AMS Community Synthesis on Innovation and Entrepreneurship in the Geosciences

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The American Meteorological Society (AMS) is a scientific and professional society of roughly 12,000 members from the United States and over 100 foreign countries.

Additional copies of this report and other AMS Policy Program studies can be found online at https://www.ametsoc.org/studies.

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Executive Summary

There is great potential for new ideas and entrepreneurial activity within the geosciences to have a significant impact throughout society. This is all the more important as the scale of human activities has grown to be large relative to the planet and the life-support services the Earth system provides.

This American Meteorological Society (AMS) Policy Program study synthesizes input on opportunities and challenges in innovation and entrepreneurship within the geosciences. The study was carried out in an accelerated time frame in response to a request from the National Science Foundation for rapid community input. We focused most heavily on the weather, water, and climate (WWC) segment of the geosciences, referred to as the Weather, Water, and Climate Enterprise, drawing from the community served by AMS. We found that there is innovation and entrepreneurship across a broad spectrum of activities within this community, from new instrumentation for observations to new analysis techniques to new applications software aimed at decision-makers. A few key challenges related to the preparation of those in the geosciences for jobs in the private sector in general, and entrepreneurship in particular, surfaced in nearly every discussion we had with members of the community. We explore those challenges here and offer some recommendations that might address aspects of them.

The input received from community members throughout the course of this study highlights the rapid pace of development as well as several areas where action could be taken to further enable entrepreneurial activity.

Key takeaways:

- There are many programs at the federal, state, and regional level that can be utilized to support entrepreneurial activities, but many individuals in the geosciences are not aware of the wealth of resources available to them. Modest changes in university curricula and new programs by scientific and professional societies could effectively raise awareness of these opportunities.
- Many researchers lack adequate preparation to make the transition to entrepreneur. There is a need for additional training to gain these needed skill sets, which includes knowing when to seek outside expertise.
- Additional funding for existing federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)programs at agencies that serve the geosciences could yield a significant increase in successful commercialization of geoscience innovations. In particular, the expansion of these programs to provide small "Phase 0" grants would support the additional training that most geoscience researchers need to be ready to take on entrepreneurial efforts.
- In some cases, the most effective path to commercialization is connecting a researcher with a new idea with an entrepreneur who can take it to commercialization. There are examples of successful matching programs that could be emulated by universities and scientific and professional societies with a high likelihood of success.

Recommendations in this report provide specific actions that can be taken by federal agencies, universities, and scientific and professional societies to address key challenges for increasing successful entrepreneurial activities and for better preparing students to enter the private sector workforce.

1. Introduction

1.1. Background

The twenty-first century has brought about numerous social, technological, and environmental changes and challenges for the United States and the world at large. It has also heralded a period of extraordinary innovation with an increasing interest in harnessing scientific advancement for societal benefit. Notably, the recent expansion of initiatives supporting scientific innovation relating to the Earth system suggests that there is great potential for new ideas and entrepreneurial activity within the geosciences to have a significant impact throughout society. This is all the more important as the scale of human activities has grown to be large relative to the planet and the life-support services the Earth system provides. Accordingly, it is a prime opportunity for the geoscience fields to consider how their communities' expertise may most effectively link to innovation and entrepreneurship endeavors in order to deliver results to society and the economy.

This American Meteorological Society (AMS) Policy Program study synthesizes input from the AMS community on fostering a thriving innovation and entrepreneurial environment within the weather, water, and climate (WWC) enterprise, and the geosciences as a whole. The WWC enterprise provides information and services that impact nearly every economic sector of the nation, in addition to playing an important role in the protection of life and property from environmental hazards and the impacts of climate change. This means there are many areas that are already seeing entrepreneurial innovation while still having the potential for much more. The study was made possible, primarily, by a grant from the National Science Foundation (NSF).

1.2. Study process

The study process solicited input from many members of the AMS community and synthesized insights from a wide range of individuals from the weather, water, and climate enterprise. About one-third of the AMS community is in the private sector, including many successful entrepreneurs who have started small- to medium-sized companies driven by innovation. AMS created a dedicated web portal to allow written input from individuals and requested and encouraged input from the full membership through a variety of media channels. Through this solicitation and through members of the AMS Commission on the Weather, Water, and Climate Enterprise, an initial list of individuals was developed to reach out to for one-on-one or small-group virtual discussions. In each of those discussions, program staff asked for the names of others who might provide additional useful input for the study. This resulted in an expanding list of contacts over the brief study period that allowed for a spectrum of input, including from students and early-career professionals as well as those later in their careers. While the list of participants is dominated by private sector individuals, which is natural given the focus of the study, we also had discussions with several government employees and academic researchers to learn more about how innovations coming from these sectors can be commercialized through entrepreneurial activities. The project team then synthesized the inputs to identify opportunities to foster increased geo-innovation within and beyond the WWC enterprise.

We gathered input from a broad range of individuals over the short time frame of this rapid study. We feel we achieved an adequate number of participants providing input because we found that participants in our later discussions were bringing up the same themes that had been covered in earlier discussions. This both reinforced that these themes were common and provided some sense that we had uncovered the most important aspects of this issue.

2. Findings

There is widespread agreement within the AMS community that there is a great deal of potential for innovation and entrepreneurial growth in the weather, water, and climate space. While the weather enterprise, with a robust private sector, has been well established for many years (NOAA Science Advisory Board 2021), it has seen a surge in innovation as technological advances, such as more sophisticated artificial intelligence and machine learning (AI/ML) techniques, are incorporated. This surge of innovation has not been limited to the weather enterprise as recent years have seen nearly explosive growth in private sector companies providing climate services across a range of applications in the United States and globally (see, e.g., NOAA Climate Program Office 2023; Ten Hoeve 2022; Perrels 2019). For many years the primary focus within the community was on getting the forecast right; however, that focus is increasingly shifting towards using improvements in forecasting capabilities to address societal problems. This in turn has opened up a wealth of opportunity for new products and services that meet the needs of businesses and the general population. Additional private sector growth is emerging in areas such as the ocean enterprise [sometimes referred to as the New Blue Economy (Spinrad 2016)] and space weather applications and services.

Although opportunities for innovation and entrepreneurship abound, conversations with entrepreneurs and researchers within the AMS community also revealed several prevalent challenges that may present barriers to these opportunities being widely realized. Participants also emphasized a number of additional areas that, while not necessarily challenges to overcome, should be accounted for accordingly in order to effectively cultivate a vibrant entrepreneurial environment within the WWC enterprise, and the geosciences as a whole.

2.1. Key challenges

2.1.1. Academic preparation and institutional incentives are largely not set up to support geoscience entrepreneurship

While there is no single path to business success, there are nonetheless certain skillsets and foundational knowledge that may facilitate an idea's journey to commercialization. Academic preparation is one means through which potential entrepreneurs can gain familiarity with these skills and, in general, those in the geosciences tend to possess at least one post-secondary degree or be otherwise highly educated. However, many current WWC entrepreneurs report having had no background or academic training in business prior to founding their company. This is not necessarily surprising as it is uncommon for undergraduate or graduate geoscience programs to include business-related coursework, such as finance or report writing, in their already packed curricula. As a result, geoscientists may be discouraged from entrepreneurship by not feeling well equipped to manage a business. A lack of business-related skills may also extend to geoscientists not being prepared for work in the private sector broadly. Surveys of early career professionals from the AMS Mind the Gap committee[1] have shown that many feel they did not

[1] See https://www.ametsoc.org/index.cfm/cwwce/committees/ad-hoc-mind-the-gap-committee/.

learn what they needed to successfully enter the private sector from their meteorological degree program.

Simply adding business coursework to geoscience programs is likely not a substantial solution to this issue. Academic institutions generally have involved processes for amending curriculum core courses or requirements, and piling on additional requirements without removing other courses is unsustainable for both students and faculty (Tipton et al. 2021). Moreover, a strong foundation of scientific and technical knowledge is a key component of geoscience innovation. As such, a handful of business courses in a science curriculum may not be as valuable for enabling future innovation as courses that build in-depth technical knowledge. An exception to this may be courses that focus on communications; whether used in conveying information to customers, investors, other scientists, or the general public, communications skills are considered to be highly transferable across sectors and situations (Tipton 2023). It is therefore almost certain that the inclusion of communications courses would benefit any science curriculum regardless of whether students go on to become geo-entrepreneurs.

For geoscientists looking to move into entrepreneurship, some foundational business management knowledge may be gained through dedicated training programs. These may be offered through a variety of institutions such as venture schools or local business development centers. However, these kinds of programs may be difficult to find, be accepted into, or afford.

Geoscientists also need to know that entrepreneurship is an option at all. In discussions, community members consistently mentioned that both students and faculty are largely not exposed to career paths outside of research. When the goal of an academic position is assumed to be the default, students who might be interested in entrepreneurship may not choose to pursue this interest because there is little to no guidance on how to succeed on alternative paths. Moreover, graduate students in particular may be bound to their (or their advisor's) source of funding and lack the flexibility to explore work that does not pertain to that funding. There are additional challenges for international students, who may not be able to take on certain kinds of work without violating the terms of their visa.

2.1.2. There are mismatches between needs of geoscience entrepreneurs and available funding sources and training opportunities

The progression of an idea from conceptualization to successful commercialization can be a long and complex process, particularly for those new to entrepreneurship. While there are a number of existing opportunities relating to funding, training, and other forms of entrepreneurial support, these opportunities may be difficult to access. Moreover, the needs of geoscience-related businesses are often highly specific in a way that makes finding appropriate support challenging. A more widespread understanding of the current entrepreneurial landscape may help geoscience entrepreneurs to realize their goals effectively.

SBIR/STTR

The federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grant programs[2] are a central component of the geoscience entrepreneurial landscape. Participating federal agencies each have their own SBIR program office and accept proposals from small businesses relating to designated research and development (R&D) topics. The programs are structured in three phases, with Phase I awarding funds to develop an idea to proof of concept, Phase II awarding funds to continue the R&D efforts initiated in Phase I, and Phase III to pursue commercialization objectives resulting from the activities of the previous phases. These awards are critically important funding sources for those actually starting a small business as an entrepreneur. Moreover, for companies that later choose to pursue venture capital (VC) funding, having obtained SBIR or STTR funding can confer an advantage by demonstrating to investors that the company has shown the technical capability to obtain a SBIR/STTR grant.

While the SBIR program is a key mechanism to reduce risks for innovation, there are some challenges with the SBIR program that represent structural issues. To secure a grant, a team needs to include strong academic members (typically Ph.D.'s) so that the proposal can show strong academic credentials. However, the commercialization process is different from scientific research, and making the transition from an academic research mindset to a commercial mindset can be very difficult. In the commercial world, every activity must be considered in terms of the cost–benefit ratio. Academic researchers are not necessarily used to thinking this way, and often are not as good at constraining their time and effort to the product being developed and not to new ideas that may not have direct impact on the task at hand.

It was also noted that each federal agency in the SBIR program differs in review criteria and agency thrust. For example, there is a sense that NSF tends to give greater weight to ideas that have high return potential, while NOAA is not as concerned with that if the idea furthers its mission. This was seen by many as both a strength of the various SBIR/STTR programs and a challenge. Without guidance from consultants or other experience in the proposal process, it is hard to know which agency to apply to or how to structure the proposal for that agency. This leads to innovators with excellent ideas sometimes needing to submit multiple proposals before the idea is funded—having learned from the reviews of failed proposals how the proposal should have been structured from the start. Moreover, individuals from certain socially or economically disadvantaged backgrounds are less likely to resubmit proposals after a rejection, which presents a challenge to achieving greater inclusivity in the program.

SBIR is a federally mandated program, with its funds provided by a set percentage of participating agencies' extramural R&D budgets. However, the number of applications for SBIR programs have increased dramatically over the past five years, while funding for the programs has not. For example, the success rate for NOAA SBIR has dropped to now be less than 10%, which has discouraged many with very good innovative ideas from seeking SBIR funding given the effort required to apply. There is also a concern that agencies do not have sufficient programs that help potential grantees navigate the process more successfully and/or obtain training needed for a successful start-up.

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[2] See https://www.sbir.gov.

I-Corps

Another opportunity at the federal level is the NSF I-Corps program[3], a training program for those pursuing entrepreneurial activities. Several participants in this study praised the I-Corps program for its approach to teaching scientists how to pitch their ideas effectively. NSF's "Beat-the-Odds Bootcamp"[4] is a noteworthy component associated with the I-Corps program.

The I-Corps program is modeled on the "lean start-up" approach (Ries 2011), which focuses on engaging with customers to find their needs and subsequently build products to meet these needs. The approach works well for products that scale easily, like software (apps, etc.), but may not address the requirements for scaling up commercialization of hardware as well.

Commercial investment

Separate from SBIR or STTR funding, it can be very hard for geoscience entrepreneurs to obtain the resources needed to fully complete the commercialization of an innovation. For the most part, commercial incubators focus on ideas that are likely to provide large returns on investment. They are less likely to support projects that might have important value to humanity but show much less potential for large returns on investment. Similarly, venture capital and angel investors are often not interested in products that have modest return potential even though they may be excellent from a public good standpoint. To these investors, the projects are seen as "passion projects" rather than money-making opportunities. This represents a challenge in the geosciences since many important innovative projects are not likely to meet the threshold of investment return sought by commercial investors. There is little doubt, based on even the limited number of participants in this study, that this investment challenge has delayed successful commercialization in the geosciences.

University incubators and venture programs

It is common for universities to have programs intended to support faculty or students with ideas that might be viable for commercialization. These can take many forms, and several universities were identified in our discussions as providing excellent support for entrepreneurial activities by faculty or students, including Columbia University, the University of Washington, the University of Utah, and Carnegie Mellon University. It was noted that taking advantage of "incubator" environments at universities typically included constraints on the resulting intellectual property (IP), so an understanding of IP issues before participating in a university program is very important.

The University of Colorado (CU) Venture Partners program offers an example of excellent university support for researchers seeking to commercialize innovations. The CU program works with university teams to help them focus on market fit and customer needs. CU uses the NSF I-Corps program and is one of 15 I-Corps hubs that are geographically dispersed in the United States. CU focuses on the make-up of the team, given that very few scientists are ready to be a CEO, and helps connect the scientific team with mentors and/or consultants who can help. In some cases, the consultants are entrepreneurs looking for their next opportunity and they can join the team to provide business acumen and help with a successful launch.

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[3] See https://new.nsf.gov/funding/initiatives/i-corps.

[4] See https://seedfund.nsf.gov/resources/awardees/phase-1/bootcamp/.

For faculty or graduate students who have a good idea that could be commercialized but who do not want to pursue that avenue for one reason or another, CU has created the Embark program[5]. This program curates ideas coming from the university and allows budding CEOs to compete for the chance to create a start-up with the idea. CU provides start-up funds and handles the IP issues. The program is funded by a state business development grant. The Embark program can also help get ideas from government labs into start-ups. For example, NIST has a relationship with CU that allows federal scientists, who are not allowed to spin up a start-up on the side, to move ideas toward commercialization.

In contrast to the situation in the geosciences, spinning up start-ups in the biomedical world has become so commonplace that there are lots of resources available to researchers (faculty and students) to help make the transition from research result to commercial business. In addition to state and federal business development, there are ample opportunities for entrepreneurial training through private avenues. One illustrative example, out of many, is the CIMIT CRAASH Program[6] that performs training similar to NSF's I-Corps program for those looking to commercialize innovations in the health industry.

FLC and CRADA

In contrast to research faculty at academic institutions, researchers at government facilities have limited opportunities to pursue outside entrepreneurship if a research idea has potential commercial value. There are, however, examples of innovations created by government labs that were subsequently licensed to the private sector for further development and distribution, such as the Deep-ocean Assessment and Reporting of Tsunamis (DART) buoys (Lawson 2016). There are also a number of examples of using a Cooperative Research and Development Agreement (CRADA) between a federal lab and a private sector company to commercialize products and services developed in the federal lab. In general, commercialization of hardware has been more successful when a federal agency secures a patent and provides a license for the IP, as compared to an "open science" approach in which a private sector company may invest resources into developing the hardware and then have the market collapse when competitors copy their product. However, there is a sense that the "open science" and especially "open data" approaches of agencies can be beneficial for the development of new software products.

While many universities have done a good job of creating incubators that can help faculty develop research ideas toward commercial products, federal scientists cannot pursue this path toward commercialization. One avenue for these scientists is to use the Federal Lab Consortium (FLC) to create pathways through partnerships with universities. For example, an idea could be provided to students in an MBA program for them to do a full market analysis and possible market plan as a project. If the analysis found the idea to be marketable, others could move it toward commercialization using the plan. Another approach is through companies that specialize in taking government ideas toward commercialization. One example is Fedtech,[7] which does this for some parts of government, creating "start-up studios" that serve as incubators for new ideas to be developed from federal research.

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[5] See https://www.colorado.edu/venturepartners/embark.
[6] See https://www.craash.org/.

[7] See https://www.fedtech.io/.

2.2. Other issues

2.2.1. Artificial intelligence and machine learning

AI/ML is poised to play a much larger role in the future of the weather, water, and climate than most had thought even a few years ago. AI approaches have become competitive in just a few years against traditional computer simulations that have been developed over decades, so we have to expect the AI approaches to pass the traditional ones relatively soon. This represents lots of challenges but also an enormous array of new opportunities. As the potential for AI to provide new products and services expands, new opportunities for entrepreneurial activities that are built on AI expand as well. This disruptive technology will require a new and differently trained workforce. Having a portion of the total workforce with deep knowledge of the underlying science will still be critical, but the training for the bulk of those working in the weather community may need to be very different, and university curriculums will need to respond rapidly to this changing world. Data assimilation is likely to be even more important than it is now. This has always needed increased investment, but it becomes more critical as you look to a future where AI/ML is driving our prediction process.

2.2.2. IP issues

Issues dealing with IP came up in many discussions in this project. It was felt that all students should be taught what IP is, how policies vary among universities, government, and private sector, and what steps can be taken to protect one's IP. It is unlikely that an entrepreneur will be able to successfully raise VC funding, for instance, if funders feel that someone else owns the IP.

Recent policy changes that encourage NOAA to buy data from private firms represent an incentive for private sector innovation. Developing a business model that addresses intellectual property issues successfully can be a challenge, however. With NOAA's policies to freely distribute data and products, private companies expecting to have customers beyond NOAA need to secure carefully constructed licensing agreements in order to preserve the commercial value of the data. These IP issues, along with potential restrictions on the data being used versus distributed by NOAA, represent a growing point of friction within the weather enterprise that is beyond the scope of the present study.

2.2.3. Regulation

There is a sense within the community that in some areas innovation has been outpacing the ability of the policy framework to have adequate regulations to address it. This is perhaps more obvious in the recent efforts to provide regulations governing various uses of AI,[8] but there are other examples more centrally located in the geosciences. For example, there are many approaches to marine CO_2 removal currently being explored,[9] some of which move into the climate intervention arena (that is, geoengineering). While geoengineering is being increasingly discussed in policy spaces, there is at present little guidance regarding its deployment.

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[8] See https://epic.org/the-state-of-state-ai-laws-2023/.

[9] See https://oceanvisions.org/launchpad/.

2.2.4. Adoption of technology

Participants in this study reported that while it is not uncommon for entrepreneurs in the WWC space to have government agencies as their primary customer, those agencies do not always incorporate new innovations that could positively impact agency activities. This is especially the case when the new innovation would replace longstanding approaches. In short, the federal agencies can be very slow to adopt new technologies, even if the new approach could provide data in a better or cheaper fashion. Innovators in this space may consequently struggle to succeed given the mismatch of timescale between private sector innovation and agency incorporation of new technology. The Office of Naval Research was noted to have an effective approach to transitions, with specific budget money allocated (what is designated "6-4" funds in the DoD framework) to take new ideas into operations. NOAA has also improved these transitions in recent years through the expansion of the Technology Transfer Program,[10] and other agencies could learn from these experiences.

[10] See https://techpartnerships.noaa.gov/techtransfer/.

3. Recommendations

3.1. Training and development opportunities

There should not be an attempt to try to turn every entrepreneurial scientist into an engineer or CEO. A better path would be to provide training for the scientist so that they understand what a company needs and know how to find the right people to do those jobs. There are professionals who make a career path of helping start-ups get established successfully, so the scientist needs to be equipped with the knowledge of how to seek out these people and find a good match for the company being established. Even if these professionals have no domain-specific knowledge, they still know what a company needs in order to operate and how to scale up a product toward commercialization.

3.2. Entrepreneurial fellowships

A possible approach would be to have a funded fellowship program focused on entrepreneurship and aimed at researchers with ideas that have potential for commercialization. The fellowship could fund the researcher to embed in an existing company and work with that company to develop their idea, with the matchmaking accomplished through some sort of competitive process. The companies would compete to receive a funded researcher for some period of time and the chance to potentially develop a new product, while the researcher would receive real world experience and develop skills that might yield new innovations later.

3.3. Workshops and bootcamps

In noting that many students are not far enough along in their thinking to recognize that they might want to pursue specifically an entrepreneurial path (even if they are thinking of a career in the private sector), several study participants suggested intensive training programs. With some modest external support, such programs could be hosted by organizations like AMS. These programs could provide entrepreneurial bootcamps of a day to a few days that could provide participants with the base level of knowledge needed to be ready to take advantage of the many other resources available to those seeking to start a business at the state and federal level. These workshops would focus mostly on providing extensive information on how to most effectively take advantage of existing programs (I-Corps, SBIR, STTR, state and local small business support, etc.), rather than reproduce them.

A set of separate, but related workshops or bootcamps should be established that are geared toward entrepreneurs in the geosciences that provide the basic information needed to start a company. These should cover the most foundational elements at the very basic practical level of how you set up a company, get insurance, establish accounting practices, etc. (that is, more foundational than existing programs like I-Corps). These could be offered as virtual courses given the small and distributed nature of geoscience entrepreneurs, or perhaps done in conjunction with the annual meetings of relevant societies (like AMS).

3.4. Mini-grant and competition programs

University programs in the geosciences that do not already have such a program should implement small, competitive, mini-grant (around $2K) programs that would allow students to pursue taking a research idea toward applications. If external funding were available, organizations like AMS could also administer modest small grant programs to help students learn more about this process of moving research ideas towards application. Other forms of competitive programs, such as hackathons, can be very effective in engaging students in efforts that expose them to the sort of creative innovation that leads to entrepreneurship. These sorts of programs, in addition to the sorts of training recommended elsewhere in this report, could increase the awareness of students to entrepreneurial career paths.

3.5. Reducing constraints on innovation

Calls for proposals from NSF and other agencies too often provide preprogrammed funding seeking solutions to a specific problem or with specific applications in mind rather than allowing flexibility for novel ideas to emerge and be pursued. Providing somewhat greater flexibility in the call would allow those with truly innovative approaches to seek funding without being as constrained.

Another option to create space for researchers to explore ideas is innovation challenge competitions. U.S. funding agencies could also explore emulating the European Union's Climate KIC program[11], which offers a possible model to support applied innovation with some flexibility, with dedicated mechanisms to support new idea creation as well as help to get workable ideas funded.

3.6. University curricula

Truly addressing some of the education and training issues to better prepare students for entrepreneurial careers will require changes in curricula and new resources that are not likely to happen quickly or easily. An emphasis should be placed on exposing students to career paths that are in the private sector and especially those with entrepreneurial characteristics. University programs should include for all students some training on IP issues so that every student is aware of the basics, as well as communications skills (both of which are useful for students regardless of their career path). Universities also need to adjust the curriculums to better train the workforce needed for a future in which AI/ML drives a lot of the products and services in the weather, water, and climate enterprises.

3.7. SBIR/STTR resources

The existing SBIR and STTR programs have been very successful in supporting innovative and entrepreneurial activities; however, this study has found that these programs are currently under-resourced relative to demand. Increased funding could almost immediately result in more innovations being put on the path to successful commercialization, particularly in conjunction with the other recommendations from this study. In addition to having the resources to provide

[11] See https://www.climate-kic.org/.

more Phase I and Phase II grants under these programs, the agencies administering them should seriously consider separately funding a small "Phase 0" grant program to support potential grantee training, which could lead to higher success rates from subsequent Phase I and Phase II grant recipients.

3.8. Formalized information exchange

The findings of this study make it clear that a key element in improving entrepreneurship in the geosciences is providing to geoscience students and researchers more information on how they can take their ideas toward commercialization. For example, some university researchers have ideas that could be commercialized but the researcher does not have an interest in pursuing that opportunity. In some cases, the researcher may not be aware of a potential market or avenues that they could pursue with their idea. Meanwhile, there are entrepreneurs who would be well placed to develop the idea if they were aware of it. This suggests that some sort of formalized information exchange through which researchers could share possible ideas with entrepreneurs, who can then follow up with the researchers to collaborate in commercialization.

A component of any formalized program that links researchers with potential entrepreneurs should be training for the researchers that covers how to navigate the licensing process in addition to helping to find entrepreneurs to develop their idea. A formal network can then be established that can match the ideas coming from academic researchers with entrepreneurs who will license them for commercial development.

AMS (and other organizations like it) offer one avenue to establish such programs. Even something like a "speed dating" session at an annual meeting that brings together researchers with ideas and entrepreneurs with experience moving an idea to product could be immensely valuable.

An example of a successful convening space for the private sector is the American Society of Adaptation Professionals (ASAP; https://adaptationprofessionals.org/), which is a "young" society compared to AMS and that has allowed it to develop into a very supportive space for entrepreneurs. ASAP pushes the notion of "coopertition" as a useful approach, where firms focus on how they can work together to grow the size of the pie (industry) rather than fight over the same piece of the pie (a segment, geography, etc.). This may be in contrast to older established societies like AMS, where there are many legacy players and it is challenging for an outsider to plug in. As one example of excellent programming that fits the recommendations in this report, ASAP has partnered with NOAA's Climate Program Office to offer training for those in the private sector looking to provide climate services.[12]

[12] See https://cpo.noaa.gov/noaa-cap-risa-sponsored-private-sector-climate-service-providers-academy-begins-oct-17/.

4. Conclusions

This study found that there is innovation and entrepreneurship across a broad spectrum of activities within the WWC community from new instrumentation for observations to new analysis techniques to new applications software aimed at decision-makers. The input received from community members throughout the course of this study highlights the rapid pace of development as well as several areas where action could be taken to further enable entrepreneurial activity.

Key takeaways:

- There are many programs at the federal, state, and regional level that can be utilized to support entrepreneurial activities, but many individuals in the geosciences are not aware of the wealth of resources available to them. Modest changes in university curricula and new programs by scientific and professional societies could effectively raise awareness of these opportunities.
- Many researchers lack adequate preparation to make the transition to entrepreneur. There is a need for additional training to gain these needed skill sets, which includes knowing when to seek outside expertise.
- Additional funding for existing federal SBIR/STTR programs at agencies that serve the geosciences could yield a significant increase in successful commercialization of geoscience innovations. In particular, the expansion of these programs to provide small "Phase 0" grants would support the additional training that most geoscience researchers need to be ready to take on entrepreneurial efforts.
- In some cases, the most effective path to commercialization is connecting a researcher with a new idea with an entrepreneur who can take it to commercialization. There are examples of successful matching programs that could be emulated by universities and scientific and professional societies with a high likelihood of success.

Recommendations in this report provide specific actions that can be taken by federal agencies, universities, and scientific and professional societies to address key challenges for increasing successful entrepreneurial activities and for better preparing students to enter the private sector workforce.

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Appendix: Study Contributors

The following individuals provided input that directly contributed to the findings and recommendations presented in this report and we thank them for their time and input. We are also grateful for many informal discussions with other individuals in the weather, water, and climate community that helped shape the direction of the study but did not directly impact its findings.

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