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What's the Forecast: A Look at the Future of Weather Research

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Chairwoman Sherrill and Ranking Member Bice, as well as the rest of the members of the Subcommittee on Environment, thank you for allowing me the opportunity to speak with you about what is a very important topic for our nation – priorities for weather research and forecasting.

My name is Kevin Petty, and I am the Vice President of Weather and Earth Intelligence at Spire Global Inc. Spire is a leading global provider of space-based data, analytics, and space services. We offer unique Earth system-related datasets and insights that help to facilitate enhanced operations across a number of industries.

As part of my comments, I would like to share some thoughts and perspectives on the NOAA Science Advisory Board's (SAB)'s Priorities for Weather Research (PWR) report. I would also like to comment on the role of the private sector in achieving the outcomes of the report. First, let me begin by sharing some additional background information on Spire and how it fits into today's discussion.

Spire was founded in 2012, and in August of 2021 the company went public on the New York Stock Exchange. During the last 10 years, Spire has launched over 150 satellites. It now operates one of the world's largest multipurpose satellite constellations, with over 100 satellites operationally in-orbit today. The constellation is predominantly built around Spire's 3U CubeSat platform called the Low Earth Multi-Use Receiver, or LEMUR. However, Spire is expanding its portfolio to include larger, more powerful 6U, 12U, and 16U form factor satellites. In addition to launching its own satellite constellation, Spire has an established Space Services division that is dedicated to deploying end user applications and sensors into space quickly, reliably, and efficiently, allowing for cost-effective, fast roll-out of new, novel capabilities.

Spire's constellation facilitates a number of data-related solutions. The company has become the global leader in capturing, analyzing, and distributing reliable, high quality Automatic Identification System (AIS) data, which is associated with maritime vessel tracking. Such data and information help to foster improved asset management, supply chain efficiency, and safety. Similarly, Spire's collection of Automatic Dependent Surveillance-Broadcast (ADS-B) data enables accurate, reliable global flight tracking, including over the oceans and remote regions of the Earth, allowing airline, aircraft, and airport operators to optimize across their network, better understand aircraft utilization, and predict maintenance windows.

Most pertinent to the discussion today is the fact that Spire's low earth orbiting satellite constellation uses radio frequency sensors to constantly gather a rich and unique set of data about the atmosphere and the Earth's surface. Through its satellite constellation, Spire collects the highest volume of Global Navigation Satellite Systems Radio Occultation (GNSS-RO) profiles in the world. The GNSS-RO technique, which analyzes the propagation of GNSS radio signals through the Earth's atmosphere, is used to produce data about the vertical structure of the atmosphere, including temperature, water vapor, and pressure. NOAA and other national meteorological centers are using these data to improve weather prediction by assimilating the data into numerical modeling frameworks. Furthermore, Spire is using its own RO data, along with numerical weather prediction and artificial intelligence/machine learning, to deliver targeted weather-related solutions to its customers in the business-to-business domain (e.g., Maritime, Aviation, Energy, Agriculture, etc.). It is also worth noting that ionospheric data, such as Total Electron Content (TEC) and scintillation, are gathered during the process of generating RO profiles. These data can be used to analyze and better predict space weather and its impacts on communication systems and power grid operations.

Spire's technology also supports the acquisition of unique environmental datasets worldwide such as soil moisture, sea ice extent, altimetry and other Earth properties. This is accomplished through the use of GNSS-Reflectometry. By leveraging these data to fuel research and development, innovative solutions can be created to address a number of disparate issues ranging from future food production to evolving shipping routes to changes in land use.

Spire is a prime example of how the Weather Enterprise continues to undergo significant transformation, particularly from the standpoint of private sector innovation and growth. This transformation began in large part in the mid-1990s and has accelerated since that time. Private sector growth has been accompanied by an expanding set of novel offerings and capabilities. Like Spire, several companies are delivering products and services to their customers by running numerical weather prediction models in-house and conducting research to advance modeling frameworks, including data assimilation. This was unheard of a few decades ago. For many years, weather-related companies were limited to selling terrestrial-based hydro-meteorological equipment, largely to the public sector. More recently, there has been private-sector expansion in the development and launch of space-based platforms for the advancement of weather analysis and forecasting. New business models have also arisen around the ownership and operation of equipment and infrastructure, with a focus on selling data instead of selling sensors. The translation of data into insights that support critical decision-making continues to be a central theme of many private sector offerings in the Weather Enterprise. In fact, sizable investments are being made in the creation of impact-based solutions rooted in artificial intelligence and machine learning techniques. Finally, the private sector is working to build and enhance pathways for efficient, effective distribution of data and information to end users, targeting user-tailored products and services. This includes the development of Application Programming Interfaces (APIs), web and mobile applications, infotainment system plug-ins, and plug-ins for smart devices. The aforementioned changes and progress in the private sector have generated a stronger, more diverse Weather Enterprise, with the capacity to tackle some of the nation's most challenging weather and climate issues. It is only by creating and leveraging strong partnerships will our great nation be able to recognize the full extent of the Weather Enterprise.

The Weather Enterprise has changed substantially over the last several decades. Specifically, the private sector has contributed significant innovation and experienced substantial growth. As a result, the influence and contributions of the private sector can be felt and experienced throughout the weather data and information value chain. Some companies in the Weather Enterprise have extensive expertise in specific parts of the value chain (e.g., observations, computing, and information delivery and translation). Accordingly, the private sector stands poised and is well-positioned to contribute to improvements spanning research to operations, including support of NOAA's mission.

The NOAA Science Advisory Board's Priorities for Weather Research report is a timely, exemplary document that identifies and recommends actions associated with weather research investment designed to culminate in new and improved capabilities that can serve to significantly enhance public safety and economic stability and resilience. The report calls out three essential pillars for investment – (1) Observations and Data Assimilation, (2) Forecasting, and (3) Information Delivery. One could argue that Observations and Data Assimilation are essentially two distinct pillars that should be addressed independently. Nonetheless, both are worthy of meaningful investment. Using the pillars as a foundation, the report proceeds to articulate some thirty-three recommendations, along with key findings. As expressed in the report, "The scope of investments necessary to support the overall advancement of weather for society is vast." As such, the human, material, and intellectual resources needed to achieve the desired outcomes are equally sizable.

Because the research and development (R&D) recommendations in the report span such a large array of priorities, it is clear that it will be difficult for NOAA to make material investments across all of the identified priority areas. Nevertheless, it is good to have a comprehensive picture of the research needs and requirements, since this will aid in formulating an effective investment strategy, including trade-offs. Where it makes sense, NOAA should not only partner with the academic sector, but it should also make use of the competencies and resources found in the private sector. Too often, the private sector is overlooked when the discussion turns to basic and applied research. However, as the private sector has grown, so has its ability to carry out R&D in all forms underscored in the SAB PWR report. This has been demonstrated by multiple private sector companies including Spire, Vaisala, IBM, Amazon, Ball, Campbell Scientific, and Advanced Environmental Monitoring, to name just a few.

In the case of Spire, significant company R&D investments were made, which led to the successful development and deployment of its Low Earth Orbiting (LEO) satellite constellation. In addition, these investments included signal processing research, which has advanced Spire's understanding as it relates to measuring and deriving Earth observations from space. Ultimately, Spire has been able to operationalize the collection of reliable, high-quality GNSS-Radio Occultation and GNSS-Reflectometry data to support its customers across all sectors. In fact, Spire is proud to be a Weather-Ready Nation Ambassador and honored to be a supplier of GNSS-RO data to NOAA through the Commercial Data Program (CDP). This would not have been possible without Spire's willingness to invest in science and technology research. Research is at the core of the company's success.

In 2017, the Weather Research and Forecasting Innovation Act was signed into law. This piece of legislation directed NOAA to explore the acquisition of commercial weather data. This legislation has helped to positively shift the data procurement paradigm for NOAA, with a focus on reducing the cost of ownership compared to conventional approaches. While the directive from the legislation, as well as NOAA's response, should be commended, the interaction in this paradigm remains transactional in nature. There is still room to enter into a stronger partnership model. Such a model could include working closely together from the ideation phase (e.g., new sensor), through the research phase, to development and deployment, and into operations. This type of collaborative approach will aid in stimulating innovative solutions, reducing risks, and meeting end-user needs. Most importantly, it can build trust.

Weather-related research and development competencies in the private sector run deep in several companies in the Weather Enterprise. These competencies include space-based and terrestrial observing sensors and systems, data assimilation and numerical modelling, artificial intelligence and machine learning, and user experience. This generates opportunity for scientific partnership across all sectors of the Enterprise. However, in terms of public-private partnerships and NOAA's investment in weather research, it is imperative that investments be made in research ventures with companies that have previously demonstrated the ability to conduct rigorous, distinguished research, along with the capacity to transition research to operation. By doing so, R&D risks can be significant lowered.

The PWR report also emphasizes, "…the urgent need imposed by climate trends, population and infrastructure increases, and disproportionate impacts on vulnerable communities…" In order to address this urgency, there is a need to quickly adapt to these trends. This requires an acceleration in the pace of research, along with faster adoption and implementation of credible outcomes. One way to accomplish this is by embracing R&D strategies that are not limited by rigid, siloed, and bureaucratic practices. Due to market demands, private sector companies have incorporated Agile and Lean strategies and practices in an effort to foster faster, flexible, iterative, efficient R&D environments, with a focus on end-user value. An attempt is made to fully address the research to operations pathway. NOAA should consider wider adoption of Lean and Agile throughout the organization. Moreover, it may be possible for NOAA to benefit from the research and development frameworks established by some companies in the Weather Enterprise, especially as it relates to increasing the pace of R&D.

It is important to recognize that NOAA has indeed taken steps to cultivate research engagement across broad parts of the Weather Enterprise, with the goal of accelerating impactful research and innovation. For example, NOAA should be acknowledged and applauded for its efforts associated with the Earth Prediction Innovation Center (EPIC), which supports and incentivizes a broad spectrum of NWP researchers. Initiatives such as EPIC have the potential to deliver innovative results quickly by creating opportunities for contribution and collaboration across the weather community, regardless of where an NWP researcher may sit in the Enterprise. It is these types of investments and initiatives that will accelerate model improvements, helping NOAA to meet its goals and objectives.

Given the fact that there are so many research priorities, as demonstrated by the PWR report, it is crucial that NOAA's investments in weather research are strategic, particularly from the perspective of ensuring that our nation is the global leader in weather prediction. Fundamentally, it is forecast accuracy and reliability that drive the effectiveness of downstream weather-related products, services, and solutions. Furthermore, the capacity to share and disseminate data and information is a key to success. Thus, special attention should be given to those research investments that will result in material improvement in these areas. The PWR report does well to articulate some of the investment pillars that would help to address these issues.

- **Observational Gaps**: it is essential that investments be made to address observation gaps, especially in the boundary layer and in data-sparse regions. This should include a balance between terrestrial, airborne, and space-based sensors and platforms. NOAA should consider the most effective and feasible solutions to close observation gaps including, but not limited to:

  - Sensor/system acquisition, ownership, and operation
  - Data buys
  - Co-hosted sensor deployment and operation (e.g., satellites)
- **Computing infrastructure:** NOAA must obtain access to more computing resources. This should likely include a hybrid approach (e.g., on premise and off premise resources, cloud and HPC). Computing resources must effectively and efficiently facilitate research, operations, data storage, and data/information dissemination.
- **Data Assimilation and NWP:** Investment in an Earth system modeling approach is absolutely necessary. However, care must be taken that such investments do not result in a proliferation of data assimilation and modeling systems, although it is recognized that one system may not fit all needs.

NOAA is and will remain a cornerstone of the Weather Enterprise, and in its capacity, it should be careful not to become all things to all people. As part of its investment strategy over the next decade and beyond, NOAA should carefully consider and account for the investments being made by others in the Weather Enterprise. For example, there continues to be a considerable amount of investment from the private sector to address the needs and requirements of select industries such as agriculture, energy, aviation, maritime, insurance, as well as a host of others. These needs have centered on tailoring data and information in an effort to increase safety and operational efficiency. NOAA should not run the risk of replicating these types of investments. Nor should it risk diluting its investments in weather research and forecasting to the point that tangible and sustained progress in key areas is limited or even negated, especially for core areas associated with forecast accuracy and reliability. This will require strong leadership and a willingness to make concrete and definitive investment trade-offs. It may also require a cultural shift in NOAA that embraces a more well-defined and focused approach when it comes to investments in weather research and forecasting. Fundamentally, NOAA should refrain from attempting to invest in everything, and where it makes sense, NOAA should develop and invest in strategic partnerships with the academic community, private sector, and other organizations to attain its weather research and forecasting goals and objectives.

Thank you for the opportunity to present this testimony. I welcome any questions or comments that you may have. I can also provide additional information as needed.