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The Aerospace Corporation is pleased to provide these responses to NIST's *Request for Information about Profile of Responsible Use of Positioning, Navigation, and Timing Services** to help foster the responsible use of PNT services called for by the Exec. Order No. 13905, Strengthening National Resilience Through Responsible Use of Positioning, Navigation, and Timing Services, 85 FR 9359 (Feb. 18, 2020).

We at The Aerospace Corporation are key stakeholders in the provision and the use of space-based PNT services. We are not a vendor of PNT technology nor are we a significant user of PNT services. We have no organizational conflict of interest and no commercial bias. As the Federally Funded Research and Development Center (FFRDC) who has been assisting the U.S. Air Force with the creation, development, testing, deployment, sustainment, and modernization of the Navstar Global Positioning System (GPS) since well before it was even called "Navstar GPS", we have a vested interest in ensuring the successful and responsible use of space-based PNT services within the US and around the world.

Besides working for the U.S. Air Force on all aspects of GPS for over a half century, we have also been working for the FAA for several decades assisting them with managing the adoption of user receiver technology for safety of life navigation in domestic, foreign, and international airspace. In recent years, much of our effort has focused on detailed analysis and planning for commercial aviation's evolution to "dual-frequency multi-constellation" (DFMC) operations. Here, dual-frequency means the addition of an ability to use satellite navigation (SatNav) signals at a second frequency (e.g., the new GPS L5 signals at 1176.45 MHz) and multi-constellation means the addition of the ability to use SatNav signals from a second Global Navigation Satellite System (specifically the European Union's Galileo constellation) to achieve an integrated level of resiliency far exceeding that provided by the baseline GPS-only C/A-code signals at just the L1 frequency (1575.42 MHz). This evolution towards DFMC operations has exposed many of the regulatory hurdles that prevent the responsible use of new technology in critical sectors of the economy like commercial aviation. For example, until recently – FCC regulations made the use of Galileo illegal in the United States. Another example is the set of U.S. regulations which prevent the use of advanced phase array antennas – which can render a commercial aircraft virtually invulnerable to any plausible spoofing or jamming threat – on commercial or civil aircraft which fly outside U.S. airspace.

The responses provided below from The Aerospace Corporation reflect the company's extensive heritage as noted above in the field of SatNav in general and in GPS in particular.

Public and private sector need for and/or dependency on the use of positioning, navigation, and timing:

We strongly commend and recommend the descriptions of the public and private sector needs for – and the dependencies on – the use of PNT given in the June 2019 report entitled "Economic Benefits of the Global

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Positioning System (GPS)", which was prepared by RTI International under the sponsorship of NIST. We know of no better compendium of those needs and descriptions.

Impacts to public or private sector operations if PNT services are disrupted or manipulated:

Again, we strongly commend and recommend the descriptions of the impacts to public and private sector operations if PNT services are disrupted – including the economic quantification of those impacts – given in the June 2019 report entitled "Economic Benefits of the Global Positioning System (GPS)", which was prepared by RTI International under the sponsorship of NIST. Some of the impacts where The Aerospace Corporation has particular expertise are as follows:

- *Disruption and direct attacks on aviation*
- *Degraded synchronization or poor quality of service and traffic handling in the Communications sector from Federal and non-Federal radio communications systems operating in close frequency or geographic proximity to GPS receivers*
- *Impacts to weather forecasting, including FAA's use of GPS to synchronize reporting of hazardous weather from radar across the US*
- *Impacts to automated business systems – from private businesses to the financial services sector – that track, update, and manage transactions, assets, and back-up communications*
- *Impacts to portable/mobile devices with GPS capabilities, including personal protection devices*
- *Impacts to location and dispatch of vehicle fleets, including the electric sector which uses GPS to locate and dispatch crews*

Approaches or technologies employed by the public or private sector to detect disruption or manipulation of PNT services:

- *Verifying PNT sources against each other. Sources are the four GNSS, WWVB, NTP, local clocks with internal timing.*
- *Although a final implementation decision has not yet been reached, the U.S. and the EU are developing approaches to using digital signatures to detect disruption or manipulation of the accuracy and integrity improvement information broadcast by national Satellite-Based Augmentation Service (SBAS) providers for aviation and other users (e.g., the FAA's WAAS over North America).*
- *Positioning GPS jamming monitors near some roads to detect illegal jamming.*
- *Aviation cybersecurity actions that industry is pursuing.*

Processes or procedures employed in the public or private sector to manage the risk that disruption or manipulation to PNT services pose:

- *Test and evaluation to simulate existing or future threats like jamming and spoofing to understand critical infrastructure vulnerabilities*
- *Continuous improvement to identify/defeat/anticipate new threats in PNT protection program*

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