FORUM

Issues regularly receives numerous letters from readers responding to our articles. We print some of them here. A fuller collection can be found in our online Forum: https://issues.org/section/forum/.

Promethean Sparks Mural (detail) by Ben Volta and Alain Locke School Students, 2024, installed at the National Academy of Sciences building, Washington, DC.

ENHANCING REGIONAL STEM ALLIANCES

A 2011 report from the National Research Council, *Successful K–12 STEM Education*, identified characteristics of highly successful schools and programs. Key elements of effective STEM instruction included a rigorous and coherent curriculum, qualified and knowledgeable teachers, sufficient instructional time, assessment that supports instruction, and equal access to learning opportunities. What that report (which I led) did *not* say, however, was how to *create* highly effective schools and programs. A decade later, the National Academies' 2021 *Call to Action for Science Education: Building Opportunity for the Future* helped answer that challenge.

In "Boost Opportunities for Science Learning With Regional Alliances" (*Issues,* Spring 2024), Susan Singer, Heidi Schweingruber, and Kerry Brenner elaborate on one of the key strategies for creating effective STEM learning opportunities. Regional STEM alliances—what the authors call "Alliances for STEM Opportunity"—can enhance learning conditions by increasing coordination among the different sectors with interests in STEM education, including K–12 and postsecondary schools, informal education, business and

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PROMETHEAN SPARKS

Inspired by the National Academy of Sciences (NAS) building, which turns 100 this year, sixth-grade students at the Alain Locke School in West Philadelphia created the *Promethean Sparks* mural. The students collaborated with artist and educator Ben Volta to imagine how scientific imagery in the NAS building's Great Hall—from the *Prometheus* mural by Albert Herter and the golden dome by Hildreth Meière—might look if recreated in the twenty-first century. Their vibrant mural is exhibited alongside a timeline of the NAS building, which depicts the accomplishments of the Academy in the context of US and world events over the past century.

Working with Mural Arts Philadelphia, students merged diverse scientific symbols to create new imagery and ignite new knowledge insights. Embodying a collective exploration of scientific heritage, this project empowered the students as creators. The students' collection of unique designs reflects a journey of experimentation, learning, and discovery. Embracing roles beyond their student identities, they engaged as artists, scientists, and innovators.

Ben Volta works at the intersection of education, restorative justice, and urban planning. He views art as a catalyst for positive change in individuals and the institutions surrounding them. After completing his studies at the University of Pennsylvania, Volta began collaborating with teachers and students in Philadelphia public schools to create participatory art that is both exploratory and educational. Over nearly two decades, he has developed this collaborative process with public schools, art organizations, and communities, receiving funding for hundreds of projects in over 50 schools.

Mural Arts Philadelphia, the nation's largest public art program, is rooted in the belief that art ignites change. For 40 years, Mural Arts has brought together artists and communities through a collaborative process steeped in mural-making traditions, creating art that transforms public spaces and individual lives.

The NAS Building Timeline & Promethean Sparks Mural is on view through December 31, 2024, at the National Academy of Sciences, 2101 Constitution Avenue, NW, Washington, DC.

1924–2024 NAS Building Timeline & Promethean Sparks Mural, 2024, installed at the National Academy of Sciences building, Washington, DC.

Promethean Sparks Mural (detail) by Ben Volta and Alain Locke School Students, 2024, installed at the National Academy of Sciences building, Washington, DC.

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workforce development, research, and philanthropy.

Coordination is valuable because of the alignment it promotes. For example, aligning school experiences with workforce opportunities creates a better fit between schooling and jobs; aligning K–12 with postsecondary learning, including through dual enrollment, gives students a boost toward productive futures; and aligning research with practice means that research may actually make a difference for what happens in classrooms.

In calling for regional alliances, the authors are building on the recent expansion of education research-practice partnerships (RPPs), which are "long-term, mutually beneficial collaborations that promote the production and use of rigorous research about problems of practice." In RPPs, research helps to strengthen practice because the investigations pursued are jointly determined and the findings are interpreted with a collaborative lens. The National Network of Education Research-Practice Partnerships now includes over 50 partnerships across the country. The *Issues* authors have expanded the partnership notion by embedding it in the full education ecosystem, including educational institutions, communities, and the workforce.

In these polarized times, alliances that surround STEM education are particularly important. Working together on mutual aims helps us find common ground instead of highlighting divisions. Allied activities help to build social capital, that is, relations of trust and shared expectations that serve as a resource to foster success. Regional alliances can help create both "bridging social capital," in which members of different constituencies forge ties based on interdependent interests, and "bonding social capital," in which connections among individuals within the same organizations are strengthened as they work together with outside groups. In these ways, regional alliances can help defuse the tensions that surround education so that educators can focus on the core work of teaching and learning.

While workforce development is a strong rationale for regional alliances, Singer, Schweingruber, and Brenner note that this is not their only goal. Effective STEM education is essential for all students, whatever their future trajectories. Once again reflecting the times we live in, young people need scientific literacy to understand the challenges and opportunities of daily life, whether in technology, health, nutrition, or the environment. Alliances for STEM Opportunity can promote a pathway to better living as much as an avenue to productive work.

Adam Gamoran
President
William T. Grant Foundation

Building on the many salient points that Susan Singer, Heidi Schweingruber, and Kerry Brenner raise, I would like to emphasize the unique potential of community colleges to respond to the challenge of creating a robust twenty-first-century STEM workforce and science-literate citizenry.

Many community colleges have mission statements that are community-oriented, such as Central Community College in Nebraska, whose mission is to maximize student and community success. Moreover, because students of color disproportionally enroll in community colleges, these institutions often play an outsize role in advancing racial equity, offering paths to upward mobility that must overcome longstanding structural barriers.

Despite these many roles, community colleges are judged—and funded—primarily based on enrollment and the academic success of their students. These measures miss key benefits that these colleges provide to communities and don't encourage colleges to focus their efforts on community well-being, including the cultivation of science literacy.

Underneath this misalignment lies the opportunity. While open access schools typically can't compete on traditional completion, earnings, and selectivity metrics that four-year colleges are often judged on, they can compete much better on community measures because their primary audience and dollars stay more local. By highlighting how valuable they truly are locally through regional alliances, these schools could secure more sustained public investment and support more students and community members in a virtuous cycle.

Promethean Sparks Mural (detail) by Ben Volta and Alain Locke School Students, 2024, installed at the National Academy of Sciences building, Washington, DC.

Additionally, emerging leaders of community colleges who have risen through the ranks during the student success movement of the past 20 years are eager for "next level" success measures to drive their institutions forward. Instead of prioritizing only enrollment and completion rates, institutional leaders could set goals with regional alliance partners for scaling science learning pathways from kindergarten through college, then work together to address unmet basic needs through partnerships with local community-based organizations, ultimately helping more BIPOC (Black, Indigenous, and People of Color) students obtain meaningful and family sustaining careers—in STEM and other high demand fields.

If we truly aspire to have a STEM workforce that is more representative of the country and equity in STEM education more broadly, regional alliances must intentionally engage and support the institutions where students of color are enrolling—and for many, that is community colleges.

Ryan Kelsey
Director, Building America's Workforce
Urban Institute

It has long been observed that collaborations, alliances, and strategic partnerships are able to accomplish greater systemic change related to science, technology, engineering, and mathematics (STEM) education and research. There is an imperative for the nation's competitiveness that we cultivate and harness the talent of individuals with a breadth of knowledge, backgrounds, and expertise.

The American Association for the Advancement for Science has spearheaded the development of a national strategy referred to as the STEMM Opportunity Alliance—the extra *M* refers to medicine—to increase access and enhance the inclusion of all the nation's talent to accelerate scientific and medical innovations and discoveries. AAAS collaborates with the Doris Duke Foundation and the White House Office of Science and Technology Policy in this effort. The alliance's stated goal, set for 2050, is to "bring together cross-sector partners in a strategic effort to achieve equity and excellence in STEMM."

Susan Singer, Heidi Schweingruber, and Kerry Brenner offer a similar approach. What is compelling about their essay is not only the delineation of the positive impact of different cross-sector collaborations across the nation on outcomes for science teaching and learning, but also the focus on the local community or region. The authors advocate for "Alliances for STEM Opportunity" along with a coordinating hub to ensure strong connections, a clear (consistent) understanding of regional and local priorities, and a collaborative action plan for addressing the needs of the community through effective and integrated science education.

This recommendation is reminiscent of the National Science Foundation's Math and Science Partnerships program, started in 2002 but now discontinued. One of its focal areas, "Community Enterprise for STEM Learning," was designed to expand partnerships "in order to provide and integrate necessary supports for students." Singer, Schweingruber, and Brenner make a strong case and provide evidence for why regional alliances could lead (and have led) to improvements, which include enhanced teacher preparation, increased scores on standardized tests, a more knowledgeable workforce with relevant skills for industry, and a stronger STEM infrastructure in the region. Not only does this approach make sense; it has also shown to be effective. I know firsthand the significant benefits of alliances and partnerships from my former role as an NSF program officer, where I served as the co-lead of the Louis Stokes Alliances for Minority Participation Program and a member of the inaugural group of program officers that implemented the INCLUDES program, a comprehensive effort to enhance US leadership in STEM discovery and innovation.

As a member of the executive committee for the National Academies of Sciences, Engineering, and Medicine's Roundtable on Systemic Change in Undergraduate STEM Education, I have engaged in wide discussions about the various factors that have been shown to contribute to the transformation of the STEM education ecosystem for the benefit of the students we are preparing to be STEM professionals, researchers, innovators, and leaders. Systemic change does not occur in silos; it occurs through intentional collaborations and a commitment from all stakeholders to transform infrastructure and culture.

Tasha R. Inniss
Vice Provost for Research
Spelman College

It is a delight to see Alliances for STEM Opportunity highlighted by Susan Singer, Heidi Schweingruber, and Kerry Brenner. Over the past three years, serving as the executive director of one of the nation's first STEM Learning Ecosystems (a term coined by the Teaching Institute for Excellence in STEM), in Tulsa, Oklahoma, I've witnessed the Tulsa Regional STEM Alliance address enduring challenges in STEM education—issues that surpass local reforms and political shifts.

The authors rightly highlight that alliances are uniquely positioned to address persistent problems, even as reforms, politics, and priorities fluctuate. Improving learning pathways, reducing teacher shortages, increasing access to teacher resources and evidence-based teaching, promoting internal accountability, and supporting continuous improvement are all issues that might be partially resolved at the local level. However, these solutions require an infrastructure that allows for their dissemination and scaling to achieve systemic equity.

At the Tulsa Regional STEM Alliance—our iteration of the Alliances for STEM Opportunity—we agree that articulating a shared vision is the first step. Ours has evolved over the past decade, and we have found great alignment around our stated quest to "inspire and prepare all youth for their STEM-enabled future." This vision represents a shift from workforce-centric thinking toward holistic youth development thinking.

To reach our goal, we collaborate with 300 partners to ensure all youth have access to excellent STEM experiences in school, out of school, and in professional settings. This entails numerous collaborations; funding and resourcing educators and partners; leading or hosting professional learning; supporting program planning and evaluation; and creating youth, family, and community events that ensure all stakeholders understand and truly feel connected to our motto: "STEM is Everywhere. STEM is Everyone. All are Welcome."

By continually defining our shared work around excellent experiences and how they feed into our shared vision, we raise awareness and support an ambitious view of STEM education that advances learning in its individual and integrated disciplines. This enables us to advocate more effectively for funding, development, implementation, and improvement efforts from a principled and consistent position—both of which are increasingly needed in education.

With clarity on the value of STEM as a vehicle for ensuring foundational disciplinary understandings, we can carefully align stakeholders around a simple idea: STEM aims to address the issue of too few students graduating with competence in the STEM disciplines, confidence in themselves, and a pathway to the STEM workforce. STEM cannot meet this demand if the experiences in which we invest our time, talent, and resources do not advance our excellent experiences (shared work) and move us closer to inspired and prepared youth (our shared vision).

I echo the authors' call for expanded funding and research into this evolving infrastructure and encourage others to connect with their local alliances by visiting https://stemecosystems.org/ecosystems.

Levi Patrick
Executive Director
Tulsa Regional STEM Alliance

A LOOK AT DIFFERENTIAL TUITION

In "Tools That Would Make STEM Degrees More Affordable Remain Unexamined" (*Issues*, Spring 2024), Dominique J. Baker makes important points regarding the state of college affordability for students pursuing STEM majors. As a fellow scholar of higher education finance, I wish to elaborate on the importance of disaggregating data within the broad fields of STEM due to differences in tuition charges and operating costs based on individual majors.

First, Baker notes that differential tuition is prevalent at public research universities, citing data indicating that just over half of all institutions charged differential tuition for at least one field of study in the 2015–16 academic year. I collected data on differential tuition policies across all public universities for 20 years and found that 56% of research universities and 27% of non-research universities charged differential tuition in engineering in the 2022–23 academic year, up from 23% and 7%, respectively, in 2003–04.

Differential tuition policies primarily affect programs located within engineering departments or colleges, with computer science programs also being frequently subject to differential tuition. There are two likely reasons why these programs most often charge higher tuition. The first is because student demand for these majors is strong and the market will bear higher charges. This is often why business schools choose to adopt differential tuition, and likely contributes to decisions to charge differential tuition in engineering and computer science.

The other reason is because engineering is the field with the highest instructional costs per student credit hour, based on research by Steven W. Hemelt and colleagues. They have estimated that the costs for electrical engineering are approximately twice as much as for mathematics and approximately 50% more than for STEM fields such as biology and computer science. Add in high operating expenses for research equipment and facilities, and it is not surprising that engineering programs often operate at a loss even with differential tuition.

The higher education community has become accustomed to detailed data on the debt and earnings of graduates by field of study, which has shown substantial variations in student outcomes within the broad umbrella of STEM fields. Yet there is also substantial variation by major in both the prices that students pay and the costs that universities face to educate students. Both of these areas deserve further attention from policymakers and researchers alike.

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DECOLONIZE THE SCIENCES!

In "Embracing the Social in Social Science" (*Issues*, Spring 2024), Rayvon Fouché covers the full range of racialized phenomena in science, from criminal use of Black bodies as experimental subjects to the renaissance he maps out for new anti-racism networks, programs, and fellowships. His call for "baking in" the social critique, rather than adding it as mere diversity sprinkles on top, could not be clearer and more compelling.

Yet I know from my experience on National Science Foundation review boards, at science and engineering conferences, and in conversations with all sorts of scientific professionals that this depth is almost always mistranslated, misidentified, and misunderstood. Fouché is calling for creating a transformation, but most organizations and individuals are hearing only the elimination of bias. What is the difference?

The distinction is perhaps most obvious in my own field of computing. For example, loan algorithms tend to create higher interest rates for Black home buyers. Ethnicity is not a variable: data that correlate merely with "being Black" can be inferred by computing, even without human directives to do so. So it is difficult to oppose using the legal system, but tempting to solve as an algorithm problem.

As important as the elimination of bias truly is, it creates the illusion that if we could only eliminate bias, the problem would be solved. Bias does not address the more significant problem: in this case, that homes and loans are extremely expensive to begin with. The costs of loans and dangers of defaulting have destroyed working-class communities of every color; and "too big to fail" means that our algorithmic banking system turns risk for the entire nation's economy into profits for banks' own making. And that is not just the case for banking. In health, industry, agriculture, and science and technology in its many forms, eliminating bias merely creates equal exploitation for all, equally unsustainable lives, and forms of wealth inequality that "see no color."

My colleagues will often conclude at this point that I am pointing toward capitalism, but I have spent my career trying to point out that communist nations generally show the same trends: wealth inequality, pollution, failure to support civil rights. And that is, from my point of view, largely because they use the same science and engineering, formulated around the principles of optimization for extracting value. Langdon Winner, the scholar known for his "artifacts have politics" thesis, was wrong, but only in that the destructive effects of technological artifacts occur no matter what the "politics" is. Communists extract value to the state, and capitalists extract value to corporations, but both alienate it from the cycles of regeneration that Indigenous societies were famously dedicated to. If we want a just and sustainable future, a good place to start is to decolonize our social sciences, not just critique science for failing to embrace them, and perhaps develop that as mutual inquiries across the divide.

What would it take to create a science and technology dedicated not to extracting value, but rather to nurturing its circulation in unalienated forms? Funding from NSF, the OpenAI Foundation, and others have kindly allowed our research network to explore these possibilities. We invite you to examine what regenerative forms of technoscience might look like at https://generativejustice.org.

Ron Eglash
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HOW TO PROCURE AI SYSTEMS THAT RESPECT RIGHTS

In 2002, my colleague Steve Schooner published a seminal paper that enumerated the numerous goals and constraints underpinning government procurement systems: competition, integrity, transparency, efficiency, customer satisfaction, best value, wealth distribution, risk avoidance, and uniformity. Despite evolving nomenclature, much of the list remains relevant and reflects foundational principles for understanding government procurement systems.

Procurement specialists periodically discuss revising this list in light of evolving procurement systems and a changing global landscape. For example, many of us might agree that sustainability should be deemed a fundamental goal of a procurement system to reflect the increasing role of global government purchasing decisions in mitigating the harms of climate change.

In reading "Don't Let Governments Buy AI Systems That Ignore Human Rights" by Merve Hickok and Evanna Hu (*Issues*, Spring 2024), I sense that they are basically advocating for the same kind of inclusion—to make human rights a foundational principle in modern government procurement systems. Taxpayer dollars should promote human rights and be used to make purchases with an eye toward processes and vendors that are transparent, ethical, unbiased, and fair. In theory, this sounds wonderful. But in practice … it's not so simple.

Hickok and Hu offer a framework, including a series of requirements, designed to ensure human rights are considered in the purchase of AI. Unsurprisingly, much of the responsibility for implementing these requirements falls to contracting officers—a dwindling group, long overworked and under-resourced yet subject to ever-increasing requirements and compliance obligations that complicate procurement decisionmaking. A framework that imposes additional burdens on these individuals is doomed to fail, despite the best intentions.

The authors' suggestions also would inadvertently erect substantial barriers to entry, dissuading new, innovative, and small companies from engaging in the federal marketplace. The industrial base has been shrinking for decades, and burdensome requirements not only cause existing contractors to forego opportunities, but deter new entrants from seeking to do business with the federal government.

Hickok and Hu brush aside these concerns without citing data to bolster their assumptions. Experience cautions against this cavalier approach. These concerns are real and present significant challenges to the authors' aspirations.

Still, I sympathize with the authors, who are clearly and understandably frustrated with the apparent ossification of practices and the glacial pace of innovation. Which leads me to a simple, effective, yet oft-ignored, suggestion: rather than railing against the existing procurement regime, talk to the procurement community about your concerns. Publish articles in industry publications. Attend and speak at the leading government procurement conferences. Develop a community of practice. Meet with procurement professionals and policymakers to help them understand

Promethean Sparks Mural (detail) by Ben Volta and Alain Locke School Students, 2024, installed at the National Academy of Sciences building, Washington, DC.

the downstream consequences of buying AI without fully understanding its potential to undermine human rights. Most importantly, explain how their extensive knowledge and experience can transform not only *which* AI systems they procure, but *how* they buy them.

This small, modest step may not immediately generate the same buzz as calls for sweeping regulatory reform. But engaging with the primary stakeholders is the most effective way to create sustainable, long-term gains.

Jessica Tillipman
Associate Dean for Government Procurement Law Studies
The George Washington University Law School

CATALYZING RENEWABLES

In "Harvesting Minnesota's Wind Twice" (*Issues*, Spring 2024), Ariel Kagan and Mike Reese discuss their efforts targeting green ammonia production using water, air, and renewable electricity to highlight the role of community-led efforts in realizing a just energy transition. The effort showcases an innovative approach to spur research and demonstrations for low-carbon ammonia production and its use as a fertilizer or for other energy-intensive applications such as fuel for grain drying. Several themes stand out: the impact that novel technologies can have on business practices, communities, and most importantly, the environment, and the critical policies needed to drive change.

The market penetration of renewables in the United States is anticipated to double by 2050, to 42% from 21% in 2020, according to the US Energy Information Administration. However, a report by the Lawrence Berkeley National Laboratory finds that rapid deployment of renewables has been severely impeded in recent years because it takes, on average, close to four years for new projects to connect to the grid. Therefore, technologies such as low-carbon ammonia production catalyze the deployment of renewables by creating value from "islanded" sources—that is, those that are not grid-connected. They also reduce the energy and carbon intensity of the agriculture sector since ammonia production is responsible for 1% of both the world's energy consumption and greenhouse gas emissions.

US Department of Energy programs such as ARPA-E REFUEL and REFUEL+IT have been instrumental in developing and showcasing next-generation green ammonia production and utilization technologies. Pilot-scale demonstrations, such as the one developed by Kagan and Reese, significantly derisk new technology to help convince early adopters and end users to pursue commercial demonstration and deployment. These programs have also created public-private partnerships to ensure that new technologies have a rapid path to market. Other DOE programs have been driving performance enhancements of enabling technologies such as water electrolyzers to reduce the cost of zero-carbon hydrogen production and further expanding end uses to include sustainable aviation fuels and low-carbon chemicals.

The leap from a new technology demonstration to deployment and adoption is often driven by policy. In their case, the authors cite a tax credit that provides up to $3 per kilogram of clean hydrogen produced. But uncertainties remain: the US government has not provided full guidance on how this and other credits will be applied. Moreover, the production tax credit expires after 10 years, lower than typical amortization periods of capital-intensive projects. Our primary research with stakeholders suggests that long-term power purchase agreements with the renewable energy producer and an ammonia (or other product) producer could help overcome barriers to market entry.

Although their article focuses on the United States, the lessons that Kagan and Reese are gaining might also prove deeply impactful worldwide. In sub-Saharan African countries such as Kenya and Ethiopia, crop productivity can be directly correlated with fertilizer application rates that are lower than global averages. However, these countries have abundant renewable resources (geothermal, hydropower, wind, and solar) and favorable policy environments to encourage green hydrogen production and use. Capitalizing on the technology being demonstrated in Minnesota, as well as in DOE's Regional Clean Hydrogen Hubs program, could enable domestic manufacturing, increase self-reliance, and improve food security in these regions and beyond.

Sameer Parvathikar
Director, Renewable Energy Technology Advancement and Commercialization
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A SPACE FUTURE BOTH VISIONARY AND GROUNDED

In "Taking Aristotle to the Moon and Beyond" (*Issues*, Spring 2024), G. Ryan Faith argues that space exploration needs a philosophical foundation to reach its full potential and inspire humanity. He calls for NASA to embrace deeper questions of purpose, values, and meaning to guide its long-term strategy.

Some observers would argue that NASA, as a technically focused agency, already grapples with questions of purpose and meaning through its scientific pursuits and public outreach. Imposing a formal "philosopher corps" could be seen as redundant or even counterproductive, diverting scarce resources from more pressing needs. Additionally, if philosophical approaches become too academic or esoteric, they risk alienating key stakeholders and the broader public. There are also valid concerns about the potential for philosophical frameworks to be misused to justify unethical decisions or to shield space activities from public scrutiny.

Yet despite these challenges, there is a compelling case for why a more robust philosophical approach could benefit space exploration in the long run. By articulating a clear and inspiring vision, grounded in shared values and long-term thinking, space organizations can build a sturdier foundation for weathering political and economic vicissitudes. Philosophy can provide a moral compass for navigating thorny issues such as planetary protection, extraterrestrial resource utilization, and settling other celestial bodies. And it may not be a big lift if small steps are taken. For example, NASA could create an external advisory committee on the ethics of space and fund collaborative research grants—NASA's Office of Technology Policy and Strategy is already examining ethical issues in the Artemis moon exploration program, and the office could serve as one place within NASA to take point. In addition, NASA could bring university-based scholars and philosophers to the agency on a rotating basis, expand public outreach to include philosophical discussions, and host international workshops and conferences on space ethics and philosophy.

Ultimately, the key is to strike a judicious balance between philosophical reflection and practical action. Space agencies should create space for pondering big-picture questions, while remaining laser-focused on scientific, technological, and operational imperatives. Philosophical thinking should be deployed strategically to inform and guide, not to dictate or obstruct. This means fostering a culture of openness, humility, and pragmatism, where philosophical insights are continually tested against real-world constraints and updated in light of new evidence.

As the United States approaches its return to the moon, we have a rare opportunity to shape a future that is both visionary and grounded. By thoughtfully harnessing the power of philosophy while staying anchored in practical realities, we can chart a wiser course for humanity's journey into the cosmos. It will require striking a delicate balance, but the potential rewards are immense—not just for space exploration, but for our enduring quest to understand our place in the grand sweep of existence. The universe beckons us to ponder big questions, and to act with boldness and resolve.

Bhavya Lal
Former Associate Administrator for Technology Policy and Strategy
Former (Acting) Chief Technologist
National Aeronautics and Space Administration

G. Ryan Faith's emphasis on ethics in space exploration is well-met given contemporary concerns regarding artificial intelligence and the recent NASA report on ethics in the Artemis program. As we know from decades of study, the very technologies we hope will be emancipatory more often carry our biases with them into the world. We should expect this to be the case in lunar and interplanetary exploration too. Without clear guidelines and mechanisms for ensuring adherence to an ethical polestar, humans will certainly reproduce the problems we had hoped to escape off-world.

Yet, as a social scientist, I find it strange to assume that embracing a single goal, or "telos," might supersede political considerations, especially when it comes to funding mechanisms. NASA is a federal agency. The notion of exploration "for all humankind" certainly illuminates and inspires, but ultimately NASA's mandate is more mundane: to further the United States' civilian interests in space. The democratic process as practiced by Congress requires annual submission of budgets and priorities to be approved or denied by committee, invoking the classic time inconsistency problem. In such a context, *telic* and *atelic* virtues alike are destined to become embroiled and contested in the brouhaha of domestic politics. Until we agree to lower democratic barriers to long-term planning, the philosophers will not carry the day.

Better grounding for a philosophy of space exploration, then, might arise from an ethical approach to political virtues, such as autonomy, voice, and the form of harmony that arises from good governance (what Aristotle calls *eudaimonia*). In my own work with spacecraft teams and among the planetary science community, I have witnessed many grounded debates as moments of statecraft, some better handled than others. All are replete with the recognizable tensions of democracy: from fights for the inclusion of minority constituents, to pushback against oligarchy, to the challenge of appropriately managing dissenting opinions. It is possible, then, to see these contestations at NASA over its ambitions not as compulsion "to act as philosophers on the spot," in Faith's words, but as examples of virtues playing out in the democratic *polis*. In this case, we should not leapfrog these essential debates, but ensure they give appropriate voice to their constituents to produce the greatest good for the greatest number.

Additionally, there is no need to assume an Aristotelian frame when there are so many philosophies to choose from. The dichotomies that animate Western philosophies are anathema to adherents of several classical, Indigenous, and contemporary philosophies, who find ready binaries far too reductive. We might instead imagine a philosophy of space exploration that enhances our responsibility to entanglements and interconnectivities: between Earth and moon, human and robotic explorers, environments terrestrial and beyond. Not only would this guiding philosophy be open to more people, cultures, and nations, and better hope to escape "terrestrial biases" by rejecting a ready distinction between Earth and space. It would also hold NASA accountable for maintaining an ethical approach to Earth-space relations throughout its exploration activities, regardless of the inevitable shifts in domestic politics.

Janet Vertesi
Associate Professor of Sociology
Princeton University

THE POWER OF SPACE ART

One of the remarkable qualities of space art is its ability to amplify the mysterious intangibility of the cosmos (as with the late-nineteenth-century French artist Étienne Trouvelot) and at the same time make the unrealized technologies of the future and the worlds beyond our reach seem to be within our grasp (as with the mid-twentieth-century American artist Chesley Bonestell). As Carolyn Russo demonstrates in "How Space Art Shaped National Identity" (*Issues*, Spring 2024), art has played an important role in making space seem both meaningful and familiar.

Its appeal has not been limited to the United States. In the Soviet Union, the paintings of Andrei Sokolov and Alexei Leonov made the achievements of their nation visible to its citizens, while also showing them what a future in space could look like. The iconography developed by graphic designers for Soviet-era propaganda posters equated spaceflight with progress toward socialist utopia.

Outside of the US and Soviet contexts, space art from other nations didn't necessarily align with either superpower's vision. The Ghana-born Nigerian artist Adebisi Fabunmi, in his 1960s woodcut *City in the Moon*, provided a vision influenced by the region's Yoruba people of community life on the moon. The idea of home and community may have appealed to the artist during an era of decolonization and civil war more than utopian aspirations or futuristic technologies. Meanwhile, in Mexico, the artist Sofía Bassi composed surrealist dreamscapes that ponder the connection between outer space and the living world. Bassi's *Viaje Espacial* includes neither flags nor space heroics.

Contemporary space art is as likely to question the human future in space as it is to celebrate it. The Los Angeles-based Brazilian artist Clarissa Tossin's work is critical of plans for the moon and Mars that she worries continue colonial projects or threaten to despoil untouched worlds. Tossin's digital jacquard tapestry *The 8th Continent* reproduces NASA images of the moon in a format associated with the Age of Exploration, reminding viewers that our medieval and Renaissance antecedents similarly sought new worlds to conquer and exploit.

Space is also a popular setting or subject matter in the works of Afrofuturist and Latino Futurist artists. These works often seek to recover and reclaim past connections as they chart new future paths. The American artist Manzel Bowman's collages combine traditional African imagery and ideas with space motifs and high technology to produce a new cosmic imaginary unconstrained by the history of colonialism. The Salvadoran artist Simón Vega's work reframes the Cold War space race via the perspective of Latin America. Vega reconstructs the space capsules and stations of the United States and the Soviet Union using found materials in ways that make visible the disparities between the nations who used space to stage technological spectacles and those who were left to follow these beacons of modernization.

The many forms that space art has taken over these past decades are surprising, but the persistence of space in art is not. From the moon's phases represented in the network of prehistoric wall paintings in Lascaux Cave in southwestern France to the images of the heavenly spheres captured by medieval and later painters across many nations, art chronicles our impressions of the universe and our place within it perhaps better than any other cultural form.

Matthew Shindell
Curator of Earth and Planetary Science
Smithsonian's National Air and Space Museum
Lead curator of the museum's new *Futures in Space* gallery

BOOSTING HARDWARE START-UPS

In "Letting Rocket Scientists Be Rocket Scientists: A New Model to Help Hardware Start-ups Scale" (*Issues*, Spring 2024), John Burer effectively highlights the challenges these companies face, particularly in the defense and space industries. The robotics company example he cites illustrates the pain points of rapid growth coupled with physical infrastructure, demonstrating the different dynamics of hardware enterprises as compared with software.

However, I believe the fundamental business issue for hardware start-ups is generating stable, recurring revenue when relying on sales of physical items that bring in a one-time influx of revenue, but bear no promise of future revenue. Consider consumer companies such as Instant Pot and Peloton, which serve as cautionary tales that rode a wave of virality to high one-time sales and suffered with the failure to create follow-on products to fill production lines and pay staff salaries.

Further analysis of the issues Burer raises would benefit from exploring how the American Center for Manufacturing and Innovation's (ACMI) industry campus model or other solutions directly address this core problem of revenue stability that any hardware company faces. Does another successful product have to follow the first? Is customer diversity required? Even hardware companies focusing solely on national security face this problem.

While providing shared infrastructure is valuable, more specifics are needed on how ACMI bridges the gap to full-scale production beyond just supplying space. Examining the broader ecosystem of hardware-focused investors, accelerators, and alternative models focused on separating design and manufacturing is also important. The global economy has undergone significant reconfiguration, with much of the manufacturing sector organizing as either factoryless producers of goods or providers of production-as-a-service, focusing on core competencies of product invention and support, or supply chain management and pooling demand. This highly digitally-coordinated model can't work for every product, but the world looks very different from the golden age of aerospace, when it made sense to make most things in-house or cluster around a local geographic sector specialized in one industry.

Overall, Bruer identifies key challenges, but the hardware innovation community needs a broader conversation on business demands, especially around revenue stability, a wider look at the hardware start-up ecosystem, and concrete evidence of the ACMI model's impact. I look forward to seeing this important conversation continue to unfold.

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John Burer eloquently describes a new paradigm to strategically assemble and develop hardware start-up companies to enhance their success within specific industrial sectors. While the article briefly mentions the integration of this novel approach into the spaceflight marketplace, it does not fully describe the tremendous benefits that a successful space systems campus could provide to the government, military, and commercial space industries, as well as academia. Such a forward-thinking approach is critical to enable innovative life sciences and health research, manufacturing, technology, and other translational applications to benefit both human space exploration and life on Earth.

The advantages of such an approach are clearly beneficial to many research areas, including space life and health sciences. These research domains have consistently shown that diverse biological systems, including animals, humans, plants, and microbes, exhibit unexpected responses pertinent to health that cannot be replicated using conventional terrestrial approaches. However, important lessons learned from previous spaceflight biomedical research revealed the need for new approaches in our process pipelines to accelerate advances in space operations and manufacturing, protect the health of space travelers and their habitats, and translate these findings back to the public on Earth.

A well-integrated, holistic space campus system could overcome many of the current gaps in space life sciences and health research by bringing together scientists and engineers from different disciplines to promote collaboration; consolidate knowledge transfer and retention; and streamline, simplify, and advance experimental spaceflight hardware design and implementation. This type of collaborative approach could disrupt the usual silos of knowledge and experience that slow hardware design and verification by repeatedly requiring reinvention of the same wheel.

Indeed, the inability of current spaceflight hardware design and capabilities to perform fully automated and simple tasks with the same analytical precision, accuracy, and reproducibility achieved in terrestrial laboratories is a major barrier to space biomedical research—and creates unnecessary risks and delays that impact scientific advancement. In addition, the inclusion and support of manufacturing elements in a space campus system can allow scaled production to meet the demands and timelines required for the success of next-generation space life and health sciences research.

The system described by Burer has clear potential to optimize our approach to such research and can lead to new medical and technological advances. By strategically nucleating our knowledge, resources, and energy into a single integrated and interdisciplinary space campus ecosystem, this approach could redefine our concept of a productive space research pipeline and catalyze a much-needed change to advance the burgeoning human spaceflight marketplace while "letting rocket scientists be rocket scientists."

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The Naval Surface Warfare Center Indian Head Division (NSWC IHD) was founded more than 130 years ago as the proving ground for naval guns, and later shifted focus to the research, development, and production of smokeless powder. We continue as a reliable provider of explosives, propellants, and energetic materials for ordnance and propulsion systems for every national conflict, leading us to be recognized as the Navy's Arsenal.

But this arsenal now needs rebuilding to strengthen and sustain the nation's deterrence against the growing power of the People's Republic of China, while also countering aggression around the world.

At the 2024 Sea-Air-Space Exposition, the Navy's chief of operations, Admiral Lisa Franchetti, discussed how supporting the conflict in Ukraine and the operations in the Red Sea is significantly depleting the US ordnance inventory. NSWC IHD is an aging facility but has untapped capacity, and the Navy is investing in infrastructure upgrades to restore wartime readiness of its arsenal. This investment will modernize production, testing, and evaluation capabilities to allow for increased throughput while maintaining current safety precautions.

NSWC IHD believes that an industrial complex of the type that John Burer describes is worth investigating. While our facility is equipped to meet current demand for energetic materials, we anticipate increased requests for a multitude of products, including precision-machined parts and composite materials. Having nearby cooperative industry partners would reduce logistical delays and elevate the opportunity for collaborations and successful technology demonstrations.

Such a state-of-the-art campus would also provide a safe virtual training environment for energetic formulations, scale-up, and production processes, eliminating the risks inherent with volatile materials and equipment. This capability would allow for the personnel delivering combat capability, to paraphrase Burer, to continue to be rocket scientists and not necessarily trainers.

The Navy recognizes the need to modernize and expand the defense industrial ecosystem to make it more resilient. This will require working in close contact with its partners, including Navy laboratories and NSWC IHD as its arsenal. We must entertain smart, outside-the-box concepts in order to outpace the nation's adversaries. With these needs in mind, exploring the creation of an industrial campus is a worthwhile endeavor.

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