promotes the use of multiple phenomenologies to ensure robust availability and to address the capability gaps listed in Section 2.3.

Interchangeable Solutions

Interchangeable solutions refer to the ability to combine signals from multiple data sources into a single PNT solution, as well as the ability to provide a solution from an alternative source when a primary source is not available. It presumes a leadership role by the U.S. in international forums as part of the effort to establish clear, reasonable standards to enable efficient, effective exploitation of diverse PNT data sources. The National PNT Architecture Implementation Plan promotes interchangeable solutions to provide the flexibility needed for timely, accurate, and reliable PNT solutions that meet user needs regardless of the data sources available.

Synergy of PNT and Communications

Data communications networks can support PNT capabilities by providing PNT aiding and augmentation data, geospatial information, *etc*. The National PNT Architecture Implementation Plan leverages users' increasing connectivity to more capable communications networks in order to use those networks as sources of PNT, not merely as data channels for PNT aiding and augmentation data. This vector promotes the fusion of PNT features with new and evolving communications capabilities (*e.g.*, wireless networks), in ways which will benefit both technologies , and in particular, which will enable increased PNT robustness by providing PNT data sources outside of the traditional radionavigation spectrum.

Cooperative Organizational Structures

The effective implementation of the National PNT Architecture Strategy and subsequent architecture development efforts require interagency coordination and cooperation. This vector promotes coordination between the responsible organizations to ensure effective operations, efficient acquisition (for both data source equipment and user equipment), and relevant science and technology application development. This vector also incorporates an enterprise-level PNT modeling and simulation capability to benefit, for example, mission planning and user equipage decisions.

2 TRANSITION PLANNING OVERVIEW

The process for transitioning from the "As-Is" Architecture to a "Should-Be" Architecture involves systematic implementation of the recommendations associated with the architecture vision, strategy, and vectors identified in the architecture development phase and conveyed in the Architecture Guidance Memorandum. This section addresses the transition planning objectives, development responsibilities, and the activities of the ATT in creating the implementation plan.

2.1 Transition Planning Objectives

The objective of the transition planning phase was to develop an implementation plan that would provide a limited, prioritized, fiscally-informed and time-phased list of tasks for stakeholders to support implementation of nineteen recommendations developed by the Architecture Development Team (ADT) to support the vision and strategy of the PNT Architecture.

2.2 Architecture Recommendations and Transition Planning Responsibilities

The PNT stakeholders formed the ATT to develop this implementation plan for the nineteen recommendations previously approved by the PNT Architecture co-sponsors:

1. Maintain GPS as a cornerstone of the National PNT Architecture.
2. Monitor PNT signals to verify service levels, observe environmental effects, detect anomalies, and identify signal interference for near real-time dissemination.
3. As GPS modernization or other methods demonstrate new operational capabilities, agencies should transition or divest U.S. Global Navigation Satellite System (GNSS) augmentation assets that are unnecessarily redundant to their requirements.
4. Continue to investigate methods to provide high accuracy with integrity solutions for safety-of-life applications.
5. Develop a national approach to protect the military PNT advantage.
6. Encourage appropriate development and employment of equipment that integrates information from diverse sources and information paths.
7. Assess the potential for the use of foreign PNT systems for safety-of-life applications and critical infrastructure users and, as appropriate, develop clear standards and criteria for their use.
8. Continue military PNT exclusive use policy while studying development of capabilities to enable military use of other signals.
9. Promote standards for PNT pseudolites and beacons to facilitate interchangeability and avoid interference.
10. Study evolution of space-based and terrestrial PNT capabilities to support diversity in PNT sources and information paths.
11. Ensure critical infrastructure precise time and time interval users have access to and take advantage of multiple available sources.

12. Use participation in international PNT-related activities to promote the interchangeability of PNT sources while assuring compatibility.
13. Evolve standards, calibration techniques, and reference frames to support future accuracy and integrity needs.
14. Identify and develop common standards that meet users’ needs for PNT information exchange, assurance, and protection.
15. Establish common standards that meet users’ needs for the depiction of position information for local and regional operations.
16. Identify and evaluate methods, standards, and potential capabilities for fusion of PNT with communications.
17. Develop a national PNT coordination process.
18. Identify and leverage centers of excellence for PNT phenomenology and applications.
19. Define, develop, sustain, and manage a PNT modeling and simulation core analytical framework.

The Transition Planning Responsibilities matrix shown in Figure 3 identifies the PNT stakeholder organizations and their responsibilities for developing the implementation plan: organizations with primary responsibilities (OPR), organizations with coordination responsibilities (OCR), observers, and facilitators.

	Role Definitions	DoD																	Civil & Interagency											DHS		
	★ Office of Primary Responsibility (OPR) ● Office of Collateral Responsibility (OCR) ○ Observer ◆ Facilitator	AFSPC	JS	NGA	NRL	NSA	OASD/NII	OUSD/AT&L/S&T	PBFA	SAF/USA	SMC	SMDC	USA	USAF	USMC	USN	USNO	USSTRATCOM	DOC	DOI	DOS	DOT/RITA	FAA	FHWA	FRA	JPDO	NASA	NIST	NCO	DHS	USCG	NSSO
	Greater Common Denominator																															
1	GPS - An Architecture Cornerstone	●	●				★	○		●	○			●			●	●	○		○	●	●			○	●					◆
2	PNT Signal Monitoring & Dissemination	●		●			★		●	○	○			●			●		●	●		●	★			○	●			●	○	◆
3	Augmentation Transition Opportunities	●	○				★	○	●	○	●			●		●	○	●	●	●		★	★		●	●	●				●	◆
4	High Accuracy with Integrity			●	●			●		○	●						○			○		★	●	★	●	●		○				◆
5	Protect Strategic Advantage	●	●				★	●	○	●	●	○	○	●	●	○	○	●	○			●	●								○	◆
	Multiple Phenomenologies																															
6	Integrated User Equipment		○	○			★	●	○	●	●	○	○	●	○	●	●		○	○		●	●			●		●			●	◆
7	Civil Use of Foreign PNT		○		●		○		●	●	●						●	○	○	○	○	★	●	●	●	●	●			★	●	◆
8	US Military Use of Non-Military Signals	●	●	○		●	★	●	●	●	●	○	●	●	●	○	●	●													○	◆
9	PNT Pseudolites & Beacons						●			○	●	○	★	●	○		○	●		○		★	●	●	●	○	●	●				◆
10	Evolution of PNT Capabilities	●	○		●		●	★		○	●	○				●	●	●				★	●	●	●	●	●	●		○	●	◆
11	Critical Infrastructure & Time				●		○	●		○	○				○		★	●				●	●			○	●	●		★	●	◆
	Interchangeable Solutions																															
12	Interchangeability with Foreign PNT Sources		○	○	●		●		○	●	●					●	●		○	○	★	●	●			○	●	○	●		○	◆
13	Standards & Reference Frames			★	●		○	○		○	●					●	★		●	○	○			○		○	●	●				◆
14	Information Exchange, Assurance & Protection	●	○	○	●	●	★			○	●			●		○	○	★	○	○		●	●			○		○		●		◆
15	Grids & Coordinate Systems		★	●			●			○	○		●	●	●	●	○	●	●	●							●			★	●	◆
	Synergy of PNT and Communications																															
16	Synergy of PNT and Communications	●	○		●	●	★	●		●	●		●	●	○	●	●	★				★	●	●		●	●			○		◆
	Cooperative Organizational Structures																															
17	National PNT Coordination Process		●				★	●		●	○					○	●	●	●	○		★	●			●	●	●	●	★		◆
18	Phenomenology & Application Champions		○	○			●	★		●	●		○			●	○	●	○	○		●	●			○		●	●	●	●	◆
19	Modeling & Simulation Framework	○			○		★	●		○	●		○	●		●	○	●	○			●	●			○	●		●	○	○	◆

Figure 3: Transition planning responsibilities matrix

2.3 Transition Planning Activities

The ATT identified nearly 350 tasks and sub-tasks needed to implement the nineteen approved recommendations. These tasks address Federal government activities and research efforts to improve the overall effectiveness of U.S. government PNT. These activities will systematically address projected gaps and opportunities for increasing efficiency.

2.3.1 Enterprise Effectiveness

A large number of tasks are focused on filling the current and projected gaps in our PNT capabilities. The following PNT gaps derived from the PNT Joint Capabilities Document, the FRP, and various civil documents:

1. Assured and real-time PNT in physically impeded (PI) environments.
2. Assured and real-time PNT in electromagnetically impeded (EMI) environments, to include operations during spoofing, jamming and unintentional interference.
3. Higher accuracy with integrity (HAWI) needed, especially for future highway and rail applications.
4. Timely notification (as short as one second in some situations) when PNT information is degraded or misleading, especially for safety-of-life applications or to avoid collateral damage.
5. High-altitude/space position and orientation (HSPO), to include real-time high-accuracy position and orientation (<ten milliarcseconds) information.
6. User access to timely geospatial information for successful navigation.
7. PNT modeling capabilities in impeded conditions to determine impacts, more timely modeling capabilities, and a capability to predict impacts in urban environments.

2.3.2 Enterprise Efficiency

There are also a number of tasks that will help improve the overall efficiency of the PNT Architecture by improving PNT capabilities, reducing or avoiding costs, eliminating unnecessary redundancy, improving schedules, or other means.

2.3.3 Selecting the Initial Tasks

The ATT identified nearly 350 tasks, but selected a set of the most necessary and immediate tasks for interagency action in order to improve programmatic executability. The ATT selected a subset of tasks from the total number by using the following criteria:

- Necessity – The ATT included those tasks absolutely necessary to realize the key elements of the PNT Architecture strategy and supporting vectors.
- Immediacy – The ATT selected tasks which could begin execution within the “two-year” horizon of the implementation plan. Tasks expected to start in the mid- to far-term were characterized using broad outlines since the specifics of their implementation will depend on the results of near-term actions which have not yet been completed.

3 TRANSITION ELEMENTS

The PNT Architecture transition elements are the necessary, near-term, and executable tasks that must be implemented by the interagency stakeholders to transition to a “Should Be” Architecture.

This implementation plan is an interagency action plan which will be updated approximately every two years. These updates will take into account accomplishments or setbacks from previous versions and will also reflect changes in the PNT environment, including technology evolution, alterations in national or agency policies, PNT program changes, and new or altered PNT requirements.

Transition elements that start in the near-term are identified for the stakeholder organizations to begin detailed planning; tasks that begin in the mid- to far-term are outlined more broadly since the specifics of their implementation depend on the results which have not yet occurred.

3.1 Roadmap to 2025

This section discusses the U.S. PNT Roadmap to 2025 in the context of the overall strategy and each of the supporting vectors. The presentation for each element consists of a general text summary of the implementation tasks, a high-level illustration of the applicable portion of the overall roadmap, and a list of approved tasks that are executable, immediate, and necessary to implement that element of the architecture recommendations. The roadmap illustration for each vector identifies activities that are or will be on-going and other activities needed to establish a foundation for the vector, evaluate and develop new architecture elements, and implement new capabilities.

3.1.1 Greater Common Denominator Strategy

The overall plan to implement the strategy, as illustrated in Figure 4, is to modernize GPS; plan for divestment of projected unnecessarily redundant GNSS augmentation assets or services; and identify, establish, and monitor levels of service provided by PNT systems. The plan also calls for exploring HAWI needs, technologies, solutions, and implications; modernizing PNT user equipment; reviewing and revising PNT export controls as well as NAVWAR technologies and techniques; and developing faster methods of equipping PNT users with new capabilities.

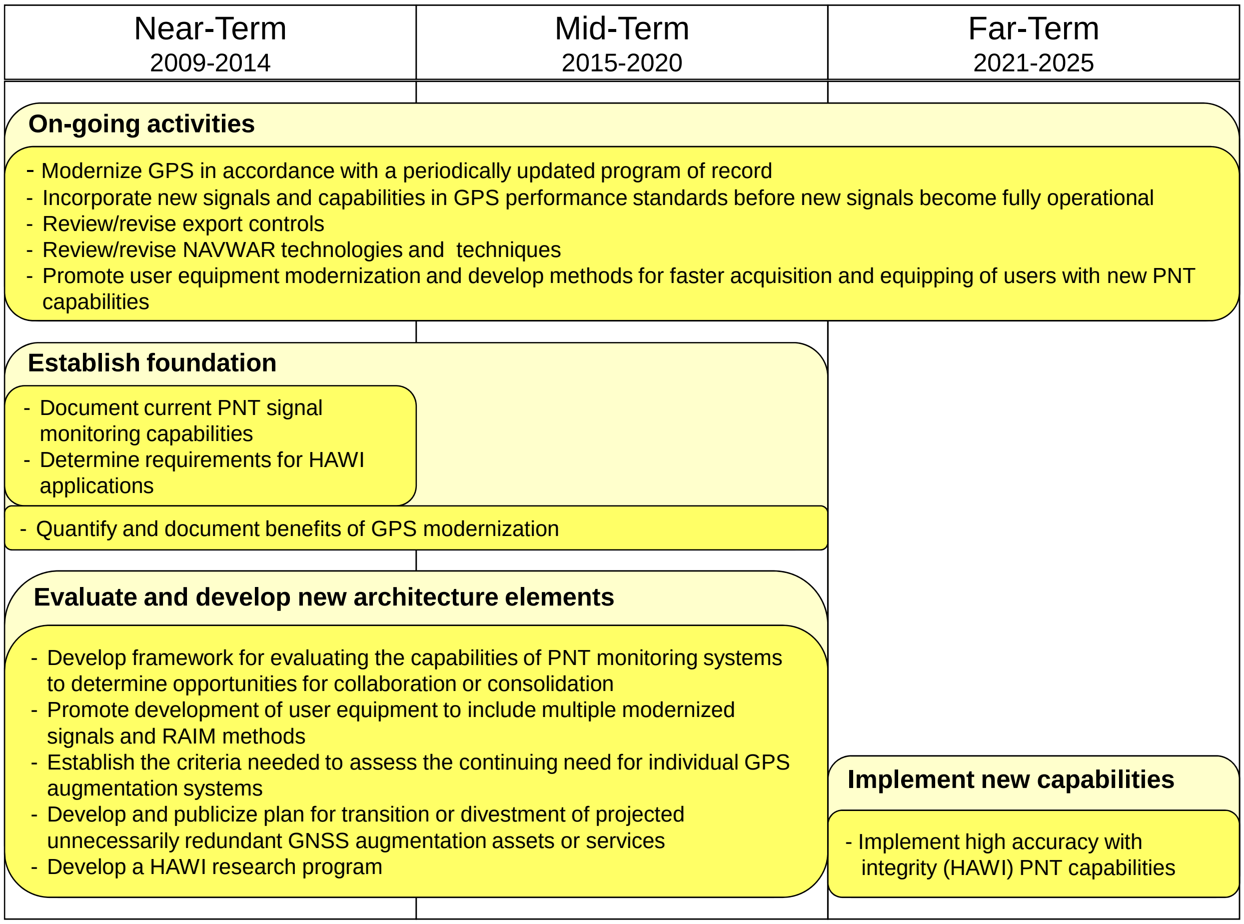

Figure 4: Roadmap to implement the Greater Common Denominator Strategy

The necessary and immediate tasks to implement the Greater Common Denominator Strategy are:

1. Modernize GPS in accordance with periodic program-of-record updates.
2. Incorporate new signals and capabilities in GPS performance standards before the new signals and capabilities become fully operational.
3. Document the current status, future needs, and projected shortfalls in the capability to monitor sources of PNT information, including the monitoring systems, best monitoring practices, and standards that will ensure the appropriate performance of systems used for PNT monitoring.
4. Establish a common approach for defining “integrity,” define a process consistent with statutory responsibilities to establish the level of PNT integrity needed to assure high accuracy navigational solutions for specific HAWI applications, and identify applications that may need HAWI.
5. Develop a coordinated HAWI research program.
6. Review the PNT export control regime’s suitability to address autonomous systems and integration technologies and present the results to the DoD PNT Working Group.
7. Develop methods for faster acquisition/equipage of new PNT/NAVWAR capabilities.

8. Develop a framework for evaluating capabilities of PNT monitoring systems to determine opportunities for collaboration or consolidation.
9. Promote development and use of improvements to user equipment to include multiple modernized signals, and receiver autonomous integrity monitoring (RAIM) methods.
10. Establish the criteria needed to assess requirements for individual GPS augmentation systems and to evaluate transition or divestment of augmentation assets or capabilities.

Implementing the plan will allow PNT users and providers to close the identified PNT gaps and shortfalls with combinations of robust PNT services. Modernization of the GPS provides a common cornerstone of capability for all users. Modernized GPS signals help in impeded environments, though these capabilities must be reflected in updated GPS performance standards to allow users to plan to take advantage of them. Coordinated monitoring of PNT signals is needed; if we plan to make use of a signal, we should plan to monitor its performance and disseminate that information to users appropriately. Such monitoring helps address a gap in the capability to provide notification of degraded or misleading information (DMI). Modernization of the GPS will eventually include integrity improvements that will reduce the risk of PNT errors that affect applications with safety-of-life issues as well as military operations that are critically dependent on reliable data. Coordinated research into solutions that provide high accuracy with integrity is needed in order to support emerging PNT applications. Promoting the development and use of improvements to user equipment will help users operate in impeded environments and receive notification when PNT information is degraded or misleading by allowing them to receive modernized signals and by inclusion of internal integrity monitoring methods. Criteria for assessing the continuing need for individual GPS augmentations and evaluation of augmentation transition or divestment plans will support decisions that may enable more effective and efficient implementation of the architecture recommendations to meet user needs. Finally, efforts to speed up the acquisition and fielding of new PNT/NAVWAR capabilities will emphasize the need for timely transition of capabilities that help maintain a military PNT advantage. This overall approach should result in more capable government- and commercially-provided PNT capabilities, and in an efficient balance between centrally-provided PNT services and more capable end-user PNT equipment.

3.1.2 Multiple Phenomenologies

The plan to give PNT users the ability to leverage multiple phenomenologies, as illustrated in Figure 5, depends primarily on fielding sensors that can detect and process these phenomena as well as on integrated user equipment (IUE) that can integrate data from different PNT sources to produce reliable PNT information. It also includes the need to develop standards and policies that enable the interoperability of PNT sources, to include foreign PNT services, exploring alternate PNT sources such as pseudolites, beacons, or inertial navigation systems, and developing supporting capabilities including precise time and time interval (PTTI) capabilities. Key preliminary tasks include identifying needed capabilities and features and then analyzing the alternatives to identify specific solutions for implementation.

Implementing the plan will give PNT users the capability to use multiple sources of data to determine their location, direction, and time, especially in impeded environments where current RF-based PNT approaches fall short. Specialized RF-based PNT infrastructure such as pseudolites and beacons may also be available to support disadvantaged PNT users when needed.

Future IUE will have the ability to compare data from different sources to detect degraded or misleading information, while more robust PTTI capabilities will enable more robust and capable PNT services.

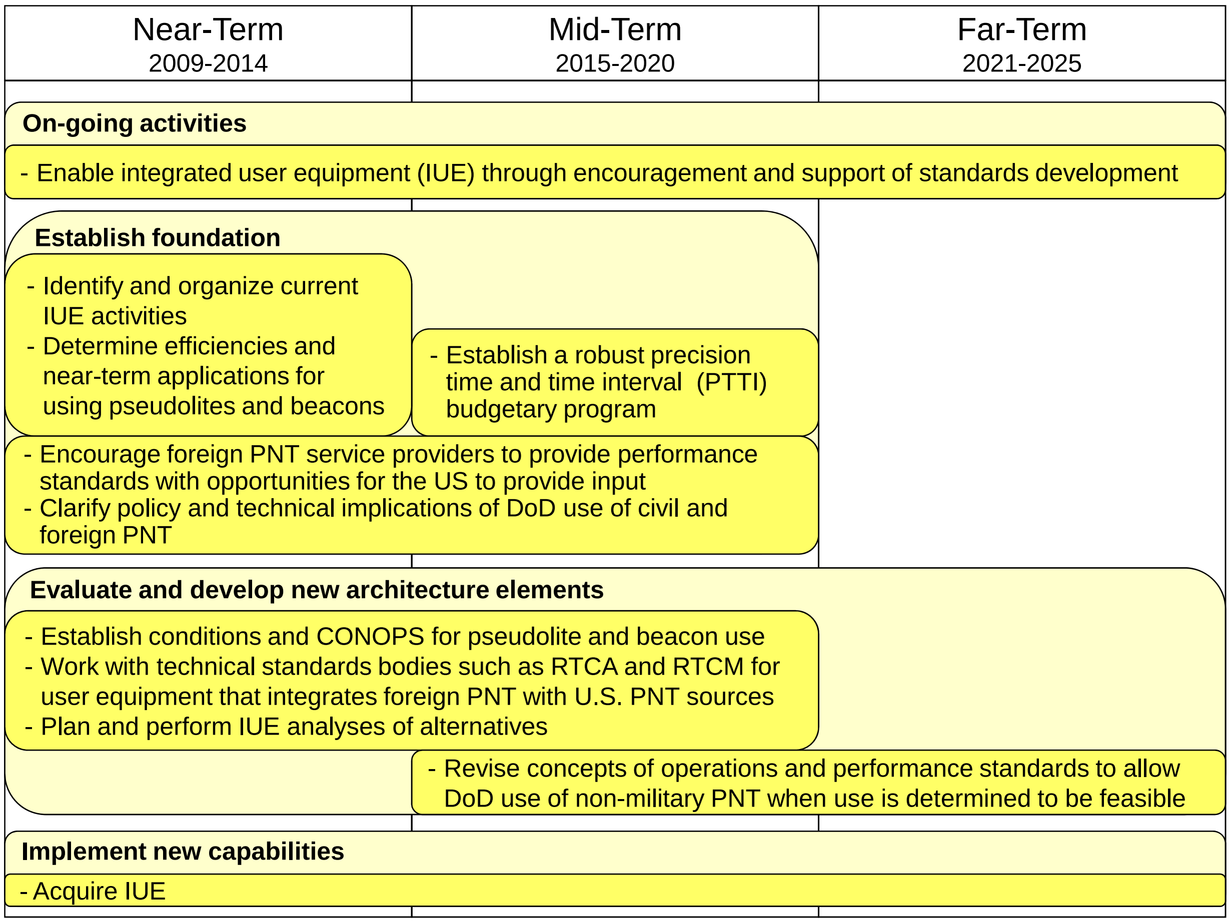

Figure 5: Roadmap to better use of multiple phenomenologies for PNT

The necessary and immediate tasks to implement the Multiple Phenomenologies Vector are:

1. Identify and organize current IUE activities, and begin performing analyses of alternatives for IUE implementations.
2. Determine the efficiencies and near-term applications for using pseudolites and beacons, establish conditions for their use, and develop appropriate concepts of operations and communications plans.
3. Identify the evolution of key technical performance parameters for space-qualified frequency standards.
4. Study present and future PTTI capabilities and develop them as appropriate.
5. Support standards for integrated user equipment and encourage the sharing of these and other PNT performance standards.
6. Require the use of appropriate fault detection algorithms and compliance with internationally accepted reference frames.

The use of integrated PNT user equipment that includes autonomous sources (such as inertial systems or clocks) helps maintain lock on external signals and allows coasting through signal outages. Integration including additional signals improves PNT availability in urban canyons, while the use of pseudolites and beacons helps ensure robust PNT in the most physically impeded locations. The use of such additional signals and sources aids detection of degraded information by allowing consistency checks between multiple PNT solutions. An integrated PNT user equipment analysis of alternatives (AoA) is needed to help users select which sources to integrate. Finally, the use of improved timing capabilities and/or autonomous relative solutions enables precise satellite formation flying applications.

3.1.3 Interchangeable Solutions

The plan to promote the interchangeability of PNT solutions, as illustrated in Figure 6, to enhance efficiency and exploit source diversity depends on the USG to promote user acceptance of interchangeability by refining PNT-related policy goals and objectives to include interchangeability, and through U.S. involvement and leadership in international forums.

Implementing the plan will enable users to fully leverage data from multiple phenomenology PNT sources to overcome existing and future gaps and shortfalls in PNT capabilities. The use of standardized coordinate and time reference systems for PNT information will facilitate development of applications by the commercial sector.

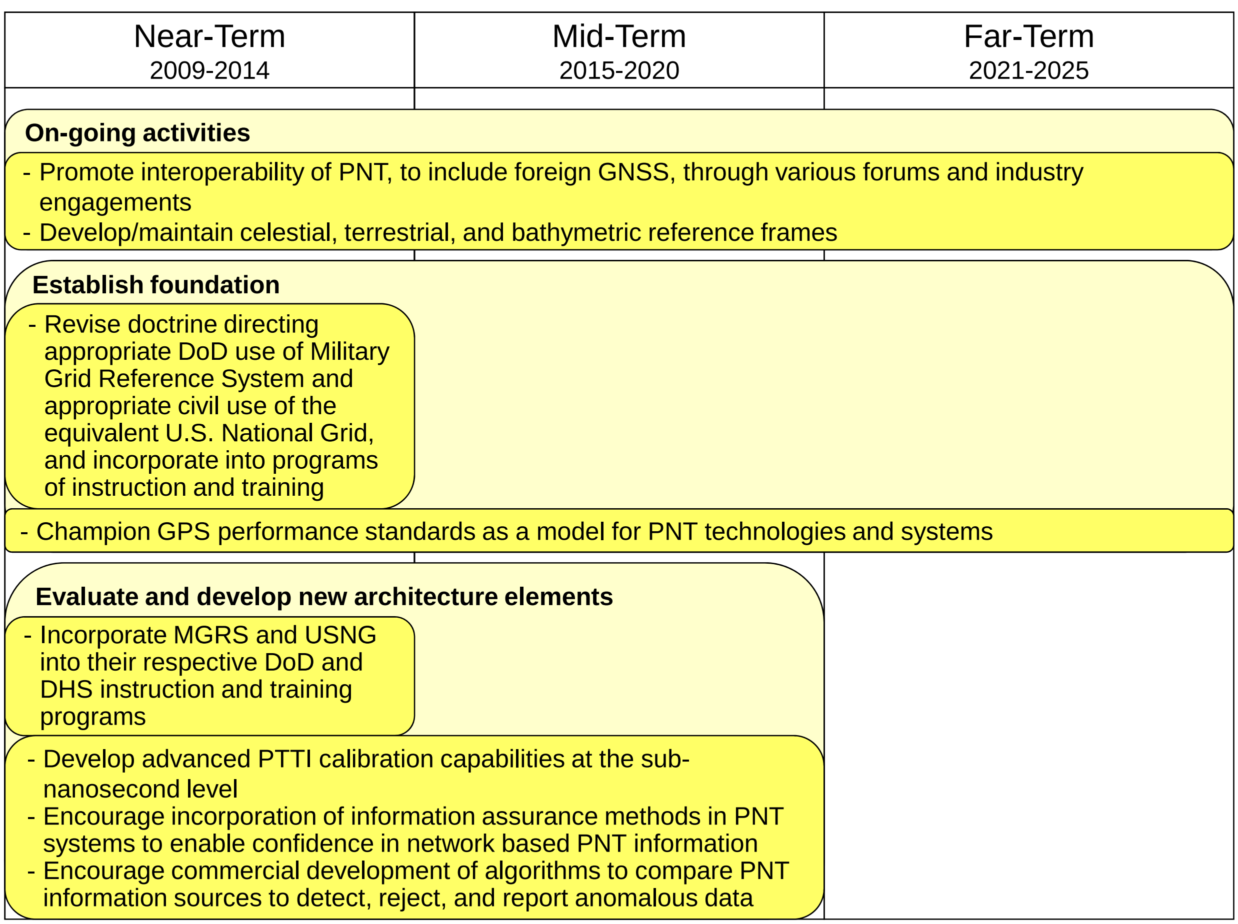

Figure 6: Roadmap to enable interchangeable solutions

The necessary and immediate tasks to implement the Interchangeable Solutions Vector are:

1. Identify venues for discussing commercial issues, including potential meetings with private industry, as part of U.S. bilateral relationships focused on GPS/GNSS cooperation.
2. Use the UN International Committee on GNSS (ICG) and its associated Provider's Forum to promote compatibility among GNSS and a high degree of civil interoperability of foreign systems with GPS.
3. Engage in international astronomical, geodetic and timing forums to ensure:
   A. The development of GNSS reference frames compatible and interoperable with the International Terrestrial and Celestial Reference Frames.
   B. The development of astronomical and geodetic models and software that provide the highest quality PNT products.
   C. Compatibility of national sources of time and frequency with international standards.
   D. Representation of U.S. national interests in international discussions of interoperability and compatibility of PNT products.
4. Study the evolution of applications which require more accurate reference frames.
5. Develop a bathymetric reference system that is seamless with respect to the terrestrial reference system and realized by an appropriate reference frame.
6. Develop and maintain a celestial reference frame addressing both terrestrial and space applications in various wavelengths to meet the needs of future PNT operations, including platform orientation.
7. Develop national PNT standards (*e.g.*, conventions, models, and algorithms for time transfer, ionospheric propagation delays) that will increase interoperability of PNT systems.
8. Evolve the USG standardized Information System Security Risk Management Framework, encourage the incorporation of information assurance methods in PNT systems, and champion GPS performance standards as a model to aid information exchange.
9. Revise doctrine directing appropriate use of Military Grid Reference System (MGRS) and its civil equivalent, the U.S. National Grid (USNG), incorporate their use into military and civil instruction and training, and develop and conduct test and evaluation exercises.

The promotion of PNT interoperability through various forums and industry engagements, accurate and compatible reference frames, and overarching national PNT standards supports the availability of additional signals for use in impeded environments and for integrity consistency checks. The development of appropriate information assurance, information exchange, and performance standards allow PNT signals from multiple sources to be combined interchangeably in integrated PNT user equipment. More accurate reference frames may be needed to support emerging needs. An updated celestial reference frame supports high altitude and space platform orientation needs. Finally, common grid reference systems improve interoperability, minimize operational confusion, and reduce the risk that positioning errors might contribute to a failure of critical objectives (*e.g.*, military targeting, fire and rescue operations, *etc*.)

3.1.4 Synergy of PNT and Communications

The plan to leverage users' increasing connectivity to communications networks for use as sources of PNT and for communicating PNT aiding and augmentation data is illustrated in Figure 7. The plan depends on the identification of PNT problems as potential candidates for PNT-Communications solutions and the creative use or modification of communications capabilities to act as PNT sources. Further research and detailed assessments regarding specific standards and solutions are needed before starting major development programs to field new systems and user equipment.

The implementation of this plan will result in increased PNT robustness by providing PNT services that leverage the ability of communications capabilities to overcome the physical and electromagnetic interference issues associated with current radionavigation spectrum. Potential applications that could be enabled by this plan include the use of signals from television, radio, and wireless cell phone broadcast towers to provide PNT service indoors and in urban canyons.

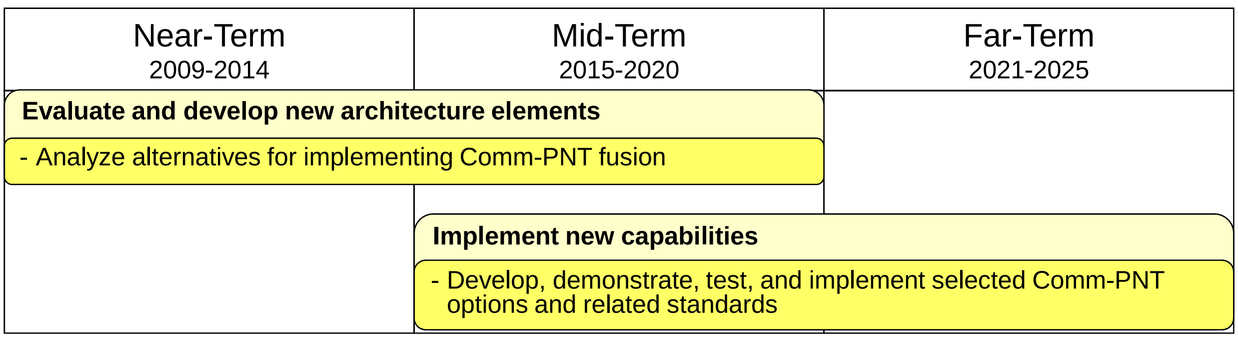

Figure 7: Roadmap to realize the synergy of PNT and communications

The necessary and immediate task to implement the Synergy of PNT and Communications Vector is:

1. Analyze alternatives for the fusion of Communications and PNT (Comm-PNT fusion).

Analyses are needed to help users determine where Comm-PNT fusion solutions would be appropriate, such as situations where users can overcome electromagnetic or physical impedances by providing additional robust sources for PNT data. Comm-PNT fusion can also aid navigation beyond earth orbit, provide communications paths for notification of degraded information, and disseminate geospatial information.

3.1.5 Cooperative Organizational Structures

The National PNT Architecture promotes activities, illustrated in Figure 8, to facilitate cooperation and information sharing. These activities are important for the review and assessment of progress toward the architecture goals and the contribution of those goals to the national interest. Centers of excellence for PNT phenomena and applications will be identified and leveraged across the community. These centers will focus national efforts on PNT-related science and technology and ensure PNT program offices are knowledgeable about performance and cost of alternative technologies. Furthermore, the architecture recommendations propose the development of an enterprise-level PNT modeling and simulation capability benefiting, for example, mission planning, user equipage decisions, and subsequent architecture efforts.

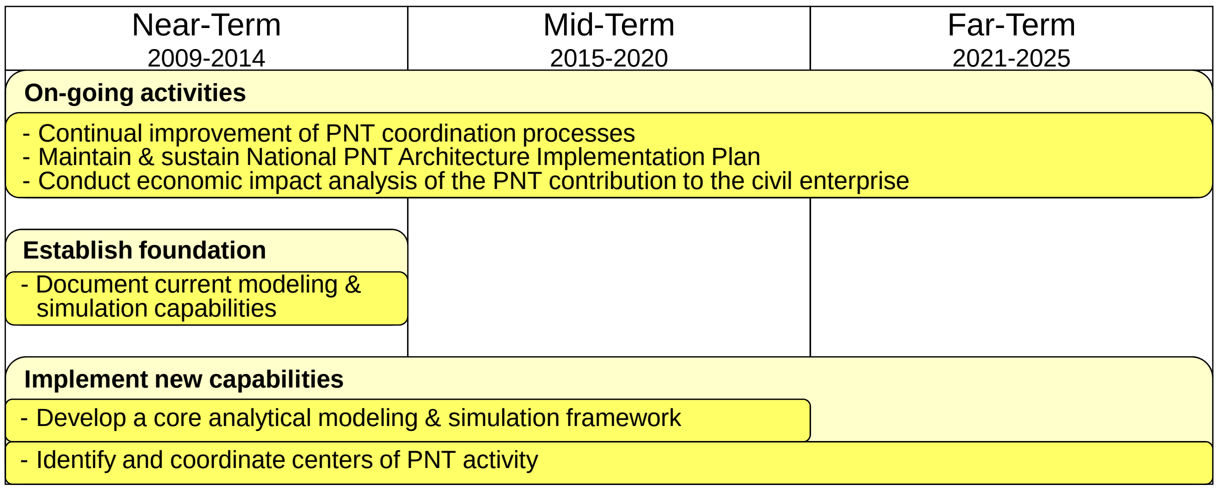

Figure 8: Roadmap to improve cooperative organizational structures

The necessary, immediate, and executable tasks (and their subtasks) to implement the vector for cooperative organizational structures are:

1. Continue to improve national PNT coordination.
2. Maintain and sustain the National PNT Architecture Implementation Plan.
3. Develop a modeling and simulation framework.
4. Identify and coordinate centers of PNT activity.

3.2 Implementing the Plan

The National PNT Architecture is an evolving framework that encompasses many separate but interrelated plans, system capabilities, standards, and policies. Implementing the plan requires a strong and continued commitment of all the PNT community stakeholders to embrace the plan's tasks in their areas of responsibility and execute needed changes through their existing departmental or agency processes (*e.g.*, acquisition process). The processes that coordinate stakeholder activities will likely need to evolve as the implementation of the PNT architecture plan progresses and the PNT architecture itself continues to evolve, and stakeholders are encouraged to initiate needed process improvements.

4 IMPLEMENTATION ACTIVITIES

4.1 Implementation Responsibilities

The overall PNT implementation strategy involves focused and consistent incremental investments and advancements in PNT capabilities and infrastructure that are consistent with the National PNT Architecture Strategy and Vectors. The PNT stakeholder organizations are responsible for implementing the PNT Architecture plan consistent with the National PNT Architecture Strategy and Vectors.

4.2 Risk Mitigation Approach

There are two types of risk related to the National PNT Architecture: those that are within the control of a particular agency and those which span more than one agency. Risks associated with a single department or agency will be mitigated through that agency's own prescribed risk mitigation procedures. These procedures generally follow the generic risk process (risk identification, analysis, risk handling, and monitoring) identified in Appendix 5 of OMB Circular A-11. Risks that span more than one agency will be addressed through PNT coordination processes.

4.3 Investment Strategy

The overall implementation strategy is to assist agencies in making focused and consistent incremental investments and changes in PNT capabilities and infrastructure, starting with studying and maturing PNT provider capabilities, user equipment, technology, management structures, and policy consistent with the National PNT Architecture Strategy and Vectors.

Funding for PNT Architecture implementation tasks will be primarily derived from the operating budgets of departments and agencies that have taken responsibility for those tasks. These departments and agencies will pursue voluntary coordination of their priorities for funding PNT architecture implementation and other PNT-related tasks, and for providing funding through their operating budgets and allocations consistent with Title 31 USC §1108 and OMB Circular A-11.

5 CONCLUSION

The objective of this implementation plan is to place the PNT community on a path to achieve a more capable future PNT Architecture in line with a vision of U.S. leadership in global PNT. It focuses on a limited number of priority tasks and offers a time-phased approach to support implementation of the architecture recommendations. The architecture co-sponsors urge strong and continued commitment from the PNT stakeholders, especially for tasks in their areas of responsibility. Proactive and coordinated implementation of this plan within and between each department and agency will help make more effective and efficient PNT capabilities for the nation a reality.

APPENDIX A – ARCHITECTURE GUIDANCE MEMORANDUM

June 16, 2008

MEMORANDUM FOR DISTRIBUTION

SUBJECT: National Positioning, Navigation, and Timing Architecture Guidance Memorandum

An interagency team led by the Office of the Assistant Secretary of Defense for Networks and Information Integration and the Department of Transportation's Research and Innovative Technology Administration recently concluded a National Positioning, Navigation, and Timing (PNT) Architecture Study. The study's vision, strategy, vectors and recommendations are at Attachment 2.

As co-sponsors of this study, and in accordance with its Terms of Reference, we approve the vision, strategy, vectors and recommendations included in Attachment 2 and direct the start of transition planning. The PNT Architecture Transition Team (Attachment 3), facilitated by the National Security Space Office, will develop a National PNT Architecture Transition Plan defining the time-phased, fiscally-informed roadmap to guide implementation. A National PNT Architecture Transition Planning progress report will be available by June 30, 2008.

Questions on this action should be directed to Captain Milton Abner, USN (571-432-1433, NSSO.PNT@osd.mil).

John G. Grimes Assistant Secretary of Defense for Networks and Information Integration	Tyler D. Duvall Acting Under Secretary of Transportation For Policy

Attachments

1. Distribution
2. Approved PNT Architecture Vision, Strategy, Vectors and Recommendations
3. Transition Planning Roles and Responsibilities

APPENDIX B – ACRONYMS AND ABBREVIATIONS

AFSPC	Air Force Space Command
AGM	Architecture Guidance Memorandum
AIM	Architecture Implementation Memorandum
AOA	Analysis of Alternatives
ASD/NII	Assistant Secretary of Defense for Networks and Information Integration
ATT	Architecture Transition Team
DHS	Department of Homeland Security
DMI	Degraded or Misleading Information
DOC	Department of Commerce
DoD	Department of Defense
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
EMI	Electromagnetic Interference
EOP	Executive Office of the President of the United States
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
GNSS	Global Navigation Satellite System (generic space-based system)
GPS	Global Positioning System
HAWI	High Accuracy With Integrity
IUE	Integrated User Equipment
JPDO	Joint Program Development Office
JPO	Joint Program Office

JS	Joint Staff
MGRS	Military Grid Reference System
NASA	National Aeronautics and Space Administration
NCO	National Space-Based PNT Coordination Office
NIST	National Institute of Standards and Technology
NGA	National Geospatial-Intelligence Agency
NRL	Naval Research Laboratory
NSA	National Security Agency
NSSO	National Security Space Office
OCR	Office of Collateral Responsibility
OPR	Office of Primary Responsibility
OUSD/AT&L/S&T	Office of the Deputy Under Secretary of Defense (Acquisition, Technology, and Logistics) for Science and Technology
PBFA	Policy Board on Federal Aviation (DoD)
PI	Physical Impedance
PNT	Positioning, Navigation, and Timing
PTTI	Precise Time and Time Interval
RITA	Research and Innovative Technology Administration (DOT)
SAF/USA	Secretary of the Air Force Directorate of Space Acquisition
SMC	Space and Missile Systems Center (AFSPC)
SMDC	Space and Missile Development Center (U.S. Army)
TOR	Terms of Reference
USA	United States Army
USAF	United States Air Force
USCG	United States Coast Guard
USG	United States Government

USMC	United States Marine Corps
USN	United States Navy
USNG	United States National Grid
USNO	United States Naval Observatory
USSTRATCOM	United States Strategic Command
UST/P	Under Secretary of Transportation for Policy

APPENDIX C – REFERENCES

The following documents are referenced in the PNT Architecture Implementation Plan

- Joint Capabilities Document for Positioning, Navigation and Timing, USSTRATCOM, 26 Sept 2006 (S/NF).
- 2005 Federal Radionavigation Plan, published by the Departments of Defense, Homeland Security, and Transportation.[*]

[*] N.B. The Federal Radionavigation Plan (FRP) was revised in 2008, after the PNT Architecture Study was completed. The Implementation Plan therefore references the FRP edition used by the study, rather than any subsequent editions.