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# Mobile Assets for Collecting Weather Information – The Aviation Example

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**September 2020**

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Aviation and meteorology have grown up together through a mutually beneficial relationship (Haupt et al. 2019, Stith et al. 2019). Weather affects the safety, efficiency and reliability of aviation, and aviation is one of the key contributors of weather data aloft, thus enhancing weather prediction. At present, aviation is undergoing a dramatic transformation (Fig. 1) through the rise of small unmanned aerial systems (sUAS) and electric vertical take-off and landing (eVTOL) aerial vehicles envisioned for on-demand ridesharing across metropolitan areas (Steiner 2019). This emerging advanced aerial mobility will occupy the lowest layers of the atmosphere (5,000 feet and below), an altitude band that has been largely devoid of weather observations. Thus, imagine a future in which every aeronautical vehicle operating in the airspace system of the United States (or globally) would provide consistent, *in situ* weather observations. How would this improve the mission execution for all modes of aerial transportation? How might that weather information be utilized to improve all weather and weather impact predictions, thus enhancing benefits to society as a whole?

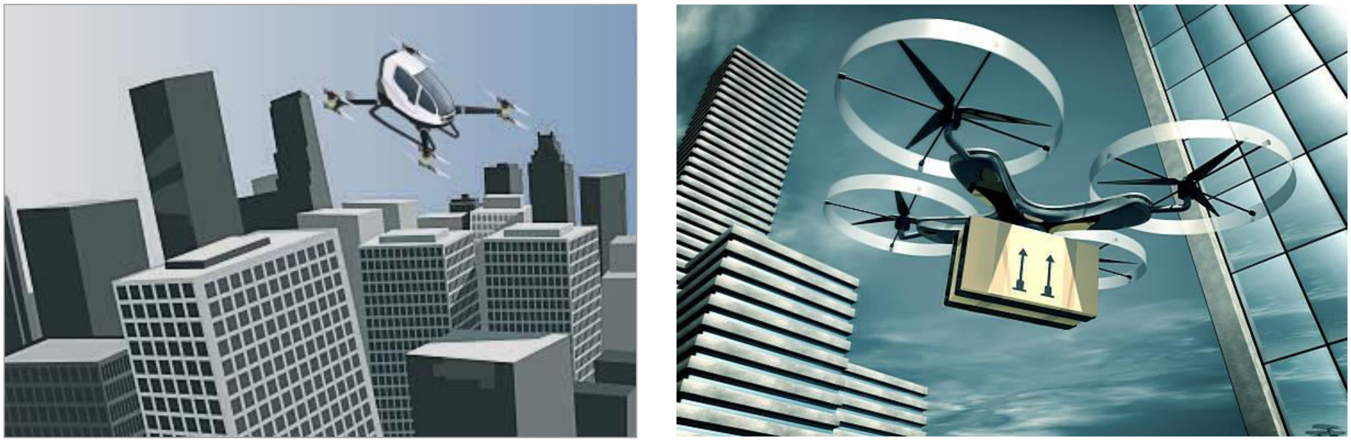

***Figure 1. Future aerial ride sharing and package deliveries.***

That is exactly the assertion that Robinson et al. (2020) are making: All aeronautical vehicles operating in the airspace of the United States should be required to measure, transmit, and share the *in situ* meteorological conditions encountered along the flight trajectory (Fig. 2). Reporting all conditions is key. Benign conditions for large aircraft may be hazardous for small aircraft due to their significantly increasing sensitivity to weather. Moreover, future automated and eventual autonomous operations will require advanced weather sensing capabilities to ensure safe and efficient operations.

This position for mandatory weather reporting will create opportunities and add value that ultimately outweighs the investment. The emerging modes of transportation, like eVTOLs and sUAS operating in non-traditional airspaces, pose more stringent requirements on our weather monitoring and prediction capabilities than can be satisfied at present. The scientific community aims to improve its understanding of atmospheric processes in the lower levels above the Earth’s surface (i.e., 0-5,000 feet AGL) and especially complex environments, like rugged terrain and urban landscapes, or near thunderstorms. Detailed observations are essential to further the scientific understanding, which in turn enables better predictions (not just of weather, but also of outcomes or responses influenced by weather).

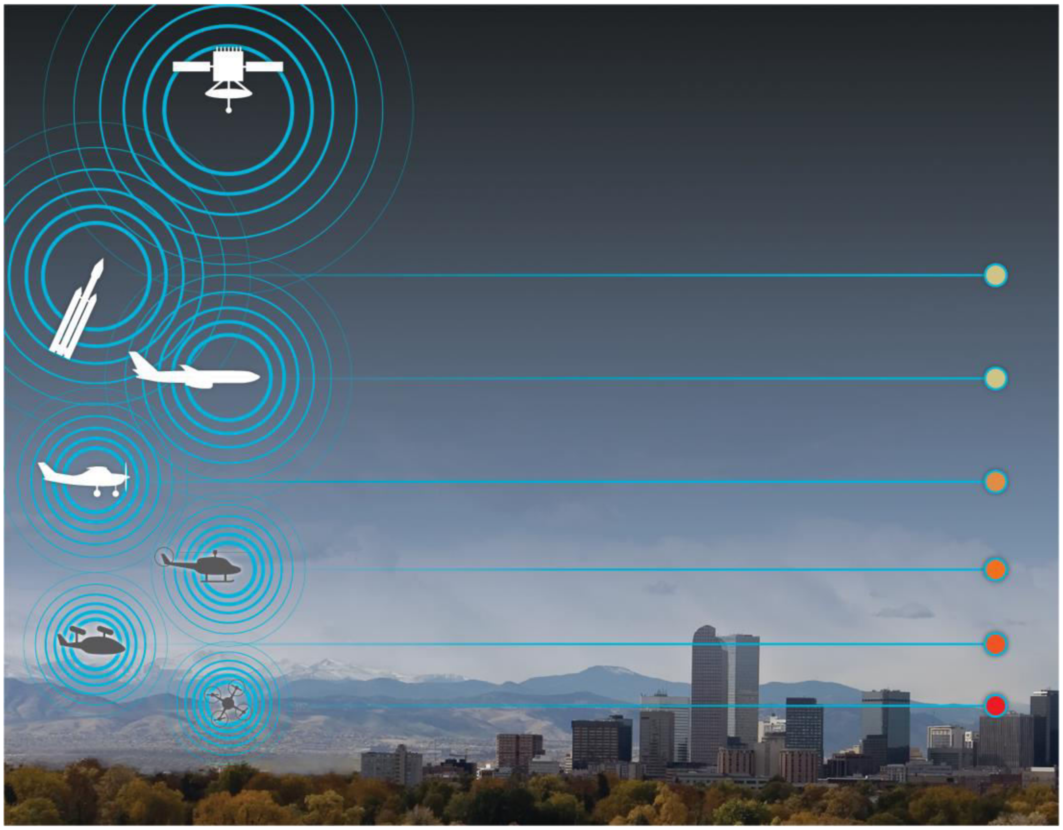

***Figure 2. Vision for future, ubiquitous observations of in situ weather conditions from all airborne aeronautical vehicles operating in the airspace system.***

While many observations are available at ground level, relatively limited observations are made aloft. Through the proposed mandate, a wealth of new and needed observations will become available (e.g., from sUAS and eVTOL vehicles operating in the lower parts of the atmosphere), thus greatly expanding the already long and mutually beneficial synergy between aviation and meteorology. It has been clearly demonstrated that observations made by large transport category aircraft have a huge positive impact on numerical weather prediction systems (James and Benjamin 2017). We anticipate that the emerging new stream of meteorological observations from vehicles operating in non-traditional airspaces and emerging crowdsourcing of individual observation stations will substantially enhance our weather prediction capabilities, in turn yielding increased safety, efficiency and reliability of aviation operations and public safety at large.

We are looking at a data-rich future, where sharing of data and information will yield greater benefits to air transportation (and beyond) than can be achieved individually by organizations and/or operators. The right time to consider such a mandate is now, as this new class of emergent vehicles is still ramping up, thus presenting more advantageous “equipage” opportunities. The overall path forward to ultimately realizing the envisioned benefits, however, is not easy (Fig. 3). There are many hurdles along the way, related to technical (e.g., sensors, communication), cost (installation, operation, return on investment), and regulatory aspects (data standards, ownership, cyber security, etc.) that will need to be worked out. In addition, tradeoff and benefits studies will be needed to address how all that data would best be utilized. These studies will include offline scientific investigations focused on process understanding and development of predictive capabilities, as well as real-time uses of such data to support more complex (and, in parts, autonomous) aviation operations and innovative data assimilation procedures for even broader societal applications and benefits.

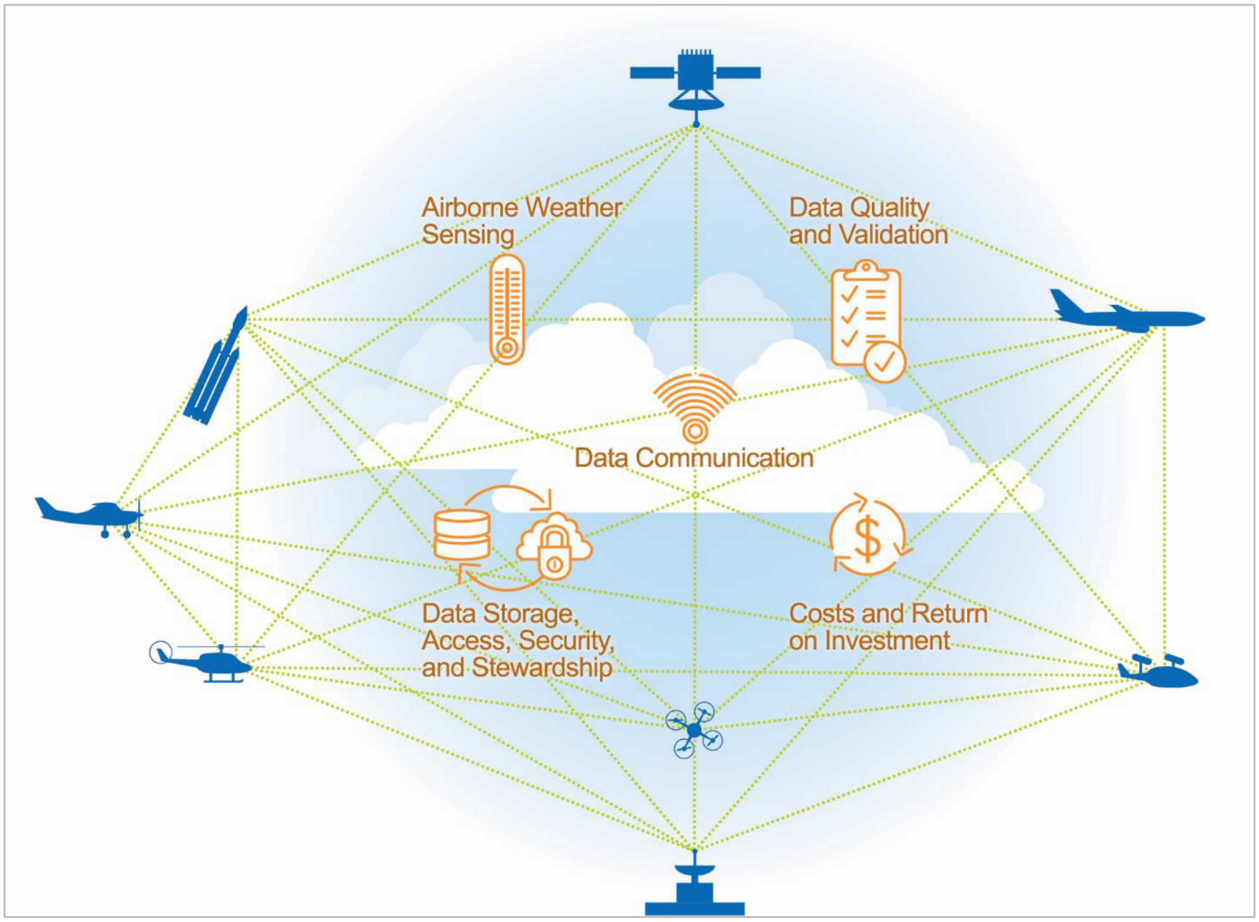


***Figure 3. Key challenge areas associated with observation mandate.***

The coming decade is considered to be the right time to provide significant weather impact mitigations and to reduce the weather sensitivity of the aviation and aerospace industries and society at large. Using recent breakthroughs in vehicle, sensor, communications and computing technologies, we believe the aviation, aerospace and meteorological communities are ready to collaboratively leverage big-data analytics, cloud storage, networking, artificial intelligence and material innovations to collect, provide, and apply ubiquitous weather data for significant air travel safety, efficiency and reliability improvements for all current operations; address the new operational concepts to be deployed in the airspace systems around the world over the next decade; and at the same time produce significant weather forecast improvements that benefit overall societal safety and well-being.

## Technical Challenges

Many universities, government laboratories, and private companies are devoting research to develop viable sensor technology that is small, lightweight, and energy-efficient, while still producing accurate atmospheric measurements (Fig. 4). Often the approach originates with radiosondes and their associated, operationalized sensor miniaturization. There is a need for developing calibration methods and aircraft-specific mounting guidance for these miniaturized sensors to produce quality measurements. Vast experience exists from working with airborne sensors (WMO 2003), although the emerging aerial vehicles pose new challenges. In addition, the response time and sampling frequency of a weather sensor needs to be considered as that ultimately defines the resolution of onboard observations.

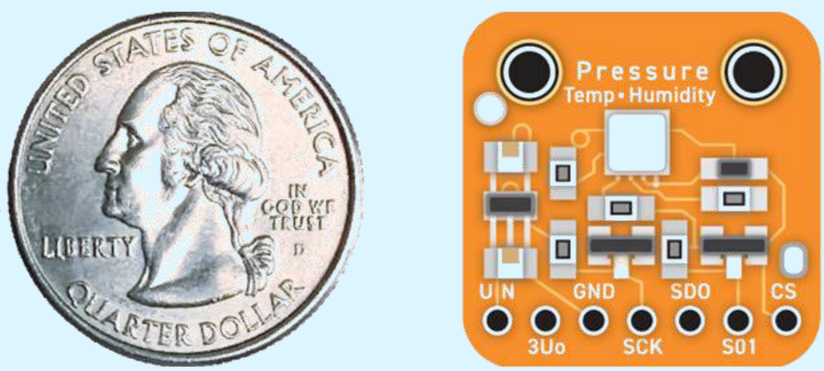


**Figure 4. Miniaturized sensor technology for pressure, temperature, and humidity measurement.**

The aviation industry has developed robust communication methods to relay weather data in real time (e.g., Aircraft Communications, Addressing, and Reporting System, or ACARS). Emerging ADS-B capabilities include weather transmission capabilities as well, although some of the ground infrastructure remains to be completed. Cellular networks and cloud-based services are being explored, but these efforts are in their infancy. Existing data repositories (like NOAA's Meteorological Assimilation Data Ingest System, or MADIS) need to be scaled up to appropriately handle the future incoming amount of weather data.

## Cost Challenges

The necessary aeronautical weather sensors and systems, the requisite communications capabilities, and any required new ground systems or upgrades to existing systems will come at a cost. Although operators may agree that the projected values and return of investment are real, they will struggle to understand how they will individually benefit from their financial participation. Funding the proposed weather data collection and sharing mandate, as is the case with most weather-related infrastructure improvements, will be a significant challenge, and the resistance to the concept will be extreme if its financial aspects are not handled adroitly. One overall financial strategy might be to minimize initial and ongoing operator costs to the extent practical, while taking advantage of existing systems and technologies, and the convergence of developing technologies wherever possible. Even with these measures, acceptance of additional financial needs will be challenging. Therefore, for all efforts to develop, define, standardize, and execute a weather data collection and sharing mandate, the quantifiable benefits and return on investment, understood from the perspectives of operators and stakeholders, must be routinely included as part of the implementation narrative.

## Regulatory Challenges

As the number of aeronautical vehicles across multiple aviation sectors that support ubiquitous weather data increases dramatically over time, formal data stewardship will be required to ensure proper retrieval and storage, appropriate data quality (validation), and ease of access for approved data users. Today, there are multiple organizations who feel they own this responsibility, such as the International Air Transport Association (IATA) for objective turbulence information from commercial aircraft, the NOAA NWS for all Aircraft Meteorological Data Relay, or AMDAR, data in the United States, and FLYHT Aerospace Solutions Ltd. for all Tropospheric Airborne Meteorological Data Reporting, or TAMDAR, data worldwide. These efforts will serve as initial roadmaps and provide some best practices for data stewardship.

At present, a relatively small number of operators have invested in advanced in situ weather observation systems that provide objective reports of relative humidity, turbulence, and icing. These operators consider that the weather information they collect belongs to them, even while understanding and appreciating its potential impact to flight safety; they only share it with other operators who have also invested in similar advanced in situ weather observation systems and share the same hazardous weather information with them. This question of data ownership and access becomes significantly more complex when there are many more operators, including substantially more commercial companies utilizing sUAS and eVTOL vehicles to support both direct and indirect business objectives. The advocated mandate requires all vehicle owners and operators to observe weather and share it with a larger community. However, scenarios where “collective access” may be considered unfair or inequitable, as well as potential opportunities to manipulate this agreement, can be envisioned. Thus, data ownership and access agreements will require careful consideration, and more detailed evaluations of best practices for similar situations in other domains (e.g., energy, natural resource access).

Communal use of weather data collected from many individual users may come with conditions for use that will need to be defined and implemented. For example, shared weather data will likely need to be encrypted and its source de-identified, to better protect privacy concerns. These types of data privacy steps will help companies and organizations maintain some anonymity when operating aeronautical vehicles for purposes specific to their business or operation. To prevent misuse of information, the proposed mandate must closely consider how best to define, implement, and govern data privacy policies and technologies. Moreover, methods to be deployed for communicating and relaying information from one aeronautical platform to another, or from an aircraft to the ground, will be at risk for cyber interference. The implication of such intrusion to airborne automation systems is great, and significant consideration is needed to determine how best to protect aeronautical vehicles, the environment in which they operate, and vast archives of collected data from bad actors.

## References:

S. Haupt et al., "100 years of progress in applied meteorology. Part I: Basic applications" (Chapter 22), *A Century of Progress in Atmospheric and Related Sciences: Celebrating the American Meteorological Society Centennial*, Monograph No. 59, American Meteorological Society (AMS), 2019.

E. James and S. Benjamin, "Observation System Experiments with the Hourly-updating Rapid Refresh model using GSI Hybrid Ensemble-variational Data Assimilation," *Monthly Weather Review*, **145**(8), 2897–2918, 2017.

J. Stith et al., "100 years of progress in atmospheric observing systems" (Chapter 2), *A Century of Progress in Atmospheric and Related Sciences: Celebrating the American Meteorological Society Centennial*, Monograph No. 59, American Meteorological Society (AMS), 2019.

M. Steiner, "Urban Air Mobility – Opportunities for the Weather Community", *Bulletin of the American Meteorological Society*, **100**(11), 2131–2133, 2019.

M. Robinson et al., "What if every aeronautical vehicle operating in our airspace were to report weather conditions?", *20th Aviation, Range, and Aerospace Meteorology Conference*, Boston, MA, 28 pp., 2020.

World Meteorological Organization (WMO), "Aircraft Meteorological Data Relay (AMDAR) Reference Manual", Geneva, Switzerland, 2003.