Federal Leadership of Future Moonshots

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In July 1945, Vannevar Bush addressed a report to President Franklin D. Roosevelt exhorting the need for basic research to become a priority, supported by the federal government. As an engineer, businessman and government administrator, Bush recognized that each of these three worlds – academia, industry, and government – plays a vital role in promoting scientific innovation. Crucially, the government's role is to provide the guiding vision for basic research, seed the related effort and sustain its pool of talent. His report led to the establishment of the National Science Foundation (NSF) and his legacy carried over to create another federal agency for innovative research and development (R&D), NASA, which landed a human on the Moon. In celebrating the 50th anniversary of the lunar landing, it is timely to reflect upon the current research landscape and the enduring role of federal support and direction.

A striking development since Bush's writing is the expansion of basic research beyond universities and national laboratories. Today, companies like Amazon, Google, Facebook, Microsoft or SpaceX maintain a trend in business, funding the majority of R&D in the U.S. Unencumbered by middling budgets and boundaries between disciplines, industry has established an innovation ecosystem with the capacity for exponential growth. At the same time, some mainstream academic research has morphed into a conservative paradigm or an agenda-driven format, stagnating the free spirit of innovation. It is remarkable to witness for-profit organizations now taking the lead over non-profit organizations on some risky projects. These private investments remind us that scientific R&D is not a zero-sum game analogous to pulling a short blanket to cover your head while taking the risk of exposing your toes. Instead, it is an infinite-sum game with an infinitely-stretchable blanket, where one discovery inspires many follow-up discoveries and innovation generates revenues that could fund additional research.

What would the future look like if risks were not a concern? Federal research support explores and creates that future, without concern for immediate economic benefit. As President John F. Kennedy articulated in his galvanizing Moon speech at Rice University in 1962, there was a grand vision driving the nation's research forward. This inspirational challenge led to the spectacular milestone in human history, a mere seven years later. But an enduring part of the Apollo legacy is the outgrowth of other technologies, as byproducts that accompanied solving a grand challenge. These innovations were borne out of the tireless work of men and women across all sectors: government, industry, and academia. The outcome of government-directed research was cross-cutting and more far-reaching than the original, singular goal. Then, as now, government played a unique role of setting a visionary blueprint for transformative research and providing the necessary funding and coordination.

It has been said that, during President Kennedy's visit to a NASA facility, he encountered a janitor. When asked what he was doing, the janitor replied, "I'm helping to send a man to the Moon." Whether that encounter was fact or fiction, it is undeniable that the federally-directed space race captured the attention, enthusiasm and curiosity of our nation. To this day, NASA remains one of the most revered brands, associated with national pride and countless career aspirations. That capacity for public engagement across an entire nation is a result of federal leadership in science and technology. As the future of research is contemplated, similar visionary goals – with broad engagement – must be considered. What should be our next grand vision? And how can we similarly involve all of society in this mission?

Naturally, one could be guided by the interests of national security and economic prosperity. But historically, the burning front of innovation advanced most vigorously when practical applications stimulated blue sky ideas in basic research. Funding of practical challenges motivates innovators to come up with new ideas that are also stimulating for their pure academic value. Notable examples are the development of the first computing device by Alan Turing while aiming to crack the Enigma code of the Nazis or the discovery of the Big Bang as the byproduct of the goal to improve communication, or many other examples in the remarkable history of Bell Labs.

In the America COMPETES Reauthorization Act of 2010, Congress directed federal agencies to build grand challenges into their efforts, to advance core missions and spur innovation. Challenge.gov has invited the public into an otherwise cloistered space, with a similar "Moonshot" - of aiming to achieve the impossible while still exploring the productive offshoots. In a time when software and rapid prototyping opportunities are ubiquitous, students, manufacturers and entrepreneurs can carry out R&D in numerous frontiers from gene editing to small satellite deployment. Visionary grand challenges, such as the Quantum Information Initiative, extend opportunities for R&D from outside the traditional halls of knowledge, continuing the bipartisan legacy of American innovation and exploration. They may lead us to tackle looming, overlooked topics, like the food-energy-water nexus or the ethical challenges associated with emerging technologies such as gene editing, artificial intelligence or robotics.

Invitations for diverse communities to get involved in grand challenges are needed not only for the public, but also within established research organizations. A similar strategy for accommodating the rapidly changing landscape of innovation is to allocate federal funding to academic researchers based on larger themes rather than organize it by discipline. Federal agencies, such as the NSF, could accelerate scientific discovery by allocating a predetermined fraction of the available funds to risky projects that could open up new horizons if successful. This implies generating funding streams for research groups that have a demonstrated track record of creativity rather than focus on narrowly defined projects with anticipated outcomes. This approach would benefit from peer review of proposals by the same innovators who are getting funded, so as to build a community for "out of the box" thinking. Fostering interactions among community members would make its impact bigger than the sum of its parts; for example, "massively collaborative mathematics" as envisioned by the Polymath Project, provides a new path for proving theorems or conjecture by a community effort rather than individuals. Engaging a larger community increases the diversity of ideas and the likelihood for success.

As we actively expand our community of innovators, it is vital for federal investments to support environments that cultivate excellence, namely our R&D infrastructure. Funding newer visionary projects cannot be divorced from funding the ongoing maintenance and updates of existing facilities. As one of its 10 Big Ideas, the NSF set forth the goal of investing in mid-scale research infrastructure, which was previously unfunded. This seemingly mundane objective is part of a larger, vital need to invest not only in ideas for research, but in the environments that enable these ideas. Carefully crafted federal research budgets should include steady allocations for scientific infrastructure, increasing the longevity of facilities and data products. National laboratories and other federally funded facilities are shared national treasures that have translational value and cannot be overlooked in our progress towards the future. For example, the opacity tables of heavy elements used for the design of nuclear weapons are now instrumental in interpreting "kilonova" flares associated with mergers of neutron stars. The NSF-funded LIGO observatory, itself a billion-dollar Moonshot, detected these violent events through the space-time ripples they produce - gravitational waves, enabling astronomers to conclude that the collisions of neutron stars, roughly the mass of the Sun and the size of a city, are the source of all the gold we weld into our wedding bands and the uranium we use for national security applications.

Infrastructure projects on the largest scale cannot be borne by the U.S. alone. Research science, today, is an international endeavor. Investment in shared international facilities is key to progress, and ensuring that the U.S. is not sidelined nor succumbs to scientific isolationism. The example of CERN - of which the U.S. is not a member state and does not have comparable domestic facilities - illustrates a competitive advantage that is being lost. The visionary gamble that characterized the NSF investment in LIGO should be celebrated and replicated. As new opportunities open up, the U.S. should be prepared to invest in similarly high-risk, high-reward facilities, such as LISA.

Equally global and even more vital to research are the talented minds in the R&D workforce. Government involvement is needed to recruit and sustain talent, by ensuring our institutions are the finest available and there are opportunities for students and researchers from diverse backgrounds to make use of them. From Maria Goeppert Mayer and Enrico Fermi involved in the Manhattan Project to Wernher von Braun who pioneered rocket technology and space science, to Sergey Brin who created Google, the U.S. has benefited greatly by attracting the most brilliant innovators into its laboratories and universities. Acknowledging this fact through appropriate government policies and investments would maintain the pool of visionaries essential for advancing American science and technology.

Moonshots are invoked to solve a seemingly-intractable problem with profound inspirational effects. The society of the future will be powered by as yet-unknown scientific and technological breakthroughs, based on research today. Stable, long-term federal support for basic research to invigorate this future, is a Moonshot of its own. Considering the economic realities and shifting roles with industry, there are challenges to overcome. Yet, with a singular focus, as in the Apollo era, the triad of visionary leadership, investments in infrastructure, and talent development, can pave the way to a brilliant future. With secure federal research opportunities, the possibilities are endless and unexpected. In the end, the future may not be forward, but upward - among the stars.

ABOUT THE AUTHORS

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