Response to RFI on Developing a Roadmap for the Directorate for Technology, Innovation, and Partnerships at the National Science Foundation

Andrew D. Maynard Ph.D.
Professor, Arizona State University School for the Future of Innovation in Society

Respondent Type
Expert in emerging technologies and advanced technology transitions

Primary focus of comments
6. Crosscutting investments

Key Technological Focus Areas
The comments provided cut across all listed technological focus areas, but are especially relevant to areas:

1: Artificial intelligence, machine learning, autonomy, and related advances

2: High performance computing, semiconductors, and advanced computer hardware and software

3: Quantum information science and technology

4: Robotics, automation, and advanced manufacturing

7: Biotechnology, medical technology, genomics, and synthetic biology

8: Data storage, data management, distributed ledger technologies, and cybersecurity, including biometrics

10: Advanced materials science, including composites, 2D materials, other next-generation materials, and related manufacturing technologies

Title

Advanced Technology Transitions as a conceptual crosscut for accelerating use-inspired research and practice in support of economically and societally beneficial innovation

Summary

Through the Directorate for Technology, Innovation, and Partnerships (TIP Directorate) roadmap, the National Science Foundation is uniquely positioned to accelerate economic and socially transformative development and application of emerging advanced technological capabilities by taking a strategic, crosscutting, and transdisciplinary approach to Advanced Technology Transitions. By supporting initiatives within this crosscut, the National Science Foundation will uniquely position the U.S. to take advantage of transformative technologies that

enhance U.S. competitiveness and support workforce growth. Envisioned initiatives will span artificial intelligence and quantum technologies to robotics and automation, immersive technologies, synthetic biology, decarbonization, advanced materials, and more. These will focus on developing novel understanding, theories, frameworks, and practices that are grounded in use-inspired research and focused on impact. A strategic and crosscutting focus on Advanced Technology Transitions will substantially strengthen alignment between the TIP Directorate roadmap and policies established in the CHIPS Act of 2022, including section 10382 (Purposes: 42 USC § 19102); section 19387 (Challenges and focus areas: 42 USC § 19107); and section 10398 (Ethical, legal, and societal considerations: 42 USC § 19118).

Full comments

As a nation, as well as globally, we are at a scientific and technological tipping point in human history, where the futures we are creating are on the cusp of departing in radical ways from past norms, trends, and expectations.

Advanced technologies, from quantum computing and generative AI to gene editing, next-generation materials, additive manufacturing, neurotechnology, and many more, are transforming what is possible in highly non-linear ways and at unprecedented rates. Emerging AI foundation models alone have seen the timescale associated with social disruption move from years to months, with the pace of disruption continuing to accelerate. At the same time, we are more interconnected, more resource-constrained, and more socially and environmentally precarious as a species, than at any previous point in history.

The result is a highly complex and convoluted dynamic between realizing the near-unimaginable possibilities that advanced technologies promise, and the challenges of avoiding potentially catastrophic economic, social, and environmental failures that are rooted in conventional thinking, naïve assumptions, siloed understanding, and limited approaches to beneficial and responsible innovation.

This is a dynamic that is increasingly veering toward potential failure modes that are not only insurmountable through conventional thinking but are obscured through established – and often outmoded – approaches to technology innovation.

As a result, successfully navigating increasingly transformative technology transitions will demand new thinking, new framings, new knowledge and insights, new philosophies, new perspectives, new skills, new jobs, and new organizational structures. It will also require new ways of collaborating across areas of expertise and understanding, domains of practice, and diverse communities and sectors. And it will depend on a new generation of leaders and innovators across public and private sectors with the knowledge, insights, skills, and vision, to steer these technology transitions toward more vibrant, promise-filled, and equitable futures.

Here, the NSF Directorate for Technology, Innovation, and Partnerships has a unique opportunity to incorporate crosscutting initiatives into its 3-year roadmap that draw on the framing and concept of "Advanced Technology Transitions" to accelerate use-inspired research and the translation of research to practice in ways that lead to transformative societal and economic value creation, while navigating an increasingly complex societal, economic, environmental, and geopolitical landscape.

Advanced Technology Transitions represent a new approach to framing effective advanced technology development and use, and is one that would provide a differentiating and transformative crosscut within the TIP roadmap. While there is existing scholarship on technology transitions (defined here as theories, frameworks, and practices, that support and enable economically and societally beneficial development, adoption, and use, of emerging technological capabilities), much of this is focused on specific domains (such as energy transitions), or theories that are only loosely connected to practice. At present, an integrated, transdisciplinary, and use-inspired approach to *advanced* technology transitions is lacking. Nevertheless, past experiences with transformative technologies such as gene sequencing and editing, nanotechnology and, more recently, artificial intelligence, provide rich material for novel and impactful research while demonstrating the need for new and integrated ways of approaching successful technology transitions. The lessons learned from nanotechnology, for instance, together with the need for new approaches to research and practice, are highlighted in a forthcoming paper in the journal Nature Nanotechnology on navigating advanced technology transitions (Maynard and Dudley 2023).

Here, there is a unique opportunity for the TIP roadmap to take a leadership role in developing research, understanding, frameworks, and processes, that will underpin the positive economic and societal benefits of emerging technologies.

If implemented, initiatives within the TIP roadmap would both develop generalizable understanding around advanced technology transitions that can be successfully applied to emerging and as-yet unidentified capabilities, while informing specific pathways to ensure the success of investments in areas such as AI, quantum technology, synthetic biology, and others. They would, through necessity, integrate scholarship across a wide range of academic disciplines (including the natural and social sciences as well as the arts and humanities), as well as integrating expertise from entrepreneurs, innovators, businesses, policy makers, and civil society. They would also be grounded in use-inspired research, bring novel transdisciplinary approaches to bear on economically and societally beneficial translation, and synergistically integrate with other initiatives within the roadmap.

While crosscutting research initiatives focused on Advanced Technology Transitions will depend on the roadmap developed within the TIP, specific research domains may include, but are not limited to:

- General theories of Advanced Technology Transitions and their application to complex and transformative emerging technologies and areas of technological convergence

- Failure modes, best practices, and emerging principles, associated with historic advanced technology transitions
- Models of advanced technology transitions within emerging complex sociotechnical systems that are informed by failure modes, best practices, and emerging principles, associated with historic advanced technology transitions
- Theory and practice of societally and economically beneficial and responsible innovation as applied to transformative advanced technology transitions
- The intersection of advanced technology transitions and Public Interest Technology
- Effective governance of advanced technology transitions, spanning the spectrum of public engagement, soft law, agile governance, hard-law regulation
- Advanced technology transitions, equity, and equality, including theories, models, frameworks, and practices, that support equitable transitions
- Public engagement, democratic decision making, and advanced technology transitions
- Understanding and leveraging the arts and humanities as potential modulators of advanced technology transitions
- The intersection of sustainable development and advanced technology transitions, particularly at the intersection of challenges such as decarbonization and energy generation/storage/distribution, and emerging capabilities such as AI, advanced materials, and complex systems.
- The ethical and responsible development and navigation of advanced technology transitions
- Novel theories, models, and approaches to risk in the context of advanced technology transitions
- Foresight theories and methodologies as applied to advanced technology transitions
- Misinformation, disinformation, and advanced technology transitions
- Advanced technology transitions and job loss/gain/displacement
- Critical and evolving knowledge and skills associated with advanced technology transitions, together with responsive approaches to learning and education

References

Maynard, A. D. and S. M. Dudley (2023). "Navigating Advanced Technology Transitions Using Lessons from Nanotechnology." Nature Nanotechnology **In Press**.