WORKFORCE DEVELOPMENT

REQUEST FOR INFORMATION SUMMARY

FUTURE TOPICS FOR WORKFORCE DEVELOPMENT IN EMERGING TECHNOLOGY CAREER PATHWAYS:
SUMMARY OF THE NSF REQUEST FOR INFORMATION

U.S. National Science Foundation
Directorate for Technology, Innovation and Partnerships

NSF 23-100

Future Topics for Workforce Development in Emerging Technology Career Pathways:

Summary of the NSF Request for Information

(NSF 23-100)

Introduction

The World Economic Forum predicts that most workers will need training (upskilling, reskilling) in the next four years to keep pace with emerging technologies[1]. Emerging technologies will create new job opportunities in fields such as big data analytics, climate, AI and machine learning, cybersecurity, biotechnology, advanced manufacturing, and semiconductors, among others.

However, U.S. workers are underprepared to fully participate in these new economies. Today's domestic workforce is the product of K-12 schools that lack access to high quality STEM programming and highly trained STEM teachers due to nationwide STEM teacher shortages and budget constraints. Decades of underinvestment in K-12 STEM teaching and learning is compounded by funding inequities across poverty-impacted districts—further shrinking levels of domestic students pursuing postsecondary STEM degrees compared to their internationally born peers[2]. Lack of exposure to STEM careers[3], community role models and mentors further exacerbates this divide, most acutely for underrepresented Americans.

In recognition that the U.S. must dramatically accelerate the pace and scale at which it prepares its domestic workforce to meet these emerging labor market needs, the "CHIPS and Science Act of 2022"allocated an unprecedented level of federal resources to the charge of developing a highly skilled domestic, diverse workforce that can support current and future innovation in these areas.

In May 2023, the Directorates for Technology, Innovation, and Partnerships (TIP) and STEM Education (EDU) jointly issued a Request for Information (RFI; NSF 23-100[4]) to seek input from stakeholders across the entire workforce development ecosystem on opportunities and challenges toward creating a robust collection of flexible and seamless STEM pathways in emerging technology areas[5].

NSF received 170 RFI submissions from respondents with expertise in the full range of technology and strategic areas in the CHIPS and Science Act (see Appendix A for details). To analyze this nearly 500 pages of respondent text data, we employed a mixed-methods approach, including qualitative thematic coding and machine learning techniques to identify key themes, strategic "**focus areas**," exemplar programs, and potential partners. We summarize key themes below.

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1 https://www.weforum.org/reports/the-future-of-jobs-report-2023/digest/

2 https://ncses.nsf.gov/pubs/nsb20211/

3 https://www.pewresearch.org/social-trends/2018/01/09/blacks-in-stem-jobs-are-especially-concerned-about-diversity-and-discrimination-in-the-workplace/

4 https://www.nsf.gov/pubs/2023/nsf23100/nsf23100.jsp

5 The NSF website includes a full set of responses: https://new.nsf.gov/tip/stem-workforce-development-rfi-responses.

Key Investment Areas

Respondents suggested investments across human capital, education programs, technology, infrastructure, and innovation ecosystems.

Human capital investment:
There is a need to build awareness, interest, and knowledge of emerging technology STEM pathways from an early age; and to support skills of a diverse emerging technology workforce across the lifespan.

Programmatic investment:
Respondents identified innovative programs at all levels of the education system—K-12, post-secondary, and workplace learning ready to scale that are preparing workers for careers in emerging technology.

Technology investment:
Respondents identified new technologies that promise to accelerate learning and expand access through distance experiential learning, promoting credit mobility across institutions, and leveraging personalized learning and competency-based models.

Infrastructure investment:
Respondents described cost as a barrier to training opportunities, such as the cost of materials, lab space, and the need for scholarships and stipends to offset the cost of training and childcare.

Ecosystem investment:
Respondents discussed the importance of nurturing and incentivizing cross-sector partnerships to sustain and scale investments. Many organizations across sectors are already working on these same issues. There is a need for mechanisms to coordinate these efforts to multiply impact.

Respondent responses were largely clustered around four "focus areas."

- ***Focus area 1:***
  Lay the groundwork in K-12 to strengthen the domestic emerging technology workforce pipeline
- ***Focus area 2:***
  Build postsecondary hybrid degree pathways that reflect emerging technology career pathways
- ***Focus area 3:***
  Test, evaluate, and scale innovations that support "wage earners as learners"
- ***Focus area 4:***
  Nurture regional STEM ecosystems

Below, we summarize each "focus area": a set of proposed strategies and example programs that emerged from the RFI response data.

Focus Area 1:
Lay the groundwork in K-12 to strengthen the domestic emerging technology workforce pipeline

RFI respondents across sectors discussed the critical role that the U.S. The K-12 education system has in building awareness and interest in emerging technology, the skills needed to be successful in emerging technology careers, and the tools needed to provide meaningful access to subjects foundational to emerging technology fields.

Strategy 1.1:
Build early awareness around emerging technology

RFI respondents are concerned that the American public, including students and teachers, lack knowledge about emerging technologies and have very limited exposure to high-quality STEM experiences that would build interest in, awareness of, and skills related to such technologies. Respondents noted the importance of engaging students early by exposing them to emerging technologies and STEM experiences by elementary school. Other key aspects of the strategy include:

- Develop engaging, hands-on activities at the K-12 and high school levels that can stimulate students' interest.
- Build and expand extra-curricular programming such as after school, bootcamps, workshops, and summer camps that are subsidized.
- Rebuild programs once viewed as 'trades' which are applications of STEM such as laboratories, workshops, and electronics shops.
- Build partnerships between industry and school districts through high school internships; create a mutual culture of applied learning.
- Prepare mentors to engage students early on, with a focus on underrepresented students.

Strategy 1.2:
Train teachers and district leadership in emerging technology areas

The U.S. has been experiencing teacher shortages in STEM for many years, disproportionately impacting poverty-impacted schools and youth. Recommended actions to train additional teachers in critical STEM fields include:

- Expand rigorous professional development through innovative, evidence-based approaches to preparing STEM teachers such as bootcamps in subjects that feed into emerging technology careers (e.g., physics).

Strategy 1.3:
Support infrastructure investments that expose students to emerging technology firsthand and through experiential learning

Even basic laptop and broadband access is a challenge in some districts. Recommended actions include:

- Increase broadband access and provide financial resources to expand the deep educators/ specialists with cloud-native and latest technology (e.g., Arduino, Raspberry Pi, 3D printers).

Strategy 1.4:
Develop and scale open-source curricula and assessments

Respondents acknowledged the challenge of the "emerging" nature of new technology fields and the need to build curricular infrastructure. Actions include:

- Create curricular resources that can easily be integrated across other STEM subjects.
- Design new courses and pathways for emerging technology careers, including curriculum, a test structure, and an ecosystem of partners.
- Create maps of core competencies, skills, and disciplinary knowledge needed to participate in the emerging technology labor market.

Below, we list example programs related to focus area 1 strategies:

- ***Example 1.1.***
  Afterschool Robotics Club: Robotics and electronics STEM club that attracts 10-20 students per week, run through a collaboration with local library, engages students as young as first grade, who are learning to type by programming.
- ***Example 1.2.***
  Texas Medical Center Innovation (TMC[i]) facilitates learners' transition into the biomanufacturing industry, by engaging students as high school freshmen through paid internships, events, and mentorship.
- ***Example 1.3.***
  Mitchell Institute Physics Enhancement Program: High-impact summer physics teacher training model that has been successfully implemented since 2011 and could be scaled nationally.

Focus area 2:
Build postsecondary hybrid degree pathways that reflect emerging technology career pathways

RFI respondents called for postsecondary programs whose degree and training aligns with emerging technology workforce development needs.

"Biomanufacturing requires a combination of technical, scientific, and engineering skills. Developing training programs that integrate these interdisciplinary skills can be challenging, as it requires collaboration among different educational institutions and industry partners..." -RFI respondent

"...rapid technological advancements require agile instructors that align with our ever-changing technology ecosystems and that must regularly upkeep training content and resources." -RFI respondent

Strategy 2.1:
Support faculty in developing interdisciplinary degree programs

- Create hybrid degree pathways and integrated postsecondary curricula that reflect emerging technology career pathways.
- Provide faculty resources to collaborate across departments and with industry to develop new programs and ensure alignment with industry.

Strategy 2.2:
Incentivize apprenticeship and experiential learning components

- Create opportunities for job seekers to obtain long-term relationships with industry through apprenticeships.
- Integrate experiential learning at the undergraduate level to promote workforce entry and advanced degrees in emerging technology fields.
- Create externships for postsecondary faculty to stay up to date on the latest industry practice and update their course offerings accordingly.

Industry engagement creates a "culture of innovation and entrepreneurship within our academic programs...Students trained in the technical aspects of quantum technology and the entrepreneurial skills required to bring these technologies to market will be better prepared to drive the quantum revolution." -RFI respondent

Strategy 2.3:
Develop multilevel educational opportunities (technical training and academic programs)

- Expand postsecondary programs that provide multiple levels of training within one subject area and bridges from one pathway to another (e.g., certificate to degree).

Strategy 2.4:
Support infrastructure investments to make emerging technology training affordable

- Provide financial resources to participants (e.g., scholarships, wraparound supports).
- Offset costs of equipment and materials to ensure up-to-date technology infrastructure, instructional materials, and instructors.

Below, we list example programs related to focus area 2 strategies:

- ***Example 2.1.***
  Quantum Technology and Metamaterials (QTM) Lab is an interdisciplinary quantum technology training program at Florida International University (FIU) that aims to break down barriers through multi-level quantum information science (QIS) courses with flexible pathways.

- ***Example 2.2.***
  Northeastern Course Development for a Re-skilled/Upskilled Workforce infuses "work challenges" or real-world experiences provided by partner organizations (companies, non-profits, government) into standard course structures. Learners and faculty in the coursework collaborate to devise solutions for sponsors. Faculty are sent into companies to learn about desired competencies.

Focus area 3:
Test, evaluate, and scale innovations that support "wage earners as learners"

RFI respondents highlighted innovations that support working adults.

Strategy 3.1:
Leverage AI and technology-based innovations in workforce development

- Expand technology-based innovations such as AI-powered online learning platforms and massive open online courses that enable learners to earn stackable credentials with different entry points and locations.
- Experiment with use of AI in workforce development such as forecasting workforce changes, anticipating training and workforce needs, and personalized skill and gap analysis matched to training needs.
- Leverage AI technologies such as generative AI for content creation, intelligent tutoring systems, VR/AR, and AI-enabled assessments and grading.

Strategy 3.2:
Expand flexible certifications pathways

- Expand flexible learning pathways in emerging technology training programs, including part-time study, online learning, and pathways to move from technical training to undergraduate and graduate studies.
- Expand other flexible learning options such summer camp (for younger learners), courses, internships, part-time jobs with a university that can provide more exposure to emerging technology fields.
- Ensure academic programs include technical training that translates into a career so that students will have a return on investment.
- Provide learners additional information on existing learning pathways and how to navigate them.
- Engage employers to upskill employees through courses, certifications, and micro-credentials or by partnering to implement existing programs (e.g. AT&T's Connected Learning Program, Microsoft's Digital Literacy Online Courses, and OneTen's Job Access Platform).

"...programs should acquire necessary credentials to be recognized as certifiable to gain value among companies and potential employers. It is essential and indispensable for scaled-up and replicated programs, across regions and industries, to be carefully planned and coordinated as this process can be extraordinarily complex." -RFI respondent

Strategy 3.3:
Build work experience through apprenticeships

- Expand access to paid apprenticeships and hands-on learning in emerging technology, such as internships, micro-internships, scholarships, mentorship, and cooperative education programs.
- Build Registered Apprenticeship Programs (RAPs) and pre-apprenticeships in emerging technology, designed to protect apprentices, ensure progressive wages, and provide portable skills.

"apprentice-like programs that open doors to tech jobs for those without four-year degrees, and, ideally, provide on-the-job training and mentorship, have shown scale potential within individual companies and adoptability across multiple companies."-RFI respondent

Strategy 3.4:
Develop innovations that promote credit mobility

- Promote credit recognition for prior formal learning to facilitate learners' transfer between educational pathways.
- Develop guidelines to validate informal learning experiences such as online course work—which may be more accessible than formal learning opportunities for nontraditional students.
- Make information about degree and training programs easily available to learners to promote clear and accessible pathways, and help learners navigate differences in program requirements and cost.
- Department leads in multilevel programs (that offer training and degrees) should map curricula across technical training and degree courses to ensure the content is provides a knowledge base.
- Promote transfer policies and articulation agreements to facilitate transitions between technical or community colleges and four-year colleges and universities.
- Provide mentoring and career advising to help students identify goals, map out pathways, and select programs that best fit their needs.

Strategy 3.5:
Provide wraparound student supports

- Provide academic support such as adult basic skills training in literacy, numeracy, and writing, or tutoring.
- Offer financial support to ease the tuition cost burden such as scholarship, discount, stipends, or employer support. Offer additional financial support for childcare, transportation, and emergencies.
- Provide support for materials such as laptops.
- Facilitate supportive networks, affinity groups, and mentoring for underrepresented students and professionals in addition to the career advising support mentioned above.

"...financial constraints remain the top reason students are discouraged or prevented from pursuing a higher education at a 2-to-2, technical, or four-year institution." -RFI respondent

Below, we list example programs related to focus area 3 strategies:

- ***Example 3.1.***
  AI-Powered AR/VR Technologies in Workforce Development can enhance learners' experience through real-time feedback, digital mentoring and coaching, and can provide skills assessments and personalized learning pathways through intelligent tutors. Drawbacks include unequal access to hardware and internet connectivity, expensive content development, and concerns about potential algorithmic bias in job training tools.
- ***Example 3.2.***
  Innovations that Promote Credit Mobility such as digital wallets can allow merging of work/academic/military experience into accessible digital files and promote the transfer of noncredit experiences into degree-supporting credits. A centralized database of equivalent courses, AI assessment of credit/skill equivalencies are other innovations that may support credit mobility.
- ***Example 3.3.***
  Matching Workers to Training Programs based on Skill Profiles is a strategy that the Advanced Robotics for Manufacturing Institute (ARM Institute) used to help workers seek training opportunities and new careers in advanced manufacturing and robotics. The ARM Institute built a site featuring career pathways from Robotics Technician through Integrator built on 26 core competencies in robotics: RoboticsCareer.org.
- ***Example 3.4.***
  The Texas Higher Education Coordinating Board's Program of Study supports community colleges in building curricula that translate academics to career-ready skills. It guarantees credit transfer across Texas, and has multiple entry/exit points including certifications, Associate of Applied Science (AAS) degrees, and credit transfer agreements between community colleges.

Focus area 4:
Nurture regional STEM ecosystems

RFI respondents recommended nurturing regional STEM ecosystems to create robust and sustainable workforce development ecosystems in emerging technology. In Exhibit A7 in the Appendix, see the the types of partners that RFI respondents mentioned.

- Create multi-sector engagement through platforms, events, forums, convenings, conferences, seminars, workshops, and online communities to share best practices, research findings, and industry insights.
- Facilitate collaboration and programming between community colleges and relevant emerging technology industries to support students in pursuing career paths aligned with workforce needs.
- Leverage collaborative efforts to directly involve industry leaders in the alignment of industry standards and STEM curricula; ensure that learners can apply new skills and knowledge to real-world problems.
- Use STEM ecosystems to disseminate practical knowledge to interested learners faster; to co-develop not just courses, but standards around practical educational content.

"...collaborative efforts can align training programs with industry demands, ensuring learners are equipped with the necessary skills and knowledge to excel in emerging technology careers. Such partnerships facilitate internships, apprenticeships, and work-integrated learning experiences." -RFI respondents

Below, we list example programs related to focus area 4 strategies:

- ***Example 4.1.***
  Innovate Illinois is a coalition of the governor, civics and education leaders, state and local economic development partners, and U.S. Senators (who serve as advisors). They aim to leverage the state's innovation hubs, public and private universities, and national laboratories to provide 21st century opportunities for state's workers, scientists, and businesses. Driven by their economic development plan, the goal is to usher in a new era of scientific and technological progress.

- ***Example 4.2.***
  Partnerships with Professional Organizations like Institute of Electrical and Electronics Engineers (IEEE) and American Society of Mechanical Engineers (ASME) should be leveraged. With large reach and close ties to industry, they can support the dissemination of academic information, application of knowledge at the practical level and convening of practice-oriented stakeholders.

- ***Example 4.3.***
  The Skills Development Fund in Texas addresses skills gaps and ensures a talent pipeline aligned with regional industry needs. Private employers or corporate foundations can collaborate with Workforce Solutions to apply for funding for workforce development activities for eight designated industry clusters such as customized training, federally funded apprenticeships, recruitment, and retention. Partners include Texas universities, community colleges and school districts, key emerging technology industries, the higher education board, state education agency, workforce commission, and STEM pathway initiatives representatives from other states.

Next Directions

NSF is grateful for the thoughtful and in-depth guidance from the community, provided in response to this Request for Information. NSF will leverage this guidance in its stakeholder engagement activities, the creation of new programs, and refinements to existing programs.

Existing NSF programs are responsive to RFI recommendations. Experiential Learning for Emerging and Novel Technologies (ExLENT) lays the groundwork to strengthen the domestic emerging technology workforce (**Focus area 1**), build postsecondary degree pathways (**Focus area 2**) and support "wage earners as learners" (**Focus area 3**). The NSF Regional Innovation Engines (NSF Engines) and the Enabling Partnerships to Increase Innovation Capacity (EPIIC) programs nurture regional STEM ecosystems (**Focus area 4**).

The task ahead for our agency and the nation is to chart a path forward in service of a larger national strategy and infrastructure to develop a scaled approach to skilling, reskilling, and upskilling for emerging technology workforce development. It will be critical to collaborate across agencies to coordinate these efforts and NSF looks forward to continuing existing work and engaging in new efforts in service of this mission.

Appendix A

Request for Information Respondents

Table A1.
CHIPS & Science Act Strategic Challenge and Key Technology Areas

Societal, National, Geostrategic challenges
United States national security
United States manufacturing and industrial productivity
United States workforce development and skills gaps
Climate change and environmental sustainability
Inequitable access to education, opportunity, or other services

Key Technology Areas
Artificial intelligence, machine learning, autonomy, and related advances
High performance computing; semiconductors, and advanced computer hardware and software
Quantum information science and technology
Robotics, automation, and advanced manufacturing
Natural and anthropogenic disaster prevention or mitigation
Advanced communications technology and immersive technology
Biotechnology, medical technology, genomics, and synthetic biology
Data storage, data management, distributed ledger technologies, and cybersecurity, including biometrics
Advanced energy and industrial efficiency technologies, such as batteries and advanced nuclear technologies, including but not limited to for the purposes of electric generation (consistent with section 15 of the National Science Foundation Act of 1950 (42 U.S.C. 1874)
Advanced materials science, including composites 2D materials, other next-generation materials, and related manufacturing technologies

Exhibit A1.
Request for Information Respondent's Organization Type

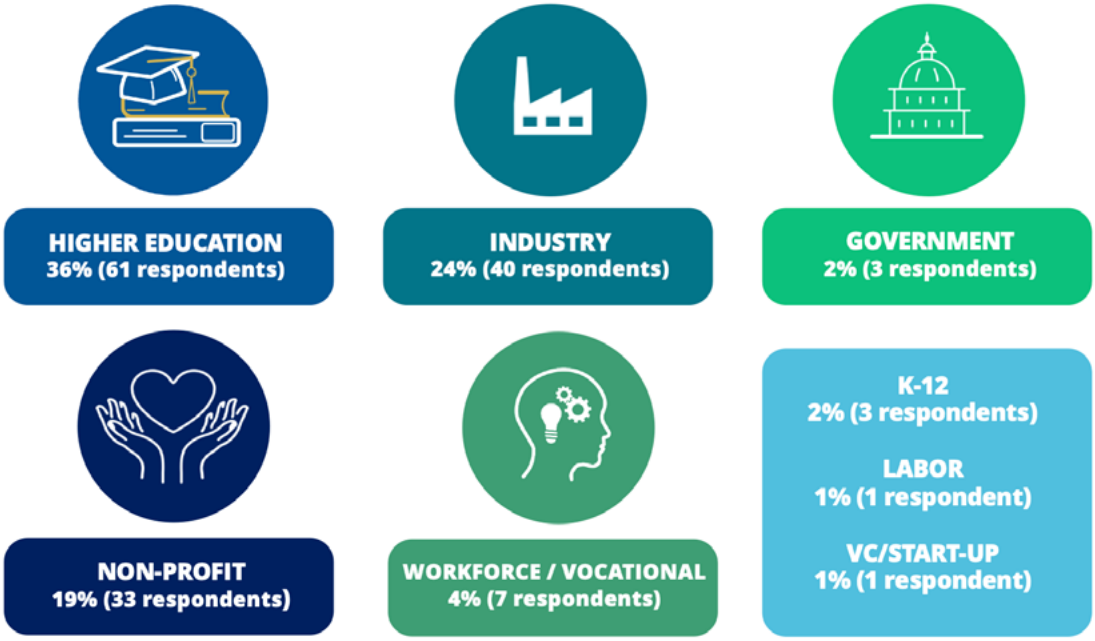

Exhibit A2.
Request for Information Respondent's Organization Type (Higher Education)

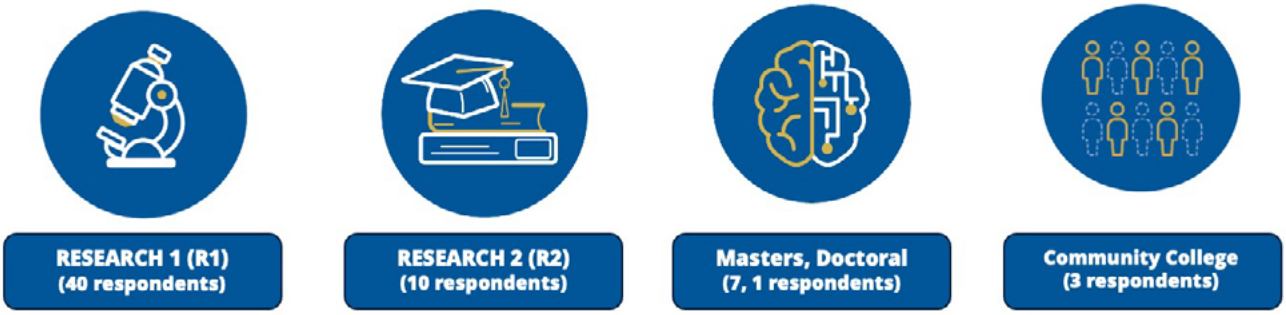

Exhibit A3.
Respondent Expertise in the CHIPS and Science Act Societal, National, Geostrategic Challenge Areas

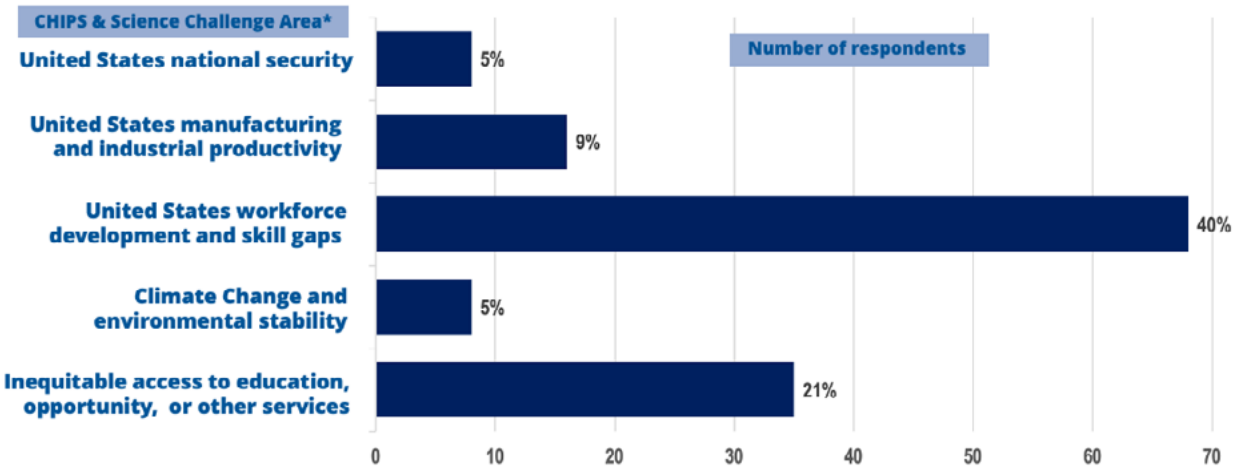

Exhibit A4.
Respondent Expertise in the CHIPS and Science Act Key Technology Areas

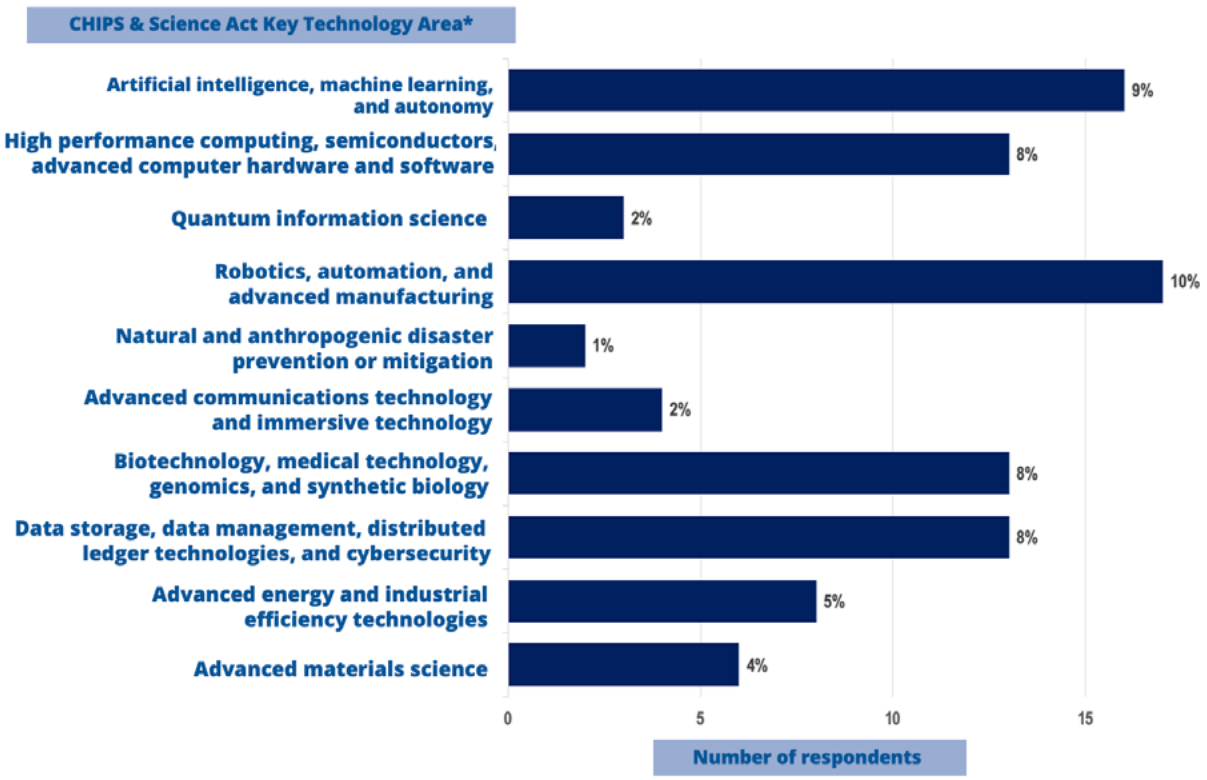

Exhibit A5.
Partner Organization Type Mentions across RFI Respondents

*Indicates top five most frequently mentioned

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