Here are 5 suggestions the committee could consider to help unlock vast new IoT opportunities, to push the frontiers of IoT innovation, to harness IoT to help solve key societal challenges, to grow our economy in enormous ways, and to enable us to solve problems in ways never before possible**:**

1) <u>Fully Funding existing IOT R&D deployment and demonstration work</u>

In order to fully unlock IoT's potential, and in reporting back to Congress, I would encourage the committee to recommend that that the vital IoT related R&D and deployment work already taking place throughout the federal government be fully funded. That means fully funding the critical investments that a bipartisan Congress has supported through the **bipartisan Chips and Science Act,** and through the **bipartisan Infrastructure Act**, and that these be fully funded at the levels congress authorized.

In addition, to unlock IoT's full potential, we need to **fully fund the science agencies** that are doing work in these areas.

- That means fully funding:
    - ARPA-H – and its connected health work
    - At DOE – and its smart building, smart manufacturing technology programs and other initiatives
        - Through ARPA –E, which is advancing its SENSOR program, and PANDA program
        - DOE Office of Science to support the work that the labs are doing, and
        - EERE's work for energy efficiency and climate gains.
    - NSF – the NSF Engines, NSF's Smart and Connected Communities program, and various other programs – that are advancing smart cities, smart manufacturing, and the new IoT smart agriculture program created under the CHIPS & Science Act
    - DOT's – fledging new ARPA-I, SMART grants program, and Sensor programs
    - At Commerce, by fully fund NIST and the vital work it does, and the Regional Tech Hubs created by the Chips and Scienc Act
    - And continue to invest in the important IOT working being done at DoD, EPA, NIOSH, USDA/NIFA (and its Sensor Technologies Program) etc
    - And lastly, but importantly – make sure OSTP is adequately resourced to be able to take on a bigger role.

Anything less will slow down these efforts and cut our IOT opportunity short.

2) Quantify the economic potential at hand.

Second, the committee ought to specifically quantify the economic potential that is created by extending our digital transformation to the physical sectors of the economy – sectors like transportation, energy, health care, agriculture and manufacturing that have thus far missed out on the major IT delivered productivity gains. There are many different analysis that look at the economic potential, and they all point in the same direction, and demonstrate the same order of magnitude from a <u>1% improvement in productivity</u> that can emerge when we extend digital opportunity to the physical sectors of the economy. One of the studies done a couple years ago by <u>Michael Mandel, and Bret Swanson,</u> found that not only could bridging the digital world with the physical world add $2.7 trillion to annual U.S. economic output

by 2031, wages and salary payments to workers would increase by a cumulative $8.6 trillion over 15 years, but it could also boost federal revenues by a cumulative $3.9 trillion.

That means innovation in this space not only lifts our economy, but every dollar invested in IOT research and adoption – likely pays for itself several times over in new income because of the more prosperous economy it generates.

For example, we learned from the Human Genome Project, that every $1 invested by the U.S. government generated $141 in economic activity – in new companies, new employees, new investment, and the resultant companies that came out of it. Studies show these companies and investments now generate more tax revenue every year for the government – about $7 billion, than its initial federal investment to map the human genome -- $3 billion overall.

IOT is the same kind of broad enabler, and it suggests that these investments that Congress and the administration are making, will likely literally pay for themselves.

3) Integrate definitions – Make them interoperable.

For the federal government, research and innovators to be able to advance common goals, we need to be able to inclusively use common terms. We don't just need to provide interoperability between IoT devices, but IOT definitions.   We've seen terms used in the private sector like:

- Internet of Things
- Internet of Everything
- The Industrial internet
- Wearables
- Connected sensors
- Smart Technologies – the smart revolution
- Embedded intelligence
- Which are largely the same thing

But within federal agencies, IoT its often called:

- Cyber-physical systems (CPS)
- Computing-Enabled Networked Physical Systems (CNPS)
- Or just Networked Sensing

These are really all the same thing, but sometimes the different word choices have historically acted as a barrier – because IoT isn't just one thing, it's a billion different things.

As NIST previously pointed out in looking at the convergence of these different terms, "Recognizing this convergence can bring currently isolated fields and sectors together for progress around shared research, application, and innovation goals and opportunities."

The first place to start is around the Administration's list of critical and emerging technologies. They need to make clear that their use of the term "Advanced and Network Sensing" technologies on its list of Critical and Emerging Technology, is in fact synonymous with IoT.

4) Further Improve and Elevate Inter-Agency Coordination.

Within the White House there is a research coordination function called the National Science and Technology Committee or NSTC. This is where coordination across the government is supposed to happed. For more than a decade, there was a **Cyber-Physical System Inter-Agency Working Group,** which has made some important contributions and recommendations to advance IoT fields. But in 2019, its focus was diluted. **It's important to ensure there is an NSTC committee that is properly elevated, named, and empowered, just like other NSTC committees focused on AI, Quantum and Nanotechnology.** For definitional purposes, as noted above, it's also critical that they take an inclusive approach to terminology that in inclusive of IoT and the many different names and enablers.

5) Need a National Strategy for Taking Full Advantage of the Opportunity

Lastly, but also importantly, **we need a coherent comprehensive coordinated national IoT strategy**, as numerous federal experts have suggested over the years.

In 2010, the President's Council of Advisors on Science and Technology recommended the Federal Government invest in a national, long-term, multi-agency, multi-faceted research initiative in these areas. They said, ""those agencies tackling problems whose solutions entail instrumenting the physical world … should conduct research to design, fabricate, and test sensors that are problem-domain specific and that are cheaper, smaller, better packaged, lower powered, and more autonomous than those available today."

In 2011, an OSTP/NSTC White Paper outlined many reasons why we needed a more comprehensive and strategic approach for taking advantage of the Cyber Physical System (IoT) opportunities over the horizon to grow our economy, and help solve our national challenges. They found that "Isolated efforts by mission agencies are simply not sufficient to address the underlying issues in a holistic manner." Trying to address them agency-by-agency or sector-by-sector would result in inefficiencies and insufficient progress relative to system development timetables, and we might never get to where we need to be, and the **recommended the creation of a long range action plan.**

> They went on to say, "Without a strong, central focus on innovation and the common issues in translational research for innovation in cyber-physical systems, including standardization, manufacture, and deployment, each of the jump start activities above runs the risk of devolving into an isolated, marginally-effective effort."

Likewise, a NITRD Report from 2012 that looked at opportunity in Agriculture, smart building, defense, emergency response, energy healthcare, manufacturing and transportation, advocated for **a multi-agency, multi-sector comprehensive focus on the difficult crosscutting R&D challenges in CPS.**

And now today, the IoT/CPS opportunities are even more pervasive, the economic stakes even more enormous, and the impacts are even more profound.

We need a comprehensive national IoT/CPS strategy that:

- That lays out a **comprehensive vision** for the federal government's role in IoT/CPS
- That articulates the role that IOT can play across sectors and agencies, and within sectors, in **advancing national priorities and solving social challenges** – across health, transportation, manufacturing, energy etc.
- A strategy that **ensures continued US leadership** in connected device technologies, a vibrant and innovative commercial sector, and US leadership in the way the technologies are harnessed to address national challenges.
- That **comprehensively catalogues the game changing work** the administration is already doing across many agencies in fundamental research, development, demonstration and deployments – and the important role agencies are playing in meeting our critical needs.
- That **identifies potential opportunities**, and synergies across agencies, and identifies remaining gaps.
- That **outlines an R&D roadmap** around the often multi-disciplinary R&D needs to push new frontiers, and achieve major grand challenges. As PCAST previously noted, research on ways to design, fabricate, and test sensors that are problem-domain specific, and that are cheaper, smaller, better packaged, lower powered, and more autonomous than those available today. In sensors, actuators, and controllers. In sensors for use in extreme environments, and those that can unlock entirely new opportunities barely imagined today. Areas to consider would be the high-risk, high-reward research to advance digital sensors for example from digital noses that can detect any gas, particle or toxin; from digital eyes that for example can leverage new electro-optical technologies, photonic chips, and other sensors to help us see the world in new ways; digital tongue type technologies that can help us better sense toxins, turbidity, e-coli, pH, heavy metals in waters, and nutrients in soils; and biochemical enablers like micro-fluidic labs on a chip to advance the Internet of biochemical things. These could unlock new IoT/CPS potential across many domains.
- A strategy that can **ensure the continued responsible development** and use of a new technologies.
- And an effort **that provides a way that can help agencies, innovators, scientists, stakeholders, and commercial partners see and engage with the effort**. Like nano.gov, quantum.gov, and ai.gov, stakeholders could also benefit from a one stop shop on the internet that would share the strategy and vision, demonstrate the many ways the government is tackling these issues, and that allows stakeholders to engage in meaningful ways.
- **OSTP has historically played a critical role in coordinating such inter-agency endeavors.**
- If Congress consider **creating a new National Coordination Office** for IOT/CPS for advancing this strategy, like it has in the areas of Nanotechnology, Qquantum, and AI, then in doing so it should also ensure that OSTP is fully resourced and funded in order to be able to take on these task – or risk losing focus on other critical needs.