Innovation Beyond GNSS

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Thank you for inviting me to speak today on "Innovation Beyond GNSS" and for the warm introduction. As the Deputy Assistant Secretary for Research and Technology at the US Department of Transportation, I will be sharing with you how my Department is working to improve the resiliency and capacity of positioning, navigation, and timing beyond Global Navigation Satellite Systems through innovation.

First things first. In a conference on position, navigation, and timing, we must begin by taking our bearings from our position today –sitting squarely in a center named for Erasmus. Can we navigate the subject of innovation more precisely by asking: why does this space science research center bear the name of one of the greatest humanists of all time? Not a scientist or astronomer, but a humanist!

I suggest that the spirit of the great humanist guides this particular conference and much of the daily work done here. As Erasmus once wrote to a friend, "That you are patriotic will be praised by many and easily

forgiven by everyone; but in my opinion it is wiser to treat men and things as though we held this world the common fatherland of all." These universalist ideals of Erasmus apply to sharing technology innovations between like-minded nations of the EU and the United States.

Second, Erasmus reminds us of the humane importance of Global Navigation Satellite Systems and space science. High in the heavens as it is, GNSS is about preserving, as British writer Dominic Green recently wrote in the obituary of philosopher Roger Scruton, "the rooted realities" of family, home, and nation, prosperity and peace.

A brief recap of my speech at the Royal Institute of Navigation last November speaks to this very point, that GPS is "one of the great heroic systems of our times, a monumental human, scientific and technical effort that has transformed culture, politics and society." These technologies are essential to national and global prosperity. What is the Department of Transportation doing to innovate beyond GNSS?

In the following, I will broadly outline the three major categories of the work we do to advance PNT to meet emerging needs. I also plan to leave time for questions at the end.

The three categories are 1) The need to augment GPS capability through use of alternate PNT technologies; 2) The need to protect GPS from harmful, as well as malicious, interference, including interference from adjacent frequencies; 2) The need to toughen receivers. Our receivers need to meet—and overcome—emerging cybersecurity threats.

Specifically, the Transportation Department seeks to augment Global Positioning System capabilities through use of alternate Positioning, Navigation, and Timing technologies. Last September, my office announced an opportunity for technology vendors to participate in a demonstration to examine possible PNT technologies that can operate in the absence of Global Navigation Satellite System signals. In November 2019 we awarded 11 contracts. We intend to conduct a demonstration of these technologies in March. The list of vendors is public and includes organizations working on technologies from terrestrial radio signals to eLoran to fiber networks for timing, Iridium satellites for encrypted signals, wi-fi and cell signals for localization and more.

The list includes the following companies.

Let's start with **OPNT BV** of Amsterdam, which will demonstrate their Global Terrestrial Timing Service, which provides GPS-independent timing-as-a-service over global fiber-based networks.

Then **Echo Ridge LLC** of Virginia will demonstrate Augmented Positioning System technology that uses signals from communications satellites to produce accurate position and timing information.

Hellen Systems LLC of Virginia, in conjunction with Harris Corporation and Microsemi, will demonstrate enhanced LORAN (eLORAN) technology.

NextNav LLC of California will demonstrate their Metropolitan Beacon System which is a 3GPP-compliant, terrestrial network of long-range broadcast beacons, transmitting a "GPS-like" signal in licensed spectrum in the sub-GHz range.

PhasorLab Inc. New Hampshire will demonstrate high-precision carrier synchronization technology, known as Hyper Sync Net technology, as a backup to GPS.

Satelles Inc. of Virginia will demonstrate timing and location solutions delivered over the Iridium constellation of 66 LEO satellites.

Serco, Inc. is a global provider of air navigation services. It also has an effort in its New London/Norwich, Connecticut office and will focus on demonstration of a Ranging Mode terrestrial backup navigation system.

Seven Solutions will demonstrate White Rabbit Technology to provide very stable time references over fiber in GPS-denied scenarios as a backup source or to complement other PNT solutions that need timing distribution at their core. The firm is based in Granada, Spain.

Skyhook Holding Inc., with offices in Boston and Philadelphia, will demonstrate a Wi-Fi Positioning system powered by an immense database of geolocated access points and cell base station IDs.

TRX Systems of Maryland will demonstrate sensor fusion and mapping algorithms to provide real-time 3-D location and mapping within buildings and underground where GPS is not always available.

Ursa Navigation Solutions Inc. (UrsaNav), headquartered in Massachusetts, will demonstrate eLoran technology.

My Department hopes to complete the analysis and assessment of the data from the demonstration by May. Then we will get together with the Defense Department and the Department of Homeland Security and choose a technology or combination of technologies. After that, we hope our Congress will allocate funds to purchase this equipment.

This effort will inform implementation of a system that by law is required to be terrestrial, wireless, have wide coverage, be difficult to disrupt, and be capable of expansion to provide positioning and navigation services.

National and economic security and safety are, and must remain, our top priorities. GPS cannot be a single point of failure for transport and other critical infrastructure.

While I am focused in this talk on discussing innovation beyond GNSS, I would like to emphasize that GPS is the cornerstone of our U.S. National PNT Architecture and we are proud of the ongoing GPS modernization efforts, including the launch of the GPS III satellites, the first of which was just recently sent up.

Therefore, we need to protect GPS, from harmful interference, including interference from adjacent frequencies. Threats to the radio frequency band adjacent to GPS pose a serious problem for GPS. The Transportation Department is committed to protecting the spectrum needed for reliable use of GPS.

The Transportation Department's Adjacent Band Compatibility assessment is the only validated test to determine degradation at various received power levels, according to the National Space-Based PNT Engineering Forum.

One of the most promising enhancements to position accuracy is the introduction of "dual frequency" Global Navigation Satellite System support. Broadcom has started selling cell phone chips that use GPS L1 and L5 for increased accuracy, faster GPS lock and better performance in urban environments. The Federal Aviation Administration is working towards dual frequency multi-constellation standards for aviation. We appreciate the great work being conducted on resiliency and Advanced Receiver Autonomous Integrity Monitoring through the US-EU Working Group C.

The Transportation Department's work on innovation that uses GNSS, along with automated vehicles and Intelligent Transportation Systems, fuels ongoing innovation.

We recognize the essential role that PNT plays in supporting not only the independent operation of automated vehicles, but also in assuring effective and often necessarily near-instantaneous connectivity between vehicles

and with the transportation infrastructure that promises to make or systems both far safer and more efficient. We must continue our cooperative work to assure that the PNT capabilities to support these beneficial connected and automated vehicle innovations remain secure and resilient while meeting ever increasing performance requirements.

My Department continues to research the current state of PNT sensor suites and the role that Global Navigation Satellite System plays in supporting safe and resilient automated vehicle operations. Two projects of note: We plan to evaluate the performance and resiliency offered by fusing navigation data from GNSS and other sensors. We will also collect data using automotive grade integrated GNSS/INS and other sensors in a GPS spoofed and jammed environments to assess the resiliency of such systems.

We must continue our cooperative work to assure that the PNT capabilities that support the great benefits of connected and automated vehicle innovations remain secure, stay resilient and meet eve- increasing performance requirements.

You may notice a theme of incubation at large scale that unites much of our approach to innovation. For example, in December 2015 we launched our Smart City Challenge, asking mid-sized cities across America to develop ideas for an integrated, first-of-its-kind smart transportation system that would use data, applications, and technology to help people and goods move more quickly, cheaply, and efficiently. The Challenge generated an overwhelming response: 78 applicant cities shared the challenges they face and ideas for how to tackle them. Then, our seven finalists worked with DOT to develop their ideas.

Our University Transportation Centers also fuel research on innovations in transportation. Thirty-seven such Centers span the country.

Projects in our University Transportation Centers include GNSS specific research, such as *Using GNSS to Evaluate Threats to Mobility of Resources and People on Coastal Roads.* The objective of this research is to develop a new technique to assess the hazard intensity of coastal erosion hotspots to existing and planned coastal roadways by continuously monitoring coastal water levels and wave heights using a new remote sensing technique with land-based Global Navigation Satellite System.

It should also be noted that our universities can bring public attention to GNSS problems. Spoofing was discounted as a realistic threat for many years because it is complicated to perform. However, high-profile demonstrations at the University of Texas that spoofed a drone and a nearly $81 million yacht brought spoofing into the public eye.

The director of the National Coordination Office for Space-Based Navigation & Timing, Harold Martin, recently spoke to an international audience and I emphasize a specific point from his talk for this audience on the need to "invest in domestic capabilities and support international activities to detect, mitigate and increase resiliency to harmful interference."

And so, we come back around to Erasmus – that great humanist and globalist, and super networker. He was a super-networker, before that term was known – keeping a correspondence with almost 500 others around the world to pursue knowledge and inspiration and conversation. I hope our conference here will yield inspiration and knowledge useful to this all-important global technology, "more information sharing on the threats, their nature, impacts and mitigations" and more fruitful communication in our larger Position Navigation and Timing community.