

Advancing Entrepreneurism in the Geosciences

Raj Pandya¹, Jesse Amin¹, Emille Beller¹, Julia Kumari Drapkin¹, Emily Gercke¹, Tanya Harrison¹, Laura Lyon¹, Andre Marshall¹, Mika McKinnon¹, Leah Nichols¹, Katherine Rubida¹, Peter Schlosser¹, Shaun Pal Smith¹, and Shah Selbe¹

¹Affiliation not available

December 10, 2023

Advancing Entrepreneurism in the Geosciences

*A Community Report by the American
Geophysical Union and with funding
from the National Science Foundation;
Directorate for Geosciences; Research,
Innovation, Synergy, and Education (RISE)*

1 DECEMBER 2023

NSF Grant #2335368



AGU
ADVANCING EARTH
AND SPACE SCIENCES

“Geosciences can be a fulcrum for advancing interdisciplinary science and entrepreneurship.”

Recommendations

1. Geosciences need to be a bigger part of the National Science Foundation’s (NSF) portfolio of applied and solutions-oriented science. This is because
 - Climate and environmental change are urgent and existential challenges;
 - Geosciences are key contributors to many of the innovations required to build sustainable futures; and,
 - NSF has a unique ability to engage and serve communities who are underserved by market-driven innovation around resilience and sustainability.

In particular, NSF can focus support on deep research that is inspired by and responsive to adaptation and mitigation needs but not yet ready for private investment.

2. The most important thing NSF can do to increase entrepreneurship in geoscience is nurture an ecosystem in which geoscientists can grow and thrive as entrepreneurs. This ecosystem needs to fulfill five functions:
 - Demonstrate that entrepreneurship is valued within geosciences;
 - Help people interested in geoscience learn entrepreneurial skills;
 - Build networks and facilities that support entrepreneurial activity by geoscientists;
 - Create career pathways into (and out of) entrepreneurial activity for geoscientists; and
 - Foreground justice, equity, diversity and inclusion in all these functions.
3. NSF can help accelerate a culture change in the geosciences, and in the sciences writ large, by investing in communications that shows entrepreneurship as a valuable part of the scientific enterprise.
4. We recommend that NSF share data related to entrepreneurship by geoscientists. Shared data would help
 - match supply and demand of geo-entrepreneurs;
 - prioritize interventions;
 - measure the efficacy of interventions; and
 - build awareness about lack of entrepreneurship.
5. A bold and specific suggestion: Create one or more new degrees or credentialing programs in geoscience-related entrepreneurship. Include the issues of historically underserved and marginalized communities and nurture entrepreneurs from groups historically underrepresented in geoscience and entrepreneurship.

How This Report Was Produced

The American Geophysical Union (AGU) produced this report at the invitation of the National Science Foundation (NSF). Guided by an eight-member steering committee composed of experts across the geosciences in academia, nonprofits, and private enterprise, the AGU project team gathered input from five focus groups of two-to-six participants each. The steering committee synthesized the focus group input and added their own perspectives on it, all of which has been compiled into this report.

Authors

Members of the Steering Committee:

Julia Kumari Drapkin
Emily Gercke
Tanya Harrison
Andre Marshall
Mika McKinnon
Leah Nichols
Peter Schlosser
Shah Selbe

AGU Staff:

Jessie Amin
Emille Beller
Laura Lyon
Raj Pandya
Katherine Rubida
Shaun Pal Smith

Summarized Recommendations

- Make geosciences a larger part of NSF's portfolio of solutions and applied science.
- Take an ecosystems approach to investing in geo-innovation, by supporting specific programs and activities while also helping those programs and activities connect and serve overarching goals.
- Celebrate, incentivize and reward entrepreneurship by geoscientists. Rebrand geosciences to include entrepreneurship.
- Share data on entrepreneurial activity by geoscientists and use that data to guide decision-making about investments going forward.
- Create new certification programs in geoscience entrepreneurship.

Problems, Barriers and Hurdles

Computer science and biomedical research both have traditions of entrepreneurship, as evidenced by the number of companies founded or led by scientists from these fields. An informal survey of clean energy, climate tech and similar companies revealed very few geoscientists as founders or in positions of leadership. Our broad outreach to members of the geoscience community also failed to turn up large numbers of geoscientists engaged in entrepreneurial activity. It is challenging to find more complete data, but this evidence suggests that geoscience is unique.

For our report, we defined geoscience entrepreneurship as geoscientists creating businesses or introducing geoscience-related innovation (geo-innovators) in the marketplace. Our focus groups revealed five intertwined factors that discourage geoscience entrepreneurship:

- **Systems:** A lack of systems to support and nurture entrepreneurship by geoscientists.
- **Culture:** A bias away from business and application-oriented science in the geosciences.
- **Education:** There are relatively few opportunities for geoscientists to develop entrepreneurial skills and mindsets within standard geoscience curriculum.
- **Equity and Justice:** Both the entrepreneurial community and the geosciences lack diversity in their own right; diversity among geoscientists engaged in entrepreneurship is even more lacking.
- **Data:** Data about entrepreneurship by geoscientists is difficult to find.

Systems that don't support entrepreneurship:

The dominance of academic research in the geosciences discourages potential geo-innovators. Professional activity in geoscience is dominated by academic research, unlike fields like biology, computer science or engineering, where professional activities and academic research are more commensurate in size, visibility and support. For instance, undergraduate and graduate geoscience students are rarely provided with pathways that present career options beyond academia. When geoscience careers outside of academia are represented, they are most often positions within established companies, not entrepreneurship.

Incentives tend to guide geoscientists back towards research: discovery geoscience research is well-supported by external funding, universities and other institutions. Students are even trained in how to win discovery-focused or fundamental science research grants. In the academic departments and research institutions that dominate geoscience careers, publications are rewarded over patents or applications. Programs and initiatives that support the production of solutions-oriented or use-inspired geoscience with market potential have not been supported with the same funding or tenacity as basic research.

To be clear, the problem isn't that geosciences have strong systems for traditional academic research—many other disciplines also invest in basic research—the problem is the relative lack of systems for geoscience related work extending outside of academic pathways.

Culture that discourages business and applications:

The culture of geoscience presents another major hurdle. Focus group participants talked about the prestige associated with research that was considered more theoretical, basic or fundamental and their perception that applied research in geosciences was regarded as less rigorous. Some participants talked about the conflict between business goals and environmental goals, and suggested that discouraged them from considering entrepreneurial pathways. The dominant mental model of geoscience-related business is tied to extractive industries (e.g. oil and gas), and that was discouraging to those who entered geoscience to pursue sustainability, resilience or environmental goals or out of a love and interest in the Earth and Earth systems.

Learning experiences that don't develop entrepreneurial skills:

Much like the systems barrier above, the university structure is intentionally siloed by discipline (e.g. a university's business program is offset from their arts and sciences school, both programmatically and geographically). Most geoscience programs don't offer options to students who may be interested in developing and practicing entrepreneurial skills even during capstone or cooperative projects and, likewise, most business programs don't foster interdisciplinary collaboration. An additional effect of this siloing is the limited interaction of geoscience students and business students at a key time in their burgeoning careers; if they are not encouraged to network with those outside their discipline, they are less likely to learn it in future career stages.

Additionally, there is a mirroring relationship between faculty and students at all levels of education. Faculty are the de facto mentors in this system, hence these tenure-track positions are the modeled example of success. Rarely are the faculty involved in non-academic endeavors, and even more rarely are they leaders in those endeavors. Participants noted strongly that these learning experience barriers are not relegated to the university setting; they begin in K-12 and also exist in community college settings. It's also a cyclical problem for leveraging alumni of geoscience programs: business-oriented alumni don't generally have as strong a connection to their geoscience programs as academic-oriented alumni, and are less frequently invited to give guest lectures or departmental talks, or to mentor existing students. This results in fewer opportunities available to students in geoscience enterprises.

Overcoming Historic Challenges of Equity and Justice:

Lack of diversity is an issue in both the geosciences, where less than 10% of PhDs are awarded to Black, Indigenous people of color (BIPOC), and in entrepreneurial communities, where less than 1% of venture capital goes to Black founders and less than 2% to women. Geoscience entrepreneurship inherits from both and, consequently, there are far too few women and BIPOC engaged in geoscience entrepreneurship. This perpetuates the problem of underrepresentation, since, as one focus group participant phrased it, “you can’t be what you can’t see.” Many marginalized communities are poorly served or even exploited by current systems for innovation, resulting in lost opportunities for geo-entrepreneurism that would benefit society. Multiple focus group participants noted that an element as simple as physical and geographical locations may act as a challenge to geo-innovation: one can’t speak up or participate if they don’t even know the conversation is happening. This is also relevant to geographically isolated and rural communities, who tend to be overlooked in discussions of equity and justice. The incorporation of measures to address equity and justice in geoscience entrepreneurship, amidst systemic barriers larger than the geosciences and business, has to be a focus of any program or investment.

Baseline Data:

Participants had many views as to the extent of the “geo-entrepreneur problem” this grant is investigating. They noted that there is no rigorous methodology nor is there sufficient data to diagnose the causes for low rates of geo-entrepreneurism. Geoscientists don’t have evaluation instruments in relation to entrepreneurship, so it’s nearly impossible to measure. Without more data, how can we design and evaluate potential remedies? However, perhaps the need to ask the question “Where are all the geo-entrepreneurs?” itself serves as an indicative data point.

Additional identified problems, hurdles and barriers that deserve mention include:

- Issues of intellectual property—who owns, controls and profits from geo-innovations.
- Frustration with funding processes: the time from submission to award could be shorter; it is expensive to produce a competitive proposal; funding applications require specialized knowledge that isn’t useful outside of NSF’s system; and sometimes the availability of funding or date of awards can change midstream. All of this limits who is able to apply for funding, which can make it an issue of equity.
- Many solicitations require applicants to have robust stakeholder and business development networks established when they apply for funding (e.g., NSF’s Innovation Corps). How are

geoscientists to build those networks before they have any funding? How and when are early career geoscientists taught and enabled to develop those networks?

- Scientists, like most people, don't generally publish failures. Entrepreneurship, on the other hand, is accelerated by knowing what not to try. Are there ways that NSF can help people learn from and improve on the experiences of others?
- Classism is another equity issue at play; there are opportunities in the trade industry and to innovate in the geosciences without higher-level education. We also note the need to welcome and include rural and geographically isolated communities.

Designing an ecosystem to help geoscientists grow into entrepreneurs

There is no single endeavor that will create more geo-entrepreneurs, largely because there is no single overarching reason for the lack of geoscientists in entrepreneurial spaces. Instead, a combination of activities, practices and mindsets are needed to support geoscientists in becoming entrepreneurs. Entrepreneurs and their companies can only be successful if they have an ecosystem that supports their work. NSF is in a unique position to nurture an ecosystem that supports geoscience entrepreneurship by addressing five complementary and mutually reinforcing needs:

- Demonstrate that entrepreneurship is valued within geosciences;
- Help people interested in geoscience also learn entrepreneurial skills;
- Build networks and facilities that support entrepreneurial activity by geoscientists;
- Create career pathways into (and out of) entrepreneurial activity for geoscientists; and
- Foreground justice, equity, diversity and inclusion in all these functions.

All five are necessary and all five are currently lacking in the geoscience community.

Additionally, our investigation surfaced small-to-medium scale activities that successfully fulfill one or more of these functions. The real work is not inventing novel activities. Instead, it's about scaling existing effective activities, then selecting appropriate activities for specific contexts. This would ensure a portfolio of activities that addresses and connects activities across all five functions.

We describe each of these five functions in more detail below, with examples of the kinds of activities that serve these functions.

Function 1: Demonstrate that entrepreneurship is valued within the geosciences

There is a clear need to normalize entrepreneurship as a legitimate way to contribute to society, protect the planet, advance geoscience understanding and practice, and advance professionally in geosciences. Ways of doing this include:

- Celebrating and elevating geoscientists who are entrepreneurs (especially BIPOC and those from traditionally excluded backgrounds);
- Highlighting innovations in clean energy and climate solutions;
- Actively emphasizing entrepreneurship as a social good;
- Revising tenure and promotions and developing new kinds of positions (like professors of practice) that support entrepreneurial activity within academia;
- Valuing licenses and patents as much as papers during career reviews and grant applications;
- Orienting graduate and undergraduate curricula toward careers in business and application, not just academia;
- Highlighting entrepreneurship at academic conferences, workshops and seminars;
- Developing and implementing strategic communications about geoscience innovation and innovators; and
- Developing ethical standards for entrepreneurship.

It is common for geoscientists to understand that policy work is a way to leverage scientific knowledge for societal good; similar messaging and programs should be applied to entrepreneurship. We also heard from entrepreneurs that having established ethical guidelines, especially around contentious issues like geoengineering, can make them feel less at risk when their businesses intersect with these issues.

Function 2: Help geoscientists learn to be entrepreneurs

Efforts to teach entrepreneurship in the geosciences should be built on sound pedagogical practices like problem-based learning, modeled on collaborative business practices, and be made convenient, accessible and relevant to geoscientists at a variety of career stages. Teaching and learning can be offered through a variety of venues and modalities. Some examples that were discussed:

- formal degree tracks in geoscience departments
- inclusion of geoscience training options in business schools
- dual-degree programs offered across departments

- certificates
- internships and Research Experiences for Undergrad-like (REU) programs focused on entrepreneurship
- conference workshops or short courses
- in 2 and 4-year colleges, post-baccalaureate, in-person and online

To advance justice, equity, diversity and inclusion, we recommend intentional investment in minority-serving institutions for these activities. It is worth mentioning that investing in curricula and learning pathways is a way of implicitly demonstrating that we value entrepreneurship (i.e., the activities in Function 2 reinforce the message of Function 1).

Function 3: Build networks and resources to support geoscientists who want to become entrepreneurs

Prospective geoscience entrepreneurs will be more likely to thrive if there are professional networks and facilities they can leverage versus having to build them from scratch. Institutions can cultivate and curate networks that connect prospective entrepreneurs with mentors, investors and experts in relevant topics like organizational management, human resources, finance and intellectual property. They can offer spaces and facilities that support innovation, like hardware testbeds and user and consumer research laboratories. By consolidating these kinds of activities in one place and tuning them to geoscience-relevant social challenges, they can take advantage of economies of scale, support multiple entrepreneurs and even create entrepreneurial communities of practice.

In the same way that NSF makes long-term investment in geo-related research infrastructure (e.g., National Center for Atmospheric Research (NCAR), Long Term Ecological Research (LTER), Ocean-Drilling Program), it could invest in a shared infrastructure that supports entrepreneurial activity by geoscientists. The placement of these geo-entrepreneurial facilities, networks, consumer and user testbeds, and innovation sandboxes can and should be planned with an eye toward equity of access and service. For instance, infrastructure can be built with and in institutions that have been historically under-invested, networks can model equitable practices, and the user-research and customer-discovery can prioritize underserved communities.

Function 4: Create smooth pathways into entrepreneurship for geoscientists

Even with exposure, learning opportunities and facilities, the transition into entrepreneurship is risky and challenging. Strategies that support transitions, encourage interdisciplinary connections and minimize the

risk can help spur entrepreneurship. Risk can be reduced through opportunities to try out entrepreneurial activities on a part-time or temporary basis: sabbaticals; short-term or part-time entrepreneurial appointments; early career start-up grants; entrepreneurial fellowships; buy-outs of teaching time; supplemental funding tied to existing research grants; and small, rapid turn-around funding from agencies and universities that bridge the space between research results and investment-ready projects. Existing programs like Small Business Innovation Research (SBIR) could be expanded, targeted to the geosciences, and take bigger risks, and funding processes could be streamlined so that applications are less onerous. Cohort-based programs, especially connected to business incubators, can support transitions by building communities of practice and connecting people with training, coaching, networks and resources. By choosing topics related to climate and environmental justice and building programs that focus on women and BIPOC, pathways into geo-entrepreneurism could be models of inclusive innovation.

Function 5: Foreground Equity, Diversity and Justice

Entrepreneurism in the context of geoscience should work toward more sustainable and resilient futures in addition to tackling environmental and climate injustice. Success depends on equity, diversity and justice: equity to ensure all community priorities are addressed; diversity to get the most ideas, input and solutions; and justice to ensure opportunity for all. Both geoscience and entrepreneurship have a history of falling short in these dimensions; anything that combines the two must necessarily prioritize addressing these shortcomings. In discussion of the five functions and the example ecosystem below, we sought to weave equity, diversity and justice throughout.

Weaving Five Functions Together: University Programs in Geo-entrepreneurism

Our steering committee imagined a self-contained ecosystem that attended to these five functions (less as a recommendation and more as an illustration). The group envisioned a new credential in a university setting: geo-entrepreneurism. The cross-departmental program would include business and geoscience courses and link content between the two. The program would adopt cohort practices and foster a learning community. It would provide infrastructure to support business development, marketing, user-testing, and so on. A key part of the student experience would be hands-on work building businesses, and the program would connect students and ideas to a network of alumni, investors and advisors. Seminars would focus on businesses and innovations, professors would maintain healthy connections with entrepreneurial alumni, and the program's marketing would elevate entrepreneurship.

Existing programs and models

We also feel obliged to note effective programs and models that already exist and that were referenced by the steering committee and focus groups (in some cases, multiple times). However, this list is not exhaustive and we provide these as examples that can be built on and included as part of an overall ecosystem approach.

- **National Science Foundation’s Innovation Corps (I-Corps) program:** Referenced for its encouragement of innovative technologies and propagation of partnerships between academia and industry. This was the program most frequently referenced by participants for its efficacy and reach, although we also heard that not many geoscientists took advantage of the program.
- **Department of Energy programs (Advanced Research Projects Agency-Energy (ARPA-E), Inspiring Generations of New Innovators to Impact Technologies in Energy (IGNITE)):** Referred to because of its targeting of early career scientists as well as the emphasis on disrupting energy technologies.
- **Small Business Innovation Research programs:** Mentioned frequently by participants for the programs’ support of small businesses and entrepreneurs in the tech industry. The programs have a strong engineering and biomedical emphasis; there is opportunity for the geosciences to be more supported.
- **Challenges, Hackathons and Pitch-fests:** This class of temporary, competitive programs was regularly mentioned by participants. While frequently referred to in a positive light from most participants, there was strong objection to them from others.
- **Maker-spaces:** Offered as an incubator for universities or communities to foster new technologies and enable experimentation. Could be geoscience-specific or not.
- **Case studies:** A form of learning that could be used in either geoscience or business courses to expose students to alternate ways of thinking and problem-solving.
- **Courses in geo-entrepreneurism and student start-up incubators:** One focus group participant shared his experience in an undergraduate program with a geo-entrepreneur class that included designing, pitching and executing a geoscience innovation—a “live-action,” hands-on version of the case study model above. The class included intellectual property agreements, basic business skills and mentorship from entrepreneurs. The top projects from the class were funded and piloted by the professor. (It should be noted that said professor was independently wealthy.)

Roles for the National Science Foundation

Based on the above, we close with four overarching roles to organize NSF's work and help the agency guide and support shared work across the geoscience community.

- **Collect and Share Data**

NSF can define, collect and share metrics for and outcomes of entrepreneurial activities. This would help everyone identify barriers and hurdles more precisely, inform gap analysis and target support to critical and unmet ecosystem functions, and allow systematic evaluation of interventions.

- **Support Entrepreneurship Pathways**

NSF can fund individual activities, pilot new approaches, and offer support for scaling proven approaches. Perhaps more importantly, it can play the role of connector, linking together programs and activities into pathways and providing support for the services on which those pathways depend. NSF could also support entrepreneurs directly, through individual and team grants and supplemental funding opportunities. Finally, NSF can invest in comprehensive communications campaigns to communicate the value and promise of entrepreneurship.

- **Nurture Demand for Geoscience in Entrepreneurial Spaces**

NSF could catalyze demand for entrepreneurially-minded geoscientists by creating and supporting entrepreneurial roles within companies and universities which could incentivize businesses and universities to hire people with geoscience skill sets in business development roles. For example, programs to place scientists in emerging companies could be modeled on programs like the science policy fellowships. NSF could partner to provide reviews for investors interested in geoscience start-ups. Finally, geoscience-related innovation can also be advanced by helping entrepreneurs outside the geosciences connect and work with geoscientists—NSF should consider this opportunity as well.

- **Prioritize Equity, Diversity, Justice and Inclusion**

NSF should prioritize historically marginalized communities, including rural communities, to address historical inequities, better support communities at the frontline of climate impacts, accelerate the pace of solutions to match the most urgent needs, and improve the quality and relevance of solutions by including more perspectives, ideas and experiences.

Conclusion

The last revolution in geosciences was coming together to understand the Earth as a system, and it required working across disciplines. That work allowed us to identify the damage humans are doing to that system. The next revolution will be about managing and even undoing that damage. This undertaking requires another coming together—this time beyond disciplines and into multiple ways of knowing, doing and understanding. Part of that, necessarily, includes working across sectors, including advancing geo-entrepreneurship.

Acknowledgements

Our deepest appreciation goes to the Steering Committee, focus group contributors, and AGU staff for their ideas, input, and participation in writing the report. We are grateful to the National Science Foundation for providing this opportunity to bring together these thought leaders.

Members of the Steering Committee:

Julia Kumari Drapkin, ISeeChange
Emily Gercke, Elemental Excelsior
Tanya Harrison, Earth and Planetary Institute of Canada
Andre Marshall, George Mason University
Mika McKinnon, Freelance Geophysicist
Leah Nichols, George Mason University
Peter Schlosser, Arizona State University
Shah Selbe, Conservify

Additional thanks to our many focus group contributors who contributed their time, expertise and enthusiasm around the subject of geo-entrepreneurism.

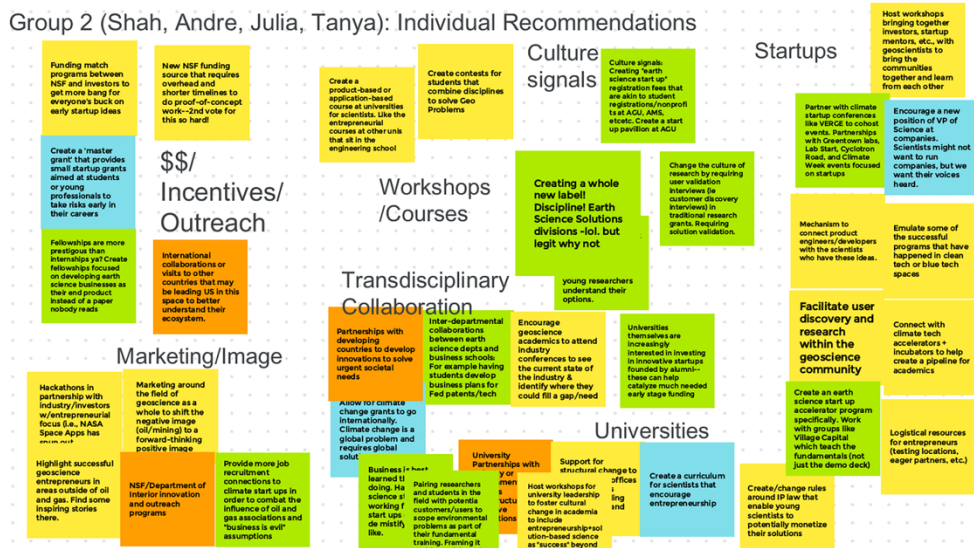
This work was funded by NSF Grant #2335368. Special thanks to GEO-RISE Program Director Barbara Ransom for the opportunity.

<https://www.agu.org/geoinnovation>

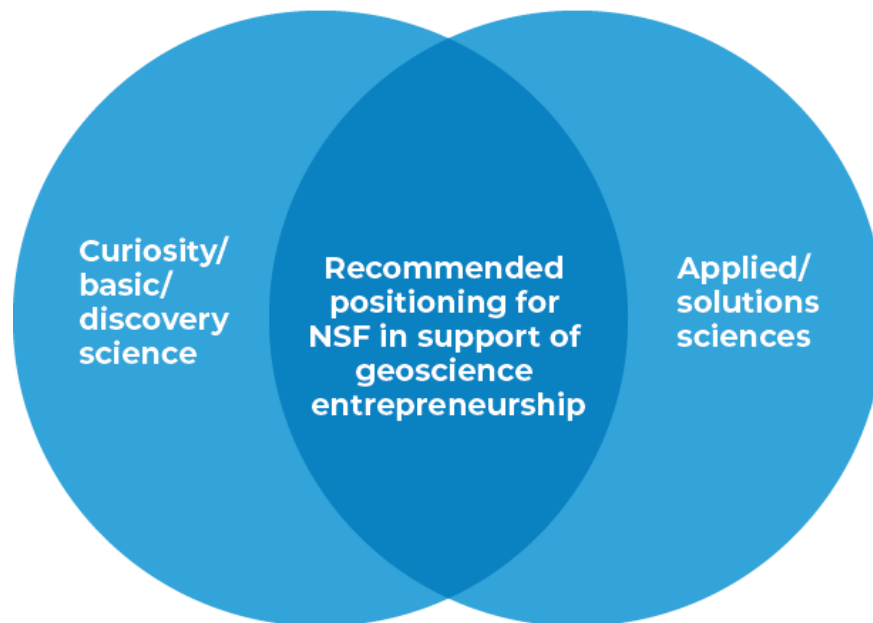
Thank you, from AGU Staff:

Jessie Amin, Emille Beller, Laura Lyon, Raj Pandya, Katherine Rubida, Shaun Pal Smith

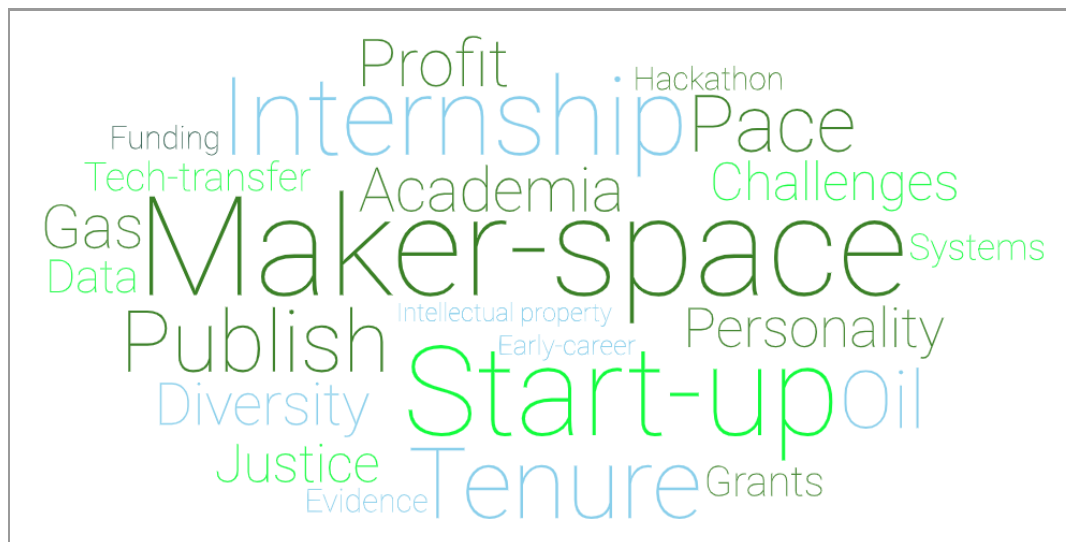
Appendix



These two Jamboards were created by steering committee members to help synthesize ideas and guide the report.



This Venn diagram was created by the steering committee. It shows the spectrum of basic to applied sciences, illustrates the need for balance across that spectrum, and points toward where in that spectrum NSF's efforts to support entrepreneurship could be most impactful.



This AI-generated word cloud came from the transcripts of the focus group discussions.