Written Public Comments Submitted to PCAST

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(Written Public Comments in order of date received)

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From: Urvishkumar Mehta [redacted]
To: MBX OSTP PCAST <MBX.OSTP.PCAST@ostp.eop.gov>
Sent: Mon 11/29/2021 3:16 PM
Subject: Internet of Space: Networking Architectures and Protocols to Support Space-Based Internet Services

ATTN: PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
Subject: Quantum Computing Technology International Framework

Matter: Science, Innovation and Technology Framework

Legal:

Quantum computing is the discipline of computing, which can leverage the power of a quantum particle. It varies from traditional computing in its most basic way. Traditional computers consist of bits, while quantum computers consist of qubits. Qubits possess the characteristics of a quantum particle, as it does play with superimposition and entanglement. Superimposition offers the qubit the ability to have two values simultaneously and hence offering a huge space to work with and quickly. Hence one can calculate the state of one qubit depending on the other.

Quantum computing ensures solving issues that are related to higher complexity and problems that need a massive amount of space to work within classical computing. It was developed to solve the problems that seemed impossible with traditional computing, by bringing the properties of quantum mechanics into computing.

In this article, let's dive deeper into the various frameworks to explore **quantum computing.**

Tensorflow Quantum (TFQ)

Tensorflow Quantum (TFQ) is a framework that is been designed for **quantum machine learning.**

It gives a splendid way to leverage Google's **quantum computing** frameworks inside Tensorflow. With Tensorflow Quantum, one can build applications depending on quantum data and hybrid quantum-classical models. The framework also offers functionality to interleave the models and logic that are built-in Cirq with Tensorflow.

One can use the Tensorflow Quantum framework for running the classical models and hybrid models like Quantum CNN (QCNN). The Tensorflow Quantum can be used to solve any issues that previously seemed difficult with the classical models. Start with Tensorflow Quantum to build quantum or quantum-classical hybrid models to solve some real-life issues.

TFQ is a library dedicated to Artificial Intelligence (AI) with quantum computing. If an individual is familiar with the fundamentals of **quantum computing** and Tensorflow then they can easily begin with TFQ.

QisKit

If one is exploring the next-generation technology, then they should understand that the IBM is must-have. QisKit, is an open-source quantum software development framework. It is suitable for the audience of all ages. IBM developed this so that even children can try it out. One can also have IBM Quantum Experience that can be used to learn more by viewing.

One can change and build pipelines and circuits without even the knowledge of coding the quantum circuits. IBM also offers its very own YouTube channel to educate about **Quantum computing** with the help of QisKit. With QisKit an individual can develop their quantum circuits, and easily execute them on both the systems and on the simulators. One add-on is the visualizing functionality. An individual can easily view the results and analyze the experiments.

To get started with QisKit, one may start using any of the sources, the official YouTube channel, the IBM quantum experience, or even the official documentation. This is the best framework to build few interesting applications, compare them, and get more insights.

Strawberry Fields

Strawberry Fields is a fun and very interesting library. It is a full-stack Python library that is especially meant for designing, optimizing, and utilizing photonic quantum computers. It was made by Xanadu, a firm based in Toronto, Canada.

With Strawberry Fields, anyone can easily implement its high-level functions available, to build some amazing practical solutions. Moreover, the library also includes the quantum simulators that were designed on NumPy and

Tensorflow. This library can be used anywhere one wants to. Strawberry Fields is mainly useful in getting solutions that are based on graphs or networks. It also gives specific functions for Machine Learning solutions. The library offers ample tools for problem-solving in the field of Chemistry.

If one is interested to build something with this fully loaded library. Then they can if they are familiar with Python. Xanadu has also developed another library **for quantum machine learning**, called PennyLane too.

Cirq

Now lastly, let's understand a tech giant's contribution to Quantum development. Cirq was built by Google's Quantum Artificial Intelligence team. It is useful for developing and optimizing quantum circuits that then can be run against quantum computers and simulators.

One best aspect about Cirq is that it gives developmental simulators, as it is in real life. This library works its way to expose the details about the hardware around Noisy Intermediate-Scale Quantum (NISQ) so that one can be sure after developing, that the algorithm or the circuit can be run on the physical quantum computer.

Cirq is very helpful to develop adaptable and deployable quantum circuits. Cirq also offers functions for interoperability. For instance, a function for import/export of the quantum circuits and simulations. One can develop circuits for textbook algorithms like Variational algorithms or QAOA. But one can also get begin by working on simpler and fun applications like the Quantum walk.

End Notes

Quantum computing will affect almost every field that requires better and huge computational specifications. It shows the potential to solve any issue. Try these frameworks to learn and explore more.

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From: Urvishkumar Mehta [redacted]
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Subject: Internet of Space: Networking Architectures and Protocols to Support Space-Based Internet Services

ATTN: PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
Matter: Science, Innovation, Technology And Space Framework
Legal: Constituent Comment

I am writing the letter with reference to include the Agenda Topic to establish the Framework Space-Based Internet Services.

This Special Section is focused on the most recent scientific research and insights on the evolution of communication architectures and protocols for an *Internet of Space,* able to boost the creation of a truly global Internet by means of the integration of the current Internet with a new *Internet of Space*. Such evolution is expected to have a significant impact on several markets such as IoT/Industrial IoT, Mobile services, Industry 4.0, Government enterprise, and Connected mobility.
The section shall cover work focused on aspects such as how to support the operation of Tier-1, Tier-2 or even Tier-3 airborne/spaceborne networks; how to address interoperability, within and across different protocol layers in the network architecture, leveraging cross-layer design; and finally how to design a more unified next generation Internet architecture able to transparently include spaceborne and airborne platforms in a way that allows for user-centric services, and a smooth operation of transient networks.

However, an original and competent *Internet of Space*, calls for the definition of a networking framework able to accommodate specific properties of dynamic systems, including heterogeneous physical layers, frequent changes in network topology, high propagation delays, and intermittent connectivity. The dominant success factor for such a networking framework is low-cost bandwidth, although its capability to support low latency and high-throughput services plays an important role.

Secondly, a global Internet is only possible with a transparent integration of an *Internet of Space* with the current Internet, while supporting multi-tenants, multi-systems in different orbits and altitudes, as well as multiple markets. Such an integration requires rethinking the Internet architecture in order to extend its operation to all systems above the Earth's surface, which requires the integration of heterogeneous communication devices and protocols. Such a unifying networking framework will have a truly global reach, allowing the connection between information producers and consumers in any corner of Earth and Space. Last but not least, the seamless integration of an *Internet of Space* with the current Internet will lead to a global empowerment, providing information access to everyone who may need it to sustain enriched human life, while mitigating some of the major limitations of a network infrastructure that is built on Earth's surface, which is subjected not only to geographic limits but also to political limits.

From a technical perspective this Special Section is focused on the design and performance evaluation of networking architectures and protocols for the Internet of Space, as well as on a more unified design that best deals with the networking challenges to be faced.

The topics of interest include, but are not limited to:

- **Network architectures**, able to support multi-tenants, multi-systems in different orbits and altitudes, as well as multiple markets, while being transparently integrated in the current Internet architecture. Such new, unifying, network architecture may require the exploitation of paradigms such as *Delay Tolerant Networking (DTN)*, and *Information Centric Networking (ICN).*

- **Network virtualization**, leveraging well-known technologies such as *Software Defined Networking (SDN)* and *Network Function Virtualization (NFV),* as well as their integration with the emerging concept of *Multi-Access Edge Computing (MEC)*, allowing the virtualization of networking, storage and computing fabrics at the edge, required for the offloading of tasks that have latency constraints from the core to the edge.
- **Decentralized Internet Infrastructure**, allowing a scalable Internetworking between computing processes and service hosted at the network edge (including flying platforms and spaceborne platforms, such as smart satellite constellations), leading to an end-to-end latency reduction due to user proximity, as well as a reduction of network traffic through traffic localization and device-to-device communications.
- **Network management,** such as support for the global orchestration of network functions on board spaceborne platforms (e.g., satellites) to best support data processing and aggregation; seamless interoperation of mobile Edge infrastructure and devices; resilience and seamless adaptation based on the capability to anticipate the behavior of services on a global scale.
- **Cognitive networking**, in which programmable spaceborne networks allow networked devices to perform customized computation, including the usage of Artificial Intelligence. Such cognitive functions will be exploited to develop more intelligent, adaptive networks, able to perceive network conditions, decide upon those conditions, and learn from the consequences of its actions.
- **Networking protocols**, including support for inter-satellite communications, and satellite to ground communications, *Quality of Service (QoS) and Quality of Experience (QoE)*, integrated security, and mobility, and their integration with existing protocols such as IP routing (e.g. segment routing), transport protocols from the *Transmission Control Protocol (TCP)* and *User Datagram Protocol (UDP)* to *Quick UDP Internet Connections* (*QUIC*), and application protocols such as *Domain Name Service (DNS)*.
- **Wireless technologies**, including not only the usage of radio frequency systems but also free space optical systems, and a combination of both.
- **Network measurement & performance**, to assist in understanding and exposing the performance of spaceborne networking resources, infrastructure, and available communication protocols in a variety of ground-to-space, inter-satellite communication scenarios.
- **Privacy, security and trustworthiness**, assuming end-to-end scenarios involving satellites with computational and storage capabilities, and covering aspects such as data security, decentralized trust architectures.
- **Impact on Internet services**, such as advanced IoT services (e.g., Augmented Reality/Virtual Reality in manufacturing or farming) served by spaceborne platforms and spaceborne communications; real-time IoT applications (e.g., critical monitoring of public infrastructures); awareness services (e.g., public safety services).
- **Impact on data management aspects,** including the support of the next generation of Edge computing in space, as well as a fast cooperation between a large set of Edge-based producers of data.

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Sent: Mon 11/29/2021 4:15 PM
Subject: Navigating Global Blockchain And Cryptocurrency Regulation and Framework

ATTN: PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
Matter: Science, Innovation, Technology And Space Framework

Legal: Constituent Comment

- Cryptocurrency adoption has soared during the COVID-19 pandemic, as everyone from private investors and public companies to underbanked individuals realised the benefits of digital currencies.

- Regulators have struggled to keep up with this growth and may limit financial inclusion by applying rules to crypto markets that are not fit for purpose.

- By looking to past eras of innovation, regulators can work collaboratively to adapt rules and policies to support open competition and rapid innovation in the cryptocurrency sector.

Global adoption of cryptocurrencies has soared across low-, middle- and high-income countries in recent years. Regulators worldwide are still evaluating how to address the novel issues posed by digital currencies, however. The Global Future Council on Cryptocurrencies' recently published paper on navigating cryptocurrency regulation shows how past eras of innovation, such as the early days of the internet, could help meet this challenge.

Here are three lessons that could support the development of crypto regulation that is fit for purpose:

1) Follow the actual drivers of cryptocurrency adoption

For years, most central banks and treasury departments have focused on risk-based reporting and containment policies for virtual assets. Meanwhile, these markets have grown exponentially, with global adoption increasing by more than 2300% since 2019 and 881% in the last year alone. During this time, Bitcoin, for example, has evolved from a small niche internet community into a well-known asset for investors, private firms and even nation-states.

Actual trends vary widely between geographies and are telling. Centralised and decentralised forms of finance (DeFi) are accelerating in the developed world, while peer-to-peer (P2P) platforms are driving adoption in emerging markets, like Vietnam, Kenya, Togo and Tanzania.

Many of these new users have turned to cryptocurrency to preserve their savings in the face of currency devaluation, to send and receive remittances, and for business transactions. Such transactions have grown even as central banks have banned access between banks and crypto exchanges in countries like Nigeria, while threatening the same in countries like India.

Several key factors are driving interest in cryptocurrencies:

● Central bank policies, hyperinflation, and macroeconomic instability have driven volatility and devaluation of local fiat currencies relative to other global currencies before and particularly during the COVID-19 pandemic. This has caused individuals and corporations such as Microstrategy, Tesla and Square to hold bitcoin and other digital monies. It has also inspired increased advocacy by users and awareness among policymakers from the US to El Salvador who are crafting new policies around cryptocurrencies.

● Remittance costs remain exorbitant for traditional payment systems at 6.8% globally and almost 9% in Sub-Saharan Africa, potentially explaining increasing P2P cryptocurrency transactions.

● The invention and rapid scaling of stablecoins as frictionless mediums of exchange between cryptocurrencies and fiat currencies. The market cap of USD Coin, for instance, has passed $25 billion with a compound annual growth rate of more than 6100%. Such traction has even inspired Sweden to pivot its planned e-krona in order to compete with such cryptocurrencies and central bank digital currencies (CBDCs).

● New cryptocurrency networks such as Stellar, Algorand and Solana are gaining users by promising less energy consumption and faster transaction speeds. Layer 2 solutions, such as Lightning Network and India-based Polygon, are being added to public blockchain to extend scalability and efficiency. Such improvements are also propelling DeFi application usage. The rapid proliferation and maturation of these innovations is in large part due to the open-source architecture and global developer communities that undergird crypto networks.

2) Work to understand the technological significance and the many use cases for crypto

Much like the development of early internet protocols, the vast potential for cryptocurrency applications makes it challenging to automatically apply existing legal frameworks and definitions ex-ante. In this context, hasty regulation will likely lead - wittingly or unwittingly - to picking winners and favouring incumbents. Even worse, it could further exacerbate a yawning digital divide within and across countries.

Cryptocurrency networks provide a new paradigm for secure data and value transmission, storage and access over the internet. They offer secure, immutable storage that is resilient to single points of failure and censorship, as was recently evidenced by the use of Arweave by Hong Kong residents. Innovative new NFT gaming platforms like Axie Infinity (now worth over $1 billion) are providing stable income for the un- and underemployed in the Philippines, which makes up 40% of the user base. New software applications across sectors including DeFi, digital art and gaming (non-fungible tokens or NFTs), and non-legal entity formation (decentralised autonomous organisations or DAOs) use cryptocurrencies to embed digital rights and capabilities within tokens in a transformational way.

To fully support the development of this new paradigm, regulators need to distinguish between the risks of centralised versus decentralised activities. For centralised exchanges and custodial financial services, cryptocurrencies pose risks congruent with financial risks that are familiar to financial authorities, capital markets regulators, consumer protection, privacy bureaus and tax authorities around the world.

Regulators have highlighted the pseudonymous and borderless nature of cryptocurrency systems as potential money laundering and terrorist financing risks. Yet, illicit activity is significantly less than in the traditional financial system, comprising just 0.34% of all cryptocurrency transactions.

The auditability of cryptocurrencies also enhances real-time transaction monitoring, record-keeping and mitigation. Instances of money laundering can be detected and deterred, creating the evidence needed to prosecute offences. Examined from this perspective, cryptocurrencies can enable transparency and provide an opportunity for regulators actively seeking to shift more transactions from the informal to the formal economy.

3) Create more inclusive global governance

Today, the differences between jurisdictions create new regulatory arbitrage opportunities as well as market uncertainty. One missing lever for global harmonisation is the lack of genuinely inclusive policy platforms. For example, global standards formulated to mitigate illicit activity have resulted in blunt derisking policies (similar to redlining) that contribute to financial exclusion, especially in Latin America, the Caribbean and Sub-Saharan Africa.

Unfortunately, many developing countries in these regions are not members of some of these standard-setting bodies such as the Bank for International Settlements (BIS) and Financial Action Taskforce (FATF) but are disproportionately affected by such financial rule-making. This disparity and its impact on un- and underbanked individuals living in these countries has contributed to the appeal of cryptocurrencies.

The Current State of Regulation in United States

Developing a framework for consumer tokens

The digital asset sector continues to evolve at a rapid pace. As SEC Commissioner Hester Peirce recently put it, the sector is “about as nimble as it gets.”1 In 2020, we have witnessed the rise of the decentralized finance, liquidity mining and governance tokens. Noncustodial decentralized exchanges are seeing explosive growth, with their share of total trading volume having grown from less than 1% in June 2020 to over 5% in August 2020, with June, July, and August each representing a record month for decentralized exchange volume.2 Non-fungible tokens (NFTs) are gaining traction in the digital art arena, with one piece of digital artwork having sold for approximately $55,000 in August 2020.3 NFTs are also becoming popular in gaming, with virtual worlds emerging where players participate in virtual economies where they trade property represented by NFTs (e.g., virtual land to build on) for other tokens or labor. We are even beginning to see NFTs being used as collateral to borrow stablecoins and the issuance of tokens that are backed by NFTs.4 As the US Securities and Exchange Commission (the SEC) continues to take action with respect to token offerings, the question on the minds of many entrepreneurs and their counsel is what the parameters are for the issuance and sale of “consumer” or “utility” tokens – those designed for use by consumers on a distributed platform and not intended to constitute securities – in the United States.5 While there appears to be a viable regulatory path to the issuance of consumer tokens that would not necessarily be viewed as “securities” subject to SEC oversight, the framework remains unclear. In this chapter, we discuss the legal issues surrounding such issuances under the US federal commodities and securities laws. This chapter serves as an update to the previous edition and reflects our most current and up-to-date thinking and analysis regarding the development of consumer token sales. Existing frameworks The securities law framework The SEC’s approach to whether a digital asset sold in a token sale would be a security derives from its application of the test set forth in SEC v. W.J. Howey Co. (the Howey Test).6 The Howey Test determines whether an asset constitutes an “investment contract,” one of the enumerated types of instruments defined in the securities laws.7 The test states that an investment contract involves (i) an investment of money, (ii) in a common enterprise, (iii) in which the investor is led to expect profits, (iv) derived from the entrepreneurial or managerial efforts of one or more third parties.8 If the test is satisfied, it is immaterial whether the enterprise is speculative or non-speculative, or whether there is a sale of property with or without intrinsic value.9 In short, the heart of the analysis is to focus on the economic reality of the arrangement in question.

The big challenge for regulators is that open-source cryptocurrency networks such as Bitcoin and Ethereum are computer protocols available to the public directly via the internet. They are permissionless interfaces for the issuance of tokens, self-hosted wallets and other DeFi services without the need for an intermediary.

Banning cryptocurrencies will not prevent adoption, however, it will only limit regulators' abilities to guide market activity around these networks and address their unique potential risks. Regulations informed by actual use cases and consultations with technology innovators will prove more robust in the long run and will reinforce important policy objectives driving economic inclusion, competition and growth.

The Commodities Law Framework

The US Commodity Futures Trading Commission (the CFTC) regulates the swaps (i.e., the CFTC's term for derivatives) and futures markets and retains general enforcement authority to police fraud and manipulation in cash or "spot" commodities markets.23 In 2014, thenCFTC Chairman Timothy Massad observed that what the CFTC has referred to as virtual currencies are "commodities" subject to provisions of the Commodity Exchange Act, as amended (the CEA).24 Since 2015, the CFTC has been active in bringing enforcement actions when virtual currency enterprises run afoul of regulatory requirements25 and in the enforcement against fraud and manipulation in the virtual currency "spot" markets.26 The CFTC also regulates certain retail commodity transactions that are leveraged, financed, or margined as if they were futures. The developing crypto spot markets have increasingly seen use of leverage and margin for trading of crypto-assets. The CFTC recently finalized interpretive guidance (Guidance) on what constitutes "actual delivery" in the context of crypto-assets that serve as a medium of exchange (i.e., virtual currency). Under the CEA and CFTC regulation, commodity transactions with retail customers that are leveraged, margin or financed are subject to regulation as futures contracts by the CFTC unless an exemption applies (the Retail Leveraged Commodity Rules). If the commodity (i.e., virtual currency) is delivered within 28 days, such a leveraged transaction will not be subject to regulation as a futures contract. The Guidance provides two primary factors for what would constitute "actual delivery" for purposes of the Retail Leveraged Commodity Rules: first, the purchaser must have possession and control over the virtual currency; and second, the purchaser must be able to use the virtual currency in commerce.

Securities Law Issues

Token presale instruments commonly fail to address the status of the underlying tokens and the impact of the presale offering on the marketing of the underlying tokens. That is, by marketing the token presale as an investment opportunity, these instruments were implicitly marketing the investment value of the underlying token. As a general matter, such instruments have been and continue to be marketed to purchasers with investment intent, such as hedge funds, venture capital funds and others, and, in at least some cases, purchasers are required to represent that they are purchasing for investment purposes.30 In addition, settlement of these instruments contemplates delivery of the token at network launch,31 and thus, at least with respect to the initial iteration of these instruments, the delivery of tokens for consumptive use will occur contemporaneously, or at least nearly so, with the delivery of tokens to purchasers who were investors. This would seem to argue in favor of the proposition that a token launch with delivery of tokens in settlement of these instruments is not directed solely to consumers, and, under the logic of Gary Plastic and the Munchee Order, is a securities transaction, not a consumer token launch.32 While recent iterations of these instruments have begun to acknowledge that issuances of the underlying tokens could be securities transactions, they continue to subject issuers and purchasers to significant risks by potentially increasing the likelihood that the underlying tokens will be deemed to be securities. This does not represent a viable outcome for many token-based networks, which require the free transfer of tokens on the network as part of their necessary function, because the US securities laws often require the existence and registration of an intermediary in securities transactions (i.e., the transfer of tokens deemed to be securities). Accordingly, an issuer or platform may be required to register as a brokerdealer or exchange (or alternative trading system)33 to permit the functioning of its tokenbased network,34 which would render many token-based networks unusable. Although recent statements indicate an acceptance of the notion that a digital asset originally issued as a security could subsequently cease to be a security once the network is sufficiently decentralized,35 the uncertainty that remains regarding the viability and timing of the consumer token sale raises challenges for appropriate disclosures to investors and potential liability for issuers. This is particularly the case when the entire investment decision is based on the availability and functionality of the underlying token, and it would seem to be challenging to craft sufficient disclosure in such a circumstance where the entire investment proposition is subject to this level of uncertainty. Recent examples of the unintended consequences of using token presale instruments can be seen in the SEC's actions against Kik and Telegram.36 Kik and Telegram each offered and sold pre-functional tokens to accredited investors in private placements pursuant to Regulation D via token presale agreements. Despite this, the SEC's view was that the private nature of the sales of tokens under the token presale instruments was vitiated because these sales were part of schemes that involved token sales to the public and thus constituted a single plan of financing that did not qualify for the private placement exemption from registration under US securities laws. In its Kik complaint, the SEC noted that "Kik sold the Kin as part of a single plan of financing, for the same general purpose, at about the same time, without creating different classes of Kin[.]"37 Similarly, in halting the delivery of Telegram tokens to the initial purchasers, the Court found that "the delivery of Grams to the Initial Purchasers, who would resell them into the public market, represents a near certain risk of future harm, namely the completion of a public distribution of a security without a registration statement."

Commodities Law Issues

Beyond the securities law concerns, the SAFT, and other similar token presale instruments, also raise commodities laws concerns. Because cryptocurrencies are commodities,39 a presale of consumer tokens through an instrument that provides the right to receive tokens in the future, or confers the right to exchange or convert such instrument into tokens that are not securities, may be a forward contract for the sale of a commodity or a commodity option, and subject to regulation by the CFTC as a swap, if an exemption is not available. (a) Commodity forward contracts Forward sales of commodities fall within the CEA's broad definition of "swap," which encompasses numerous types of derivatives, and are subject to regulation by the CFTC absent an applicable exclusion.40 Notably, the sale of a non-financial commodity for deferred shipment or delivery is excluded from the swap definition, so long as it is intended to be physically delivered,41 but provided such forward contract also qualifies as a commercial merchandising transaction (Non-Financial Forward Contract Exclusion).42 If such instruments are purchased by investors or speculators, they will not satisfy the requirement of the Non-Financial Forward Contract Exclusion because the purchasers are not "commercial market participants."43 The CFTC has expressly stated that hedge funds, acting in their capacity as investors, are not commercial market participants.44 As such, token presale instruments are effectively a prepaid forward contract of a commodity whereby parties have agreed a price or percentage discount on the token to be delivered at a later date. As discussed above, the many token presale agreements are (and continue to be) largely marketed to investors and not commercial market participants;45 such investors would not be eligible for the Non-Financial Forward Contract Exclusion. (b) Commodity options More recent versions of token presale instruments have also included convertible features, which provide investors or the issuer, as applicable, a call or put right to deliver tokens upon the consummation of a token sale at an agreed price or discount. Such an instrument may constitute a commodity option and would be subject to CFTC regulation as a swap,46 unless an exemption applies. Trade options are generally exempt from regulation by the CFTC, other than certain large trader reporting requirements and the CFTC's general anti-fraud and anti-manipulation enforcement authority (the Trade Option Exemption).47 In order to qualify as a trade option and benefit from the Trade Option Exemption,48 the commodity option in question must be: (i) intended to be physically settled if exercised; (ii) entered into with an offeror who is either an eligible contract participant (ECP)49 or a producer, processor or commercial user of, or merchant handling, the commodity (or products or by-products thereof) that is the subject of the option, and such offeror is offering to enter into such option solely for the purposes related to its business as such; and (iii) entered into with an offeree who is either a producer, processor or commercial user of, or merchant handling, the commodity (or products or by-products thereof) that is the subject of the option, and such offeree is entering into such option solely for the purposes related to its business as such. Unfortunately (as stated above in connection with the Non-Financial Forward Contract Exclusion), many of the token presale instruments are not offered to commercial market participants who would satisfy the “offeree” prong, even if the issuer of the instrument could satisfy the “offeror” prong. Additionally, even if such instruments are offered to “consumers,” they would not necessarily satisfy the “offeree” prong of the Trade Option Exemption, unless such consumers could establish a nexus to a business activity. Accordingly, token presale investors are unlikely to qualify for the Trade Option Exemption.

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Sent: Mon 11/29/2021 7:07 PM
Subject: FRAMEWORK FOR ARTIFICIAL INTELLIGENCE INTERNATIONAL ACCORD

ATTN: PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
Subject: Navigating Global Blockchain And Cryptocurrency Regulation

Matter: Science, Innovation, Technology And Space Framework

Consistent with the principles the provisions of the Budapest Convention on Cybercrime as well as the EU General Directives, and respecting the *Social Contract for the AI Age,* the AIIA draft framework is conceived and designed as:

- A multi-stakeholder, consensus-based international agreement to establish common policy and practice in development, use, implementation and applications of AI
- Anchored in the balance of influence and responsibility among governments, businesses, civil society, individuals, and other entities.
- Respectful of national authority and international commitments and requires assurances of rights and responsibilities for all participants and decision-entities.

To consolidate the design into a formal International Accord, it is essential to:

- **Review** legal frameworks for AI at various levels of aggregation to identify elements essential for an international AI legal framework.
- **Recognize** methods to prevent abuses by governments and businesses in uses of AI, Data, Digital Technology, and Cyberspace (including attacks on companies, organizations, and individuals, and other venues of the Internet)
- **Consolidate** working norms to manage all aspects of AI innovations, and
- **Construct** and enable response-systems for violations of rights and responsibilities associated with the development, design, applications, or implementation of AI.

Genesis for Development of the AI Risk Management Framework

Artificial intelligence (AI) is rapidly transforming our world.

Surges in AI capabilities have led to a wide range of innovations. These new AI-enabled systems are benefitting many parts of society and economy from commerce and healthcare to transportation and cybersecurity. At the same time, new AI-based technologies, products, and services bring technical and societal challenges and risks, including ensuring that AI comports with ethical values. While there is no objective standard for ethical values, as they are grounded in the norms and legal expectations of specific societies or cultures, it is widely agreed that AI must be designed, developed, used, and evaluated in a trustworthy and responsible manner to foster public confidence and trust. Trust is established by ensuring that AI systems are cognizant of and are built to align with core values in society, and in ways which minimize harms to individuals, groups, communities, and societies at large.

Defining trustworthiness in meaningful, actionable, and testable ways remains a work in progress. Inside and outside the United States there are diverse views about what that entails, including who is responsible for instilling trustworthiness during the stages of design, development,use, and evaluation. There also are different ideas about how to assure conformity with principles and characteristics of AI trustworthiness.

NIST is among the institutions addressing these issues. NIST aims to cultivate the public's trust in the design, development, use, and evaluation of AI technologies and systems in ways that enhance economic security, and improve quality of life. NIST focuses on improving measurement science, standards, technology, and related tools, including evaluation and data. NIST is developing forward-thinking approaches that support innovation and confidence in AI systems. The agency's work on an AI RMF is consistent with recommendations by the National Security Commission on Artificial Intelligence [1] and the Plan for Federal Engagement in Developing AI Technical Standards and Related Tools.[2]

Congress has directed NIST to collaborate with the private and public sectors to develop a voluntary AI RMF.[3] The Framework is intended to help designers, developers, users and evaluators of AI systems better manage risks across the AI lifecycle. For purposes of this RFI, “managing” means: Identifying, assessing, responding to, and communicating AI risks. “Responding” to AI risks means: Avoiding, mitigating, sharing, transferring, or accepting risk. “Communicating” AI risk means: Disclosing and negotiating risk and sharing with connected systems and actors in the domain of design, deployment and use. “Design, development, use, and evaluation” of AI systems includes procurement, monitoring, or sustainment of AI components and systems.

The Framework aims to foster the development of innovative approaches to address characteristics of trustworthiness including accuracy, explainability and interpretability, reliability, privacy, robustness, safety, security (resilience), and mitigation of unintended and/or harmful bias, as well as of harmful uses. The Framework should consider and encompass principles such as transparency, fairness, and accountability during design, deployment, use, and evaluation of AI technologies and systems. With broad and complex uses of AI, the Framework should consider risks from unintentional, unanticipated, or harmful outcomes that arise from intended uses, secondary uses, and misuses of the AI. These characteristics and principles are generally considered as contributing to the trustworthiness of AI technologies and systems, products, and services. NIST is interested in whether stakeholders define or use other characteristics and principles.

AI RMF Development and Attributes

NIST is soliciting input from all interested stakeholders, seeking to understand how individuals, groups and organizations involved with designing, developing, using, or evaluating AI systems might be better able to address the full scope of AI risk and how a framework for managing AI risks might be constructed. Stakeholders include but are not limited to industry, civil society groups, academic institutions, federal agencies, state, local, territorial, tribal, and foreign governments, standards developing organizations and researchers.

NIST intends the Framework to provide a prioritized, flexible, risk-based, outcome-focused, and cost-effective approach that is useful to the community of AI designers, developers, users, evaluators, and other decision makers and is likely to be widely adopted. The Framework's development process will involve several iterations to encourage robust and continuing engagement and collaboration with interested stakeholders. This will include open, public workshops, along with other forms of outreach and feedback. This RFI is an important part of that process.

NIST believes that the AI RMF should have the following attributes:

1. Be consensus-driven and developed and regularly updated through an open, transparent process. All stakeholders should have the opportunity to contribute to the Framework's development. NIST has a long track record of successfully and collaboratively working with a range of stakeholders to develop standards and guidelines. NIST will model its approach on the open, transparent, and collaborative approaches used to develop the Framework for Improving Critical Infrastructure Cybersecurity (“Cybersecurity Framework”) as well as the Privacy Framework: A Tool for Improving Privacy through Enterprise Risk Management (“Privacy Framework”).

2. Provide common definitions. The Framework should provide definitions and characterizations for aspects of AI risk and trustworthiness that are common and relevant across all sectors. The Framework should establish common AI risk taxonomy, terminology, and agreed-upon definitions, including that of trust and trustworthiness.

3. Use plain language that is understandable by a broad audience, including senior executives and those who are not AI professionals, while still of sufficient technical depth to be useful to practitioners across many domains.

4. Be adaptable to many different organizations, AI technologies, lifecycle phases, sectors, and uses. The Framework should be scalable to organizations of all sizes, public or private, in any sector, and operating within or across domestic borders. It should be platform- and technology- agnostic and customizable. It should meet the needs of AI designers, developers, users, and evaluators alike.

5. Be risk-based, outcome-focused, voluntary, and non-prescriptive. The Framework should focus on the value of trustworthiness and related needs, capabilities, and outcomes. It should provide a catalog of outcomes and approaches to be used voluntarily, rather than a set of one-size-fits-all requirements, in order to: Foster innovation in design, development, use and evaluation of trustworthy and responsible AI systems; inform education and workforce development; and promote research on and adoption of effective solutions. The Framework should assist those designing, developing, using, and evaluating AI to better manage AI risks for their intended use cases or scenarios.

6. Be readily usable as part of any enterprise's broader risk management strategy and processes.

7. Be consistent, to the extent possible, with other approaches to managing AI risk. The Framework should, when possible, take advantage of and provide greater awareness of existing standards, guidelines, best practices, methodologies, and tools for managing AI risks whether presented as frameworks or in other formats. It should be law- and regulation-agnostic to support organizations' ability to operate under applicable domestic and international legal or regulatory regimes.

8. Be a living document. The Framework should be capable of being readily updated as technology, understanding, and approaches to AI trustworthiness and uses of AI change and as stakeholders learn from implementing AI risk management. NIST expects there may be aspects of AI trustworthiness that are not sufficiently developed for inclusion in the initial Framework.

Sincerely,
Auto Legislative Policy Director
Office of Urvishkumar Mehta
Commissioner, Federal Government, USA
Pronounce: (He|Him|His)
Phone: [redacted]
@: [redacted]

From: Urvishkumar Mehta [redacted]
To: MBX OSTP PCAST <MBX.OSTP.PCAST@ostp.eop.gov>
Sent: Sat 12/11/2021 6:01 AM
Subject: USA-India: International Relations: 'Orbit Tax' proposed to Tackle Growing Problem of Space Junk

ATTN: PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
Matter: Legal | International Relation Industry: Science, Technology, Innovation and Space
Type: Space Law | Congressional Bill Development

I am writing the letter with reference to introduce a Congressional Bill to develop for the Orbit Tax to propose to manage the International Space with Space Junk.

The researchers say similar approaches are already in place to tax carbon emissions and for fisheries management.The impact of reducing collisions and collision-related costs would help drive the satellite industry from the $600bn market it is projected to become by 2040 to a $3tn one.

The global race to save outer space could lead to sustainable development of space resources. While the very idea of outer space brings to mind concepts such as boundless expanses, immensity and even infinity, it would be a mistake to assume that outer space is an infinite resource. The reality is that the portion of outer space currently used for orbiting man-made satellites is a finite resource, and one that is coming under serious threat from what could be described as man-made pollution: space debris.

Space debris, commonly defined as pieces of man-made hardware orbiting around the earth and no longer functional, is littering low, medium and geostationary orbits, threatening the sustainability of the satellite industry.

The phenomenon has been known for years and comes as no surprise. The first space debris was a consequence of the first satellite launch in 1957, when the upper stage of a Vostock rocket was left orbiting the earth until it re-entered the atmosphere the following year. Similarly, the first space debris in geostationary orbit is believed to date back to 1964.

What has changed, however, is the scale of the problem. In 1991, US engineer Donald Kessler stated that the space debris problem could reach a tipping point where the issue could get out of control, with a cascade of in-orbit collisions knocking out functional satellites. Naturally, the risk of the so-called Kessler Syndrome becoming a reality is that large parts of outer space could become overcrowded with debris and therefore impossible to be used for decades.

"We believe that unless action is taken immediately, such a scenario could become a reality in a few years," explained Tommaso Sgobba, who heads the **European Space Agency**'s (ESA) Office of Independent Flight Safety and Planetary Protection, at a roundtable discussion on the issue of space debris organized in Vienna, Austria, by the **United Nations** Office for Outer Space Affairs (UNOOSA) and the Diplomatic Academy of Vienna. The event was part of the 2010 World Space Week.

The seriousness of the situation should not be underestimated, as the 2009 in-orbit collision between an **Iridium** satellite and an out of control Russian spacecraft clearly illustrates. In other words, there should be a global race to save valuable outer space resources. The numbers are quite simply staggering. "Whether through radars or optical systems, we can only see objects larger than 30cm in GEO and 10cm in LEO,". "Of these, there are a total of around 17,000 to 20,000 items."

But there are also fragments that we cannot see but that we can safely assume exist: 300,000,000 fragments of less than 1mm, and 600,000 less than 1 cm. Sgobba explained eloquently what the impact of these debris could be on the satellite industry.

“In orbit, 1mm objects can damage a satellite sub-system, 1 cm objects are likely to disable satellites while 10 cm objects are likely to cause catastrophic satellite break-ups.”

It is worth considering that the issue of space debris does not only affect the space industry, aviation traffic is also at risk as a fragment of 300g could bring down an airplane. While the vast majority of these objects are made up of fragments (59 percent), satellites, whether operational or retired, make up 22 percent, rocket orbital stages 12 percent, and mission related objects 7 percent. Recent episodes, such as the 2007 test of a Chinese missile that took down a satellite in LEO creating a cloud of debris, suggest that the problem is here to stay. Even with the natural decay of debris re-entering the atmosphere, the amount of debris is set to grow in coming years.

The international community is responding to the issue through a number of initiatives. “The Space Debris Mitigation Guidelines were issued in 2007,” said UNOOSA’s Niklas Hedman, who heads the Committee Services and Research Section. “It is non-binding but was adopted by the **UN General Assembly**. Other initiatives include the creation of a UN Register of objects launched in outer space. It is clear, however, that despite the rules in place, the amount of debris is growing, if anything because of the large number of satellites launched before the Mitigation Guideline was issued. In other words, proactive mitigation action is needed.”

Although it can seem like an endless void from Earth, the truth is our near-space area is getting quite crowded, warns a paper published in the Proceedings of the National Academy of Sciences.

There are many old satellites and both natural and man-made debris crowding low-Earth orbit. Every time a new satellite is launched it adds to the risk of a collision.

According to the new study by economists, the most effective way to solve the problem of space junk isn't to try and capture this debris or try to make old satellites crash to Earth. Instead they propose an international agreement to charge satellite operators an "orbital-use fee", essentially a tax, for every satellite put into orbit.The annual fee, rising to $235,000 (£188,000) annually per satellite, would quadruple the value of the satellite industry by 2040, claim the researchers.

"Space is a common resource, but companies aren't accounting for the cost their satellites impose on other operators when they decide whether or not to launch,". But the researchers say these solutions won't work because they don't change the incentives for satellite operators. Instead, the economists propose an orbit tax. The objects crowding low-Earth orbit are an example of what economists call the Tragedy of the Commons - when many individuals acting in their own self-interest ultimately ruin a shared resource. There have been many solutions to the issue of space junk, including **technology which can capture debris** using nets or harpoons, or destroy it with lasers.

Yours,
Auto Legislative Policy Director (International & Congressional Affairs)
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From: Michael Sampson [redacted]
To: MBX OSTP PCAST <MBX.OSTP.PCAST@ostp.eop.gov>
Sent: Wed 12/15/2021 8:12 AM
Subject: Independent Energy Systems

To whom it may concern,
My name is Michael Sampson and i am First to File USPTO patents pending (with covid petition filed) on a NEW Renewable Energy that will make electric vehicle charging stations obsolete. currently the Inspector Generals Office of the Department of Energy has opened investigation based on evidences collected and submitted proving conclusively conspiracy to suppress, hinder and misappropriate my new Renewable energy technology. Please respond as to acknowledge the information I have just informed your office of. You have now been notified of a new technology that exist that can negate the need to build charging stations that simply change from fossil fuels to electric fuels. With the electric power infrastructure in such a bad shape as to cause blackouts across the grid, pulling more electricity from the power plants is not the answer for anyone but the Gas,Oil and Electric companies. My invention is the fueless solution that the United States needs to implement into our society. History will record every decisiion that we make concerning this technology, including those who stood by and did nothing for the Betterment of Mankind innovation that is Independent Energy Systems. i await your positive response. Respectfully Michael Sampson

From: Urvishkumar Mehta [redacted]
To: MBX OSTP PCAST <MBX.OSTP.PCAST@ostp.eop.gov>
Sent: Sun 12/19/2021 8:27 PM
Subject: Medical Vaccination Digital Passport ACT - Congressional Bill Development and Commission

ATTN: PRESIDENT'S COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY
Matter: Legal | Family, Medical and Health Care

I am writing a letter with reference to the Congressional Bill Development for the Medical Vaccination Digital Passport with Hologram, Digital Med ID, Bio-Graphic Fingerprint Sensor ID, Scannable QR Code and Face Recognition enabled Digital Photograph.

World Health Organization director-general Dr Tedros Ghebreyesus and International Labor Organization director-general Guy Ryder have confirmed their organizations will form an action group with major transport bodies to ensure freedom of movement for international transport workers.

The commitment came after organizations and unions representing road, air and sea companies and workers met with Tedros and Ryder. They warned of the impact of new travel restrictions on transport workers and the already fragile global supply chain in the wake of the Omicron variant.

The International Air Transport Association (IATA), the International Chamber of Shipping (ICS), the International Road Transport Union (IRU), and the International Transport Workers' Federation (ITF), have made urgent pleas for governments' health departments to coordinate measures and avoid restricting the movement of transport workers.

The action group will ensure the implementation of existing travel protocols developed by industry to protect the rights of transport workers. The WHO and the ILO also confirmed that the UN Secretary General's Executive Committee in January 2022 will discuss further solutions.

British Prime Minister Boris Johnson's Comment on:
We want the Government to commit to not rolling out any e-vaccination status/immunity passport to the British public. Such passports could be used to restrict the rights of people who have refused a Covid-19 vaccine, which would be unacceptable. (>https://petition.parliament.uk/petitions/569957<)

Your attention to this matter is appreciated.

Yours,
Auto Legislative Director Policy
Office of Urvishkumar Mehta
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From: Urvishkumar Mehta [redacted]
To: MBX OSTP PCAST <MBX.OSTP.PCAST@ostp.eop.gov>
Sent: Tue 1/4/2022 4:19 PM
Subject: U.S. MISSION TO THE UNITED NATIONS IN GENEVA

ATTN:
President's Council Advisor on Science and Technology
Matter: Legal | US-India Relation | Press-Media

Joint Statement of the Leaders of the Five Nuclear-Weapon States on Preventing Nuclear War and Avoiding Arms Races

The People's Republic of China, the French Republic, the Russian Federation, the United Kingdom of Great Britain and Northern Ireland, and the United States of America consider the avoidance of war between Nuclear-Weapon States and the reduction of strategic risks as our foremost responsibilities.

We affirm that a nuclear war cannot be won and must never be fought. As nuclear use would have far-reaching consequences, we also affirm that nuclear weapons—for as long as they continue to exist—should serve defensive purposes, deter aggression, and prevent war. We believe strongly that the further spread of such weapons must be prevented.

We reaffirm the importance of addressing nuclear threats and emphasize the importance of preserving and complying with our bilateral and multilateral non-proliferation, disarmament, and arms control agreements and commitments. We remain committed to our Nuclear Non-Proliferation Treaty (NPT) obligations, including our Article VI obligation "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."

We each intend to maintain and further strengthen our national measures to prevent unauthorized or unintended use of nuclear weapons. We reiterate the validity of our previous statements on de-targeting, reaffirming that none of our nuclear weapons are targeted at each other or at any other State.

We underline our desire to work with all states to create a security environment more conducive to progress on disarmament with the ultimate goal of a world without nuclear weapons with undiminished security for all. We intend to continue seeking bilateral and multilateral diplomatic approaches to avoid military confrontations, strengthen stability and predictability, increase mutual understanding and confidence, and prevent an arms race that would benefit none and endanger all. We are resolved to pursue constructive dialogue with mutual respect and acknowledgment of each other's security interests and concerns.

Yours,
Auto Legislative Policy Director (International and Congressional Public Affairs Committee)
Office of Urvishkumar Mehta
Chair and Commissioner,
Federal Government, United States of America
Email: [redacted]
Phone: [redacted]

From: Bevis, Michael [redacted]
To: MBX OSTP PCAST <MBX.OSTP.PCAST@ostp.eop.gov>
Sent: Wed 1/5/2022 3:28 PM
Subject: America's loss of capacity and international competitiveness in geodesy

Dear Ms. Mazza and Ms. Domnitz

I attach a white paper called "**America's loss of capacity and international competitiveness in geodesy, the economic and military implications, and some modes of corrective action** " co-authored by 15 geodesists, that I hope you will bring to the attention of the PCAST. The Executive Summary appears on page 2.

best wishes

Michael Bevis, on behalf of the authors

America's loss of capacity and international competitiveness in geodesy, the economic and military implications, and some modes of corrective action

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Ohio State University

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John Factor
Former Geodesist at
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January 1, 2022

Executive Summary

Geodesy is the fundamental science of geospace. It supports and drives innovation in geospatial technology, the ~ $ 1 trillion/year geospatial economy, and the geospatial systems of nearly all military platforms and activities. In the early 1990s the U.S. government, especially the Department of Defense (DOD), largely disinvested in academic research and education in geodesy. In contrast, the countries of the European Union that contributed the most to the development of geodesy in the preceding centuries have maintained healthy academic training and research programs, which is also the case in Japan, Canada, Australia and New Zealand. Furthermore, in the early 2000's, China began to make large and ever-growing investments in geodetic training and research. It now has more Ph.D. geodesists than the rest of the world combined. During this time period the greatest national collapse in geodetic capability occurred in the U.S., as its geodesists steadily retired, and most were not replaced. The Chinese military and defense industries now have access to hundreds of Ph.D. geodesists. Perhaps the most shocking example of the U.S. decline relative to China is that the number of Ph.D. geodesists in the entire DOD, including the National Geospatial-Intelligence Agency (NGA), is now approaching zero. The same is true of the U.S. defense industry. The U.S. is on the verge of being permanently eclipsed in geodesy and in the downstream geospatial technologies. This threatens our national security and poses major risks to an economy that is strongly tied to the geospatial revolution, on Earth and, eventually, in space.

Averting these dangers at such a late date will require the U.S. to invest in geodetic research and training on an *industrial* scale. We recommend three distinct modes of training necessary to reverse the capacity crisis, and a more diverse and robust approach to the funding of geodetic research. There must be a major increase in funding for basic and applied research in geodesy and in the allied disciplines and technologies. This research should take place in academia, industry and government/DOD labs. All of the U.S. government's geospatial agencies and services should be involved in the direction and funding of that research, to make that process more robust, and to ensure that all the important R&D issues are explored and addressed. A parallel educational effort should incorporate three complementary modes of training: (i) open-access, self-paced, no barrier to entry, internet-based instruction in geodesy designed to recruit large numbers of STEM students into the geodesy and adjacent disciplines, (ii) in-house training programs within the geospatial agencies of the U.S., and (iii) specialized training for the next generation of geodetic researchers. The third mode is necessarily tied to a major expansion of basic geodetic research in academia.

The situation in academia is particularly urgent because if it is not addressed very soon the U.S. will lose its ability to take corrective action at the scale required to avoid permanent disadvantage.

Introduction

Geodesy is the most fundamental science of geospace[1]. It underpins all the other geospatial sciences, all geospatial technologies, the ~$ 1 trillion/year global geospatial economy[2], and a large fraction of all DOD platforms and systems. The persistent decline of geodetic capacity in the U.S. over the last 25+ years, and the loss of competitiveness in geospatial technology that this has already triggered, now constitute a threat to our national security, and expose our defense, space and high technology industries to rising levels of risk[3]. Increasing accuracy requirements, and a growing emphasis on real-time applications, require constant improvements in geodetic techniques and infrastructure that are increasingly being developed outside of the US.

This crisis arose due to the combined effects of two opposed and long-sustained developments: (1) the U.S. government, most especially the DOD, greatly reduced their funding of academic (basic) research and graduate training in geodesy in the early 1990's, a disinvestment process largely completed by the year 1995, whereas (2) China began to make massive investments in geodetic training and research in the early 2000's which have continued, and even expanded, up to the present day.

Consider that:

• There are about 150 colleges and universities in China with undergraduate and graduate programs in geodesy, surveying, mapping and geomatics. We estimate that their combined undergraduate enrollment is in the range of 9,000-12,500 students per year, which provides a huge pool of candidates for graduate training in geodesy. Chinese graduate (M.S. and Ph.D.) students in geodesy are also drawn from undergraduate programs in physics, geophysics, mathematics, aerospace and electrical engineering, and astronomy.

• The city of Wuhan with its university, national research centers and institutes is now the single biggest center of geodetic research in the world. The number of geodesy graduate students educated in Wuhan alone exceeds that of the U.S.

• China has been out-training the rest of the world in geodesy for about 15 years. China now has more geodesists than the rest of the world combined, and its numerical advantage continues to grow. During this time period, the largest national decline (worldwide) in geodetic research and training capacity has occurred in the U.S.

• Geodesy researchers in China are better funded than most of their counterparts in the west.

• China is reaching parity with the U.S. and Europe in terms of the number of peer-reviewed scientific papers published per year in pure and applied geodesy, and its publication rate is increasing more rapidly.

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[1] Geospace includes the Earth, its oceans and ice sheets, its atmosphere and ionosphere, etc., and nearby outer space. Geodesy focuses on the representation and measurement of space, mass and time; reference systems, coordinates and orientation; gravity, rotational dynamics, and orbital mechanics; and how all of these processes and descriptions change over time. Planetary geodesy does the same for the moon, other planets and planetoids.

[2] This includes shipping, aviation, the space industry, driverless vehicles, drones, intelligent grids, computer and smart phone ecosystems, smart cities, location-based commerce, precision agriculture, AI, data analytics, the Internet of Things, as well as a many other scientific and engineering disciplines in academia.

[3] In a 2019 letter to NGA, Neil Vancans, VP of Septentrio USA, a leading developer of GNSS technology, stated that "It cannot be plainer that a range of serious threats will develop if we continue to allow the slow collapse of what is one of the most technologically productive of all the sciences".

The Chinese military and defense industries now have access to hundreds of Ph.D. geodesists. Perhaps the most shocking example of America's decline relative to China, in this strategically vital science[3], is that the number of Ph.D. geodesists in the entire DOD, including the NGA, is now approaching zero. The same is true of the U.S. defense industry.

In the modern world, a major competitive advantage in science quickly translates into a major competitive advantage in technology. This 'domino effect' is not some future prospect, it is already underway. For example:

• China's BeiDou system is at least as good as GPS, and arguably it is significantly better. BeiDou now has more world-wide users than GPS.

• The geodetic sub-systems that enable China's satellites and space program seem to have reached parity with our own.

• The collapse of geodetic capacity in NGA, the DOD and the defense industry will undermine next-generation GEOINT technologies, such as those based on artificial intelligence (AI)[4].

• The near disappearance of American geodesists has led to large numbers of young geospatial engineers who are inadequately trained in the scientific underpinnings of their own discipline[5].

In some cases, the science to technology linkage is imminent, but not yet immediate. For instance, NGA's Earth Gravitational Model EGM2008 was indisputably the world's best in 2012, but now Europe's and China's global gravity models—though highly derivative—are competitive, mostly because they are supported by many physical geodesy specialists, which is no longer the case in the NGA[6]. Such models provide 'gravity compensation' to inertial navigation systems (INS), and the need to improve that technology is quite pressing, given the looming dangers of GPS denial. NGA still retains a major advantage over its competitors, in that it owns the largest global gravity database. But to fully leverage that advantage, it must re-incorporate expertise in modern physical geodesy. The gravity-INS connection will become increasingly important on the moon and other planetary bodies, as well.

America's loss of a world-leading position in global positioning is not an isolated occurrence in satellite geodesy. Most of what we know about marine gravity (and a lot of what we know about ocean dynamics, tides, sea level rise and ocean bathymetry) is derived from satellite radar altimetry. For decades the U.S. was the undisputed leader in this field, but with the TOPEX and Jason satellites, that lead was shared with Europe, and more recently Europe has pulled ahead—and China is making great strides to catch up. Similarly, satellite gravimetry was once dominated by the U.S., but during the GRACE and GOCE

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[4] In 2019, Anthony Robbins, NVIDIA's VP for the Public Sector, stated in a letter to NGA: "it is essential that new AI-powered GEOINT capabilities be developed around a fundamental competency in geodesy and geospatial science in order to maximize efficacy and ensure long-term viability".

[5] In 2019, Trevor Greening, CTO of Towill, Inc., a leading geospatial engineering company, stated: "we have noted that the rapid development of many new technologies has placed a premium on geodetic science knowledge" but "we see graduates insufficiently skilled to comprehend the basis of the new technology including hardware, software, and procedures".

[6] We intend no disrespect of the hardworking geophysicists, physicists and others engaged with EGM at NGA. We simply assert that the world's largest and most complex physical geodesy project needs the active participation of physical geodesists. The Manhattan project at Los Alamos necessarily required the participation of chemists, mathematicians and engineers, etc., but what would have happened if all the physicists had disappeared?

missions Europe reached scientific and technological parity, and given that it now has many more physical and satellite geodesists than the U.S., it seems set to take the leading position. And in terms of civilian (unclassified) satellite missions, at least, Europe now has the leading InSAR technology. This decline in America's competitiveness on Earth has major implications for the moon and space race, too.

The U.S. disinvestment process not only restricted basic research in pure and applied geodesy, thereby reducing the flow of the new ideas and knowledge that drive innovation in our geospatial technologies, it has done tremendous damage to academic programs in geodesy as well. This is particularly worrying, in that the programs that should play a central role in any concerted effort to reverse America's 25- to 30-year blunder might soon be too few and too small to have any significant impact.

The situation is not uniformly bleak. The National Science Foundation (NSF) has had a positive influence on geodesy in this century, especially in terms of America's geodetic infrastructure. It funded the development and maintenance of a national GNSS network (now referred to as NOTA) to support research in the Earth sciences. This remains the most important geodetic network in the US. But NSF's core purpose is supporting scientific discovery and innovation, therefore it cannot divert large parts of its funding to *permanent* operational infrastructure. So, NSF is now disinvesting in NOTA. It would make sense for an operational geodetic agency such as NGS to take over NOTA, but, characteristically, NGS does not have the necessary resources. So, this major geodetic asset is being downsized and slowly degraded instead. While NSF does fund applied geodesy, essentially as a tool for many other sciences, it very rarely funds basic research in geodesy itself. The Directorate of Geosciences in NSF has many dozens of scientific funding programs, but it has never had one in geodesy *per se*.

Today, the single biggest institutional center of basic and applied geodetic research in America is NASA. During the 1980's and early-mid 1990's, NASA was a major funder of academic research in geodesy. Now, nearly all NASA funding in geodesy, most of which is for applied geodesy, is consumed internally. NASA does not play a significant role in geodetic training. While NASA's internal capabilities in geodesy, including at its laboratories, have not suffered to the extent seen in the NGA, DOD, NGS, USGS, etc., it has not been able to stem the national collapse in geodetic capacity, nor prevent the centers of expertise in radar altimetry, satellite gravimetry or GNSS shifting towards Europe and/or China.

Given that the U.S. capacity collapse in geodesy developed slowly, over three decades, most of the relevant government leaders must have failed to recognize what was happening, since no agency intervened. While the consequences of U.S. disinvestment and Chinese investment were not obvious in 2005, by 2015 nearly all experienced geodesists could see what had happened, and what would happen next.

The geodetic and geospatial authorities in China, for the last 15 years at least, were in possession of the facts and their implications that proved so elusive for most of their American counterparts. This 'awareness gap' has worked very powerfully in China's favor, bringing us uncomfortably close to the point of no recovery. We suggest that understanding the *mechanisms* that promoted unawareness, determining which still operate, and what other consequences they might produce, should be a high organizational priority (especially in the DOD), if the U.S. seeks to recover much of the geodetic/geospatial ground it has ceded to other countries. We suggest possible mechanisms in the Appendix and invite additional ideas from you.

The fact that China's large investments in geodesy and adjacent disciplines not only persisted, but have increased over time, suggests that China seeks to pass the U.S. with high forward velocity, while the U.S. continues its slow and backwards drift. This would allow China to take a commanding lead in "one of the most technologically productive of all the sciences"[3], and the downstream technologies, and thereby attain a permanent geospatial ascendancy.

A dawning but nationally incomplete recognition of the crisis

In 2017, Juliana Blackwell, the Director of the National Geodetic Survey (NGS), told Ohio State University (OSU) leadership that "the rapidly shrinking pool of well-trained, American geodesists now threatens our ability to achieve core aspects of the NGS mission, and we are sure this concern is shared by NGA and other agencies of the Federal Government"[7]. In 2018, Director Blackwell noted in a letter to the NGA that "the reduction in the population of graduate students training in this field is clearly tied to declines in government funding of geodetic research in academia". The DOD was long established as the largest funder of geodesy training and research circa 1990, so its subsequent disinvestment had a particularly large impact on American geodesy in academia, in industry[8] and, eventually, in the DOD itself.

While the recognition and the diagnosis of the problem by the NGS is very welcome, we have not observed any vigorous and concrete actions that suggest this understanding extends 'upwards' to NOAA, at the top of the organizational chart, or has led to a determined effort to revitalize geodesy in the NGS or in academia, before it is permanently eclipsed.

Some geospatial agencies have a detailed understanding of the crisis, but cannot seem to communicate it upwards; for other agencies the understanding itself is incomplete.

During an extended OSU-NGA-NGS study[9] of the U.S. geodesy crisis, which began in early 2018 and continued through early 2020, nearly all the NGA scientists engaged with global gravity modeling had an understanding similar to that of geodesists in academia and the NGS. Some NGA administrators shared this view, but others seemed uncertain as to whether the capacity crisis was focused in geodesy, or was

[7] Indeed, in 2019, Kevin Gallagher, the Associate Director of the U.S. Geological Survey wrote to the NGA saying "The USGS shares the concerns expressed by both the NGA and the National Geodetic Survey (NGS) that the candidate pool of trained geodesists eligible to work for U.S. government agencies is currently inadequate to support our missions in the future".

[8] In 2019, Dawn Wright, the Chief Scientist of ESRI stated in a letter to NGA: "We are well aware of the alarming shortage of geodetic scientists in the USA, and the fact that far fewer Americans have been trained in this discipline in the USA than is true in Europe, Japan and China. The American shortage has grown to its present crisis stage over a period of about two decades. China's spending on fundamental research and development, and on higher education, in geodetic science and geomatics, is probably now an order of magnitude greater than in the USA, and that gap appears to be growing".

[9] This study led to the white paper "*The Case for a DOD University-Affiliated Research Center (UARC) focused on Geodesy and Geospatial Technology*" by M. Bevis, R. Salman, D. Caccamise and C. Sanford (2020), available on request from the NGA Office of Geomatics.

uniformly distributed across all the geospatial disciplines—even though NGA had ~2,000 GIS specialists, but only 2 Ph.D. geodesists (one close to retirement age.)

Curiously, exactly the same misunderstanding—that geodesy is not the epicenter of the geospatial crisis—was and remains common among university administrators, despite the fact that there are more than 50 very good and viable GIS programs in American universities, while only a handful of tiny geodesy programs remain. In some universities, remote sensing groups can be found in many different colleges and departments focused on Earth and environmental sciences, biological science, engineering, forestry, agriculture, economics, and geography. But in most of these universities there is not a single geodesy program. We suspect that the mechanisms responsible for this administrative indifference to geodesy are peculiar to academia (*e.g.*, resource battles between disciplines and sub-disciplines, and a tendency to equate value with size), but its consequences—the slow but continuing decline of U.S. geodetic capacity—are not.

If an agency, institution or institutional sector (such as academia) remains uncertain about the structure of the U.S. geospatial crisis, then any corrective actions it adopts are likely to be off-target and sub-optimal. Therefore, we consider the NGA's recent (December 2021) RFI expressing interest in a future consortium focused on expanding research and training capacity in geodesy and adjacent geospatial disciplines to be a very encouraging development, particularly because the statement of work places so much emphasis on pure and applied geodesy. Much will depend on the scale, speed and the success of this initiative.

At the time of this writing (Oct-Dec 2021), it seems that the military services and their scientific research offices either have not recognized the U.S. geodesy crisis, or place relatively little importance on it. It is not surprising that the part of the government which led the disinvestment process, and which no longer contains any geodesists, would take longer to understand the problems driven by its withdrawal. Disengaging with a science obviously discourages awareness of that science and its role in adjacent disciplines, technologies and applications.

Several of the authors of this white paper have encountered strange misconceptions among individual scientific administrators in U.S. geospatial and defense agencies. One member of a scientific funding agency within the DOD has repeatedly stated to several of us that there has been no need to fund geodesy research for decades because all important geodesy problems were solved many years ago. We wonder why this person thinks China is investing many tens of millions of dollars in geodesy research every year—because they are deeply curious about the unimportant? If there is a crisis of the imagination here, it is not in the science itself. The number of interesting scientific questions in geodesy today, all pregnant with possibilities for geospatial technologies and applications, greatly exceeds the numbers of open questions and opportunities that prevailed 25 or even 15 years ago. Beliefs to the contrary are worrying in an office whose central purpose is the funding of strategically-important R&D.

Another example: a DOD scientist-administrator has remarked in encounters with academia (that included more than one of us) that there *is* a serious capacity crisis in geodesy, but it can be resolved by recruiting physicists, engineers, and other members of the STEM community. This is roughly equivalent to saying that a shortage of quantum physicists might be resolved by recruiting and repurposing mechanical engineers and statisticians. So why are Europe and China making such very large investments in the training of geodesy specialists? Presumably because they understand that they will win an increasingly complex and challenging geodetic contest (on Earth and in space) if their competition is almost entirely composed of non-geodesists.

We do not mean to single out any one institution, since there is plenty of blame to share. The academic geodesists co-authoring this white paper know, only too well, that the 'awareness gap' pervades American academia, just as it does much of our government and the DOD. This is why the few remaining American geodesy programs are small and mostly shrinking, while larger programs in Germany, for example, remain viable[10], and much larger programs in Chinese universities are vigorous, well-endowed and growing.

We are convinced that the fate of geodesy in U.S. academia, NGS and the NGA are all bound together.

Corrective action: Some objectives

It is not too hard to *imagine* the national situation of geodesy *if and when* the U.S. had reversed its disastrous course. There would be many more geodesists in the government, in the defense, high tech, space and geospatial industries, and in academia. There would be much larger budgets focused on geodesy and its interface to downstream technologies and applications. Not only would the NGS be far more active in geodesy, but so would its parent organization NOAA[11]. The NGS, in partnership with state survey agencies, would take over the NOTA GNSS network that NSF no longer wishes to support, and further develop its capabilities and applications. The NGA Office of Geomatics and the NGA Research Directorate would have been assigned the resources that allow them to make much larger internal and external investments in geodesy. Military research offices such as AFOSR and ONR would have re-engaged too. The USGS would have more geodesists than it did in 1995 and not far fewer, and, like its sister agencies, it might choose to emphasize methodologies, technologies and applications of special interest to it (*e.g.*, real-time earthquake hazard warnings, or geodetic imaging of flood plains). There would be far more government-industry-academic partnerships in geodesy and the adjacent disciplines and applications, and forums in which all three stakeholder groups could explain their experiences, perspectives and ambitions to the others. There would be a national movement to recapture America's place as a leading global player in pure and applied geodesy, and to translate that gain into more advanced geospatial technologies, novel applications, and improved national and economic security.

To ensure that the renaissance of geodesy was robust, the funding of geodesy research and training would be decentralized. Geospatial agencies, such as the NGS, which had been designated 'non-funding agencies' by the central government, would be reclassified as funding agencies. It makes sense that geodetic agencies be intimately involved in the funding of external geodetic research and not just focused on their internal geodetic activities. The renaissance will be more successful, and more rapid, if agencies

[10] German geodesy graduate programs are often based in research institutes, and often benefit from considerable support from China. For example, the Space Geodetic Techniques section of GFZ's Department of Geodesy has more than 30 Ph.D. geodesists, and roughly half of them were trained in China.

[11] Why is it that GPS Meteorology, which was invented in the USA, was perfected in Europe, where it has helped to produce the best numerical weather predictions in the world, despite that fact that the necessary collaboration between geodesists and meteorologists required an international collaboration Europe, versus a domestic collaboration here? It is ironic that NOAA contains both the National Weather Service and the National Geodetic Survey, and that many of the academic inventors of GPS Met were based in U.S. universities, but is more than one decade behind Europe. Characteristically, China's investments in GNSS Meteorology now dwarf those of the USA.

with differing specialties and goals are all driving investments in research, training and geodetic infrastructure. Such a diverse approach would require national coordination (*e.g.*, on shared geodetic infrastructure), but given that different agencies are interested in different areas of geodesy, having most of them involved in funding decisions will help research in every important branch of geodesy become adequately funded.

The problem, of course, is *getting from here to there*. Even if the DOD and other government agencies wanted to quadruple the number of geodesists they employ within a year, they would find that there are not enough geodesists available, because America's graduate research and education programs have been starved of resources for decades, and our national training capacity is now absurdly small. It follows that one of the highest priorities, especially at the beginning of the renaissance, should be to grow national training capacity as quickly as possible, and here revitalized academic geodesy programs must do the heaviest lifting (though summer internships in government and industry would help). As we explain below, graduate training in geodesy and basic research in geodesy are intrinsically coupled. There must be a major and sustained increase of basic and applied research in geodesy in the U.S. to drive innovation in our geospatial agencies and industries. Such research programs will provide the training grounds for most future geodesists.

Recovery mechanism 1: Greatly expanded training and recruitment

We believe that to reverse the U.S. collapse in geodetic capacity it will be necessary to engage in three distinct modes of training[12], and to succeed at them all.

Mode 1: A general education, outreach and mass recruitment effort aimed at thousands (eventually tens of thousands) of mostly young people, that provides free, self-paced and useful instruction in the various branches of geodesy via the internet (using a YouTube channel for example), supplemented by occasional 'inspirational' videos in which geodesists and other geospatial specialists from the NGA, NGS, different branches of industry, and academic research groups describe the fascinations of our discipline, the adventures of geodetic fieldwork, and the career opportunities available to suitably-trained individuals. The hope is that a significant fraction of these trainees would eventually enter one of the geospatial professions, including geodesy. The objectives of Mode 1 training include

• Mass recruitment of young STEM talent into geodesy—in grad school, the NGS, the NGA, the DOD, the USGS, the geospatial industry, the defense industry, high tech companies, the space industry, etc.

• Basic or supplemental training in geodesy for the people already working in the other geospatial sciences, geospatial engineering, etc., that currently lack the geodetic skills that they need[5] .

• Basic training (via the entry level courses) for managers and administrators who need at least a passing familiarity with the concepts, language and techniques of geodesy, and an understanding of the relevance of geodesy to other geospatial sciences, geospatial technology, geospatial services and applications, *i.e.*, across the entire spectrum of what some now call the 4th industrial revolution.

• Increasing the 'visibility' of geodesy in other STEM disciplines

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[12] This theme is developed at greater length in a white paper by M. Bevis (2021) *"Can the USA train itself out of the capacity crisis in geodesy and geospatial technology?"*, available on request (mbevis@gmail.com).

To maximize the scale of Mode 1 activity it is essential to eliminate *all* barriers to entry, which means no tuition, no requirements, no exams, no schedules, no imposed rate of learning, etc. Therefore Mode 1 training is learning for its own sake, and delivers no grades, certificates or degrees. However, it can be used to prepare people (at their own pace) for formal modes of education that do provide credentials, should they so wish.

All U.S. academics understand that one of the biggest challenges of teaching the present generation is that it has a much shorter attention span than had students 25 years ago. This means that the video training courses must be of very high quality, unusually compelling, up-to-date and relevant.

Mode 2: In-house training (basic and supplemental) of the existing employees of the government's geospatial organizations, via remote-access to university courses, by enrolling part-time in local universities, or providing employees with leave to obtain certificates or an M.S. degree from a full-time graduate program anywhere in the country, at the geospatial organization's expense. Without Mode 2 training, organizations like NGA cannot help their own employees adapt to the evolving technical requirements of their missions, or the constant reinvention of the geodetic sciences and technologies[5], and it will also be difficult for these employees to grow their technical competencies from one geospatial discipline into an adjacent one.

Mode 3: Advanced academic training for young researchers. The purpose of teaching or training is to disseminate or propagate existing knowledge, whereas the purpose of research is to discover or create new knowledge. Young scientists learn to do research by working with already accomplished researchers on important and difficult research problems. In practice, academic research projects both produce new knowledge *and* train the next generation of researchers. Each generation of researchers, at their peak, will create the future of their science, and they will train the next generation of researchers.

Nearly all truly *major* innovations in any science, including geodesy, are made by just the top few percent of the professional research scientists in that field, and nearly all of these were trained in the context of high-level research projects, mostly in strong and established graduate programs[13]. The greater the number of researchers in a given science, the greater the rate of major breakthroughs. Therefore, a significant fraction of the most talented and hardworking (and mostly young) scientists that can be encouraged to enter a strategically important field, such as geodesy, should become full-time graduate students engaged in serious research in a top-flight program. One reason we need Mode 1 training is to attract a lot of young people into a very big basic training and selection funnel[14].

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[13] Think about the physicists who built the atomic bomb in Los Alamos. They were either leading academic physicists of the day, like Fermi, Bethe, Oppenheimer, and Wigner, or they were graduate students in, or recent graduates of top physics programs, like Richard Feynman.

[14] Continuing with the physics analogy, if one or two thousand students enter the physics funnel as undergrads, many hundreds go on to grad school, many dozens or perhaps one hundred become professional Ph.D. level researchers, and while nearly all of those scientists will play very useful roles, probably less than five of them will make truly ground-breaking discoveries or innovations. Presumably this is one motivation for the great size of China's geodetic training apparatus.

Recovery mechanism 2: Greatly expanded research and technical development

Basic research drives applied research and technology forward[15]. Basic research fills the reservoir of new principles, facts and opportunities that supply and power technological innovation. If a nation's capacity for basic research shrivels, its downstream technologies will surely follow. The history of science makes it clear that it is impossible to predict if a given basic research project will lead to a major discovery. Most truly transformative discoveries are accidents that occur in front of well-prepared minds. The way to increase the probability of major scientific advances, is to have larger numbers of research groups poking around at the boundaries between the known and the unknown in the areas of interest.

China is pursuing a nearly optimal strategy. If one examines the acknowledgements sections of China's peer-reviewed scientific publications in pure and applied geodesy, one notices two patterns: (i) most research groups, even not particularly accomplished ones (as yet), are citing support from anywhere between 3 and 8 research grants or contracts, and (ii) Chinese government funding agencies often fund 5-10 research groups to work simultaneously in the same area of geodetic research. In most cases these overlapping investigations are largely independent efforts, though most cite the major findings of the others. This redundant or duplicated tasking increases the probability of success. Chinese industry certainly takes advantage of these discoveries, and it also absorbs a significant fraction of the research students who cut their teeth on fundamental research projects.

In the last year or two, increasing numbers of China's geodetic research papers are being published in Chinese. This change must reflect a reversal in government policy. While the Chinese research community, mostly fluent in English, can assimilate the West's publications, that advantage is asymmetric. Presumably, the shift in publication policy reflects the Chinese government's conviction that soon, if not now, the West will have more to learn from Chinese research in geodesy than vice-versa.

Unless there is a major expansion of both basic and applied research in geodesy in the U.S.—soon—we believe that it is inevitable that China will surpass both the U.S. and Europe, not just in these disciplines, but in most of the technologies and applications they support. While our *basic* research should be concentrated in academia (though not exclusively so), applied research should be pursued in academia and our geospatial industries and the geospatial agencies of the government and the DOD. Industry, government agencies and the military would also tend to lead most 'operational' applications.

While China has learned from America's traditional approach to the funding of science and technology, at this point we need to learn from theirs. There should be a concerted effort to fund multiple geodesy research projects in each academic geodesy program, ensuring that these contracts and grants allow for the expansion of the geodetic faculty and their Ph.D. staff scientists and technicians, and provide the necessary funds for many more American graduate students as well. More than one research group should be funded to investigate any technically difficult and potentially crucial topic. As the community of U.S. geodesists expands, so should the level of funding, to keep this growth on track. There should be regular

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[15] There is a positive feedback: new technologies provide new tools for basic research, extending its reach into the unknown. The relationship between science and technology is like that of a double helix, with each helix climbing up the back of the other.

encounters between academic geodesists, their students, government geodesists and industry, not only to seek synergies in R&D, but so that recent M.S. and Ph.D. graduates are quickly and optimally placed.

Concluding remarks

The DOD began to withdraw its support for academic geodesy around the time that it fully realized its original conception of the Global Positioning System (GPS) and established itself as the world's only geodetic superpower. This disinvestment was not an isolated event: the DOD also closed down its own geodetic research group in Hanscom AFB, for example. In retrospect, we can see that it was GPS rather than earlier developments in satellite geodesy that really launched the geospatial revolution and what is now a vast geospatial economy. GPS drove an explosion of scientific and technological creativity that extended far beyond the original conception of 'positioning, navigation and timing'.

Based on his wartime experiences, Vannevar Bush[16] published in 1945 his highly influential report "Science, The Endless Frontier" in which he argued that basic research was the "the pacemaker of technological progress" and explained that "new products and new processes do not appear full-grown" but are "founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science!" Europe, and especially China, were deeply impressed by the strategic, technological and economic advantages that accrued to the U.S. as a result of its enormous investments in science in the aftermath of WWII ("the physicist's war"). They still believe this formula to be valid, while the DOD seems to have lost that conviction, at least when it comes to geodesy.

Perhaps the DOD felt in the early 1990's that it could leave all basic geodetic research to the NSF and NASA. However, while NSF has funded many scientific *applications* of geodesy (in tectonics, seismology, glaciology, climate change, etc.), it has rarely funded the development of geodesy itself. NASA has supported basic research in geodesy, but its funding of external academic research in geodesy, especially basic research, has declined in relative terms, and now amounts to a very small fraction of the investments being made in basic geodetic research and training by the Chinese government.

One of us recalls the DOD geodesist Owen 'Obie' Williams telling him that he had just attended a Pentagon meeting where he was told by a group of generals and admirals that there was no "military requirement" for geodetic positioning with an accuracy better than 1 meter. This was around the time that the DOD began to withdraw funding from its own geodesists, and those in academia and industry. The traditional criticism of generals is that they are always preparing for the last war. In this case, these military leaders were fixated on the applications of geodesy that they could then identify then, based on past experience, with little interest in what might lie just beyond the "endless frontier".

China seeks to eclipse the U.S. in many strategic sciences, but we assert that it is in the field of geodesy that this goal is closest to being *fully* realized. It is not too late for the U.S. to reverse course, but only if it

[16] Bush was an engineer by training, a prolific inventor, a public intellectual, and arguably the greatest scientific administrator of the 20th century. During World War II he chaired the National Defense Research Committee, and later the Office of Scientific Research and Development that coordinated nearly all wartime R&D. After the war he was, in effect, the first presidential science advisor.

starts to do so very soon. If the necessary corrective action is delayed for several more years, the U.S. will have to send most of its future geodesists to Europe or China to obtain the necessary training. It is also important for the U.S. government to realize that governments, including the military, have *always* been the main funders of geodesy research and training, and that this is still the case now over most of the developed world. It certainly is in Europe, Japan and China. The recently established geodetic/geospatial partnership involving academia, government and industry in Australia provides another case in point.

The American geodetic community bears some of the blame for its own decline. It has been far too passive as it has watched its government and increasingly 'corporate' university administrations undermine the nation's research and training capacity in one of the most technologically productive and strategically important of all the sciences. We must do better than that.

Awareness of the U.S. geospatial capacity crisis, and the central role that geodesy plays in that crisis, has become more widespread than it was just 2-3 years ago. Even so, we remain very concerned that the national response could easily prove to be 'too little, too late'. Gearing up an adequate response at this late date will require a wider and deeper appreciation of the problem in government and the DOD, a shared commitment to overcome it, a coordination of vision and effort across academia, industry and all relevant civilian government and military agencies and services, and large and sustained investments. We believe that much can be learned from China's human and capital investments in geodesy and the adjacent disciplines and technologies, including their use of parallel or redundant tasking in the pursuit of its key goals, so as to ensure that its overall strategy is much less vulnerable to sequential 'weakest link' failures.

APPENDIX

Mechanisms that blocked and may still limit institutional and national awareness of the U.S. capacity crisis in geodesy and some adjacent geospatial disciplines

What were (and are) the mechanisms that created and sustain such a costly awareness gap between the U.S. and China? We are not experts in organizational dynamics, but we can offer the following ideas:

• *Broken lines of communication* in top-down systems of policy making and implementation, that block 'upward' transmission of information from the technical experts who best understand a given problem (and the possible avenues of redress) to those with the power and resources to drive the necessary change[17]. This is a particularly potent mechanism in any organization that strongly adheres to 'narrow' chains of command. Even one or two people in the middle of a communication channel one person wide can block vital information from reaching the leaders (who really need to know) for years at a time.

• *Divisional conflicts of interest*. The term 'conflict of interest' is widely used, usually in a highly negative context, but we use it in a rather more general sense. By divisions we mean the sequential embedding of smaller organizational units in larger ones, as in NGS-NOS-NOAA, or Office of Geomatics-NGA-DOD, and, in some cases, we refer to conflicts between organizational units that are placed at the same level in the organizational chart of their owner, for example, different colleges within a university. The conflicts of interest may be hidden or obscure, but more often they are not, and they may include differences in priority that make sense at the divisional level, but do not serve the interests of the parent organization, or, in this case, the national interest.

• *Monetary distraction*, by which we refer to people and institutions being so fixated on the big money/ large scale applications end of the geospatial spectrum, they do not perceive a rolling collapse propagating from the opposite (scientific) end of the spectrum. Picture an inverted geospatial pyramid [18] which grows upwards from its narrow scientific tip, geodesy, through geospatial technology, large-scale geospatial engineering and services, to governmental, military, space and business applications. The present global economic value of that pyramid is roughly $ 1 trillion per year. Nearly all that money is concentrated in the top third of the inverted pyramid. Mission-oriented entities like the military naturally tend to focus on applications, and on very-big-money programs as well. They have been staring at the top of the inverted pyramid, while its tip or base is crumbling, threatening the technical and economic integrity of the entire edifice.

• *Self-reinforcing trends.* That is, positive feedback mechanisms that amplify original forcings. Geodesists often joke that geodesy has become an 'invisible science' [19]. One of the problems of a shrinking pool of experts, is that there are fewer encounters between those technical experts and senior organizational

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[17] As in the punchline of a military joke, "General, we need some PWAKS". People Who Actually Know Something.

[18] The inverted geospatial pyramid is discussed in greater detail in "*The Case for a DOD University-Affiliated Research Center (UARC) focused on Geodesy and Geospatial Technology*" by M. Bevis, R. Salman, D. Caccamise and C. Sanford (2020), available from the NGA Office of Geomatics.

[19] This is rather ironic, since about 3.5 billion people worldwide, knowingly or unknowingly, utilize one or more Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS), via their smartphones, every day.

administrators, so the technical misconceptions or wishful thinking of the latter are much less likely to be corrected. If and when corrective measures are finally adopted, they may be so detached from technical feedback and reality, that they have very little prospect of success. The numerical decline in the number of representatives of a particular technical discipline will often lower their political clout, and even suggest to some non-technical administrators that, by association, their discipline is unimportant, and unworthy of administrative concern.

• *The Geospatial Tower of Babel.* Here we refer to confusion driven by ambiguous or misunderstood terminology that the disciplines of geodesy, the other geospatial sciences, and geodetic/geospatial engineering, have used to describe themselves or each other. We address here the most worrying of these confusions.

The term 'geomatics' was created in the 1980s and emphasized in the 1990s and 2000s. Some agencies and universities changed their program names to include the word geomatics. The term geomatics was based on the concept that the increasing potential of electronic computing was revolutionizing surveys and representation sciences: "Geomatics is defined as a systemic, multidisciplinary, integrated approach to selecting the instruments and the appropriate techniques for collecting, storing, integrating, modeling, analyzing, retrieving at will, transforming, displaying, and distributing spatially georeferenced data from different sources with well-defined accuracy characteristics and continuity in a digital format."[20] It does state the following: "Erected on the scientific framework of geodesy, it uses terrestrial, marine, airborne, and satellite-based sensors to acquire spatial and other data". But, geodesy has, in effect, been eliminated from the definition of geomatics used by most people today. In academia, geodesy is usually considered to be distinct from geomatics. But this understanding is not universal.

This ambiguity as to what geomatics really means, and, even more importantly, what it depends on, has led some individuals to believe that investments in geodetic research are not necessary for innovation in geospatial technology. Nothing could be further from the truth. Advances in geospatial technology often depend on advances in geodesy. Furthermore, optimal utilization of a geospatial technology often requires a sophisticated understanding of geodesy.

• *The Tragedy of the Commons* refers to a situation in which people (but also organizations and governments) with access to a shared resource (*i.e.*, the commons) pursue their narrow self-interests to the extent that they collectively deplete or destroy that resource. In this case, each of the many geospatial funding agencies, civilian or military, that rely on geodesy, focuses its investments on geospatial applications of greatest interest to them (be it climate change or satellite technology), and leaves all the other agencies to support the infrastructural science that underpins the common good. As a result, that resource is not nurtured or renewed at all, but relentlessly declines, which ultimately damages *every* entity engaged in such 'selfish' or myopic behavior.

We invite you to write to us with additional mechanisms that can explain a major strategic blunder that took at least 25 years to unfold, and did so in plain sight, apparently undetected.

[20] for example, Appl Geomat (2010) 2:137–146, Basics of geomatics, Mario A. Gomarasca, Published online: 27 July 2010, National Research Council of Italy.