Report of the Site Visit Team on the University of Wyoming

King Air, LIDAR and RADAR Facilities

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Lower Atmosphere Observing Facility

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Charge to the Site Visit Team: The objective of the site review is to assess the quality and effectiveness of the University of Wyoming's performance as a provider of a national lower atmosphere observing facility (the UW King Air, Cloud Radar and Cloud Lidar) and to provide recommendations to NSF AGS about the future need for this specific and this type of facility.

Procedure: The team traveled to Laramie, WY on 10 October 2016 and visited the facilities at UW on 11 October followed by internal meetings and a debrief with UW staff on 12 October 2016. The attached is a consensus document of the three SVT members.

Report Overview

This report reviews the University of Wyoming facilities supported by NSF, and details the assets and areas that could be improved. In general the strengths of the facilities include their unique role as research-grade aircraft, radar, and lidar available to a single investigator or a small team. The King Air provides an essential, national capability especially useful for supporting and entraining new investigators into observational atmospheric and earth system science. The capabilities for cloud penetration and studies of aerosols, microphysics, and ice are outstanding. Areas where there is room for improvement include documenting and enhancing the major scientific accomplishments and expanding the user community.

- **Major assets**

The University of Wyoming King Air research facility (UWKA) has a long record, dating back to 1960's, in studying cloud microphysics and dynamics. These studies have been carried out using in situ observations and, more recently, remote sensing techniques, namely airborne cloud radar (WCR) and cloud lidar (WCL) systems. Since 2004, more than ~165 refereed journal articles have been published using the datasets obtained in projects supported by the facility. Cloud microphysical properties and dynamics determine frequency, type, and severity of precipitation, and therefore are research areas of national and international importance while still highly uncertain in climate models. Recent upgrades made to the aging state sensors and cloud probes have allowed the aircraft to be equipped with state of the art instrumentation for measurements of pressure, temperature, wind speed, turbulence, and water vapor as well as cloud microphysics (e.g., droplet size distribution and imaging, liquid water content). Furthermore, reliability and capabilities (e.g., control software, communication, radar near-range measurements) of the WCR and WCL units are continuously being improved, mostly through support from individual PIs and some support from NSF through CA5-7. These remote sensing instruments are key to provide a 3-dimensional view of clouds and the boundary layer as the airplane traverses the flight track. Compatibility of the WCR and WCL units with NSF C130 aircraft is an added bonus to provide these instruments to a wider scientific community. The strength of the facility in carrying out projects related to cloud microphysics and dynamics not only comes from the state of the art instrumentation available at the facility, but equally important arises from the high level of effort dedicated by the technical staff to maintaining and calibrating these instruments under varying conditions in addition to improving various data analysis software tools for data synthesis. A definite added value in this effort is the close partnership between the staff at the UWKA facility and the faculty at U. of Wyoming Atmospheric Sciences Department. During the site visit and laboratory tours in the Department, it was apparent that the faculty and their students play a pivotal role in supporting the instrumentation and designing innovative techniques to improve data quality and reduce uncertainties associated with some of these complicated sensors- efforts that are one of a kind in the area of cloud microphysical measurements.

- Aerosol capabilities are not as advanced, but instruments are available and it appears they are moving forward.

Since aerosol related research in the Department is expanding through recent hires, the comprehensive view of clouds microphysics and dynamics provided by the in situ and remote sensing payload of the UWKA opens up the opportunity for studying specific aerosol/cloud interaction processes under varying atmospheric conditions. This research area is not as mature as the capabilities related to cloud microphysics at the facility although basic aerosol size distribution measurements in clear-sky are currently available. However, the value in designing/improving instrumentation to characterize aerosol chemical and microphysical properties as they relate to cloud formation and modification has been recognized in CA7. As an example, initial stages of developing a photoacoustic instrument for aerosol absorption measurements are currently underway. Once fully tested on the ground and on the mobile van available in the Atmospheric Sciences Department, a more compact version of the instrument is planned to be developed for future operation aboard the UWKA and possible integration into the base facility payload.

- Structural DER certification and electrical DER in training.

The UWKA missions require numerous modifications to the King Air airframe to accommodate new and/or updated equipment. Each time a modification is needed, the facility is required to obtain a Supplemental Type Certificate (STC) from the FAA. This costs money, and takes significant time to complete the paperwork required. By regulation, the aircraft may not fly with modifications until the STC is obtained. To counteract this time commitment, the UWKA has added a full-time Mechanical Engineer dedicated to instrument design and an engineer recently certified as a FAA Designated Engineering Representative (DER) for structural engineering. Another engineer is in training to become a DER for Electrical engineering. As a DER, these individuals may approve or recommend approval of technical data to the FAA. This certification is a long process (approximately three years including application and acceptance into the program, a mentorship, satisfactory progress, and training completion). It will however, save time and increase aircraft utilization in the future. This will be particularly useful if/when the UWKA facility upgrades to a new aircraft requiring multiple modifications prior to being operational.

- Achievement of SMS Level 3

The UWKA research facility considers safety of paramount importance in their operations. Atmospheric research missions are inherently risky. There are no standard guidelines for conducting such missions, however the UWKA staff conduct their research and run their facility in accordance with the International Standard for Business Aircraft Operator (ISBAO) best practices. The facility has had a Safety Management System (SMS) in place since 2008, and in 2012 they received SMS Level 3 certification, the highest level attainable. Level 3 was renewed in 2015. This achievement shows the dedication from all levels to conducting missions while managing risk and ensuring the effectiveness of safety controls through systematic procedures, practices, and policies. SMS Level 3 is focused on proactive processes, applying the elements of level 1 and level 2 certifications to the initial design of systems and products, procedures, and planned changes to operations. With a proven history of safety risk management and the SMS level 3 certification, the UWKA research facility can accept mission requests with non-standard operations and complete them with a high degree of safety. This positive safety culture reflects well on the program and gives principal investigators confidence in conducting missions with higher risk factors.

- Additional workstation for scientific crew.

The UWKA was recently modified to allow an additional scientific workstation located directly behind the flight deck. This workstation provides flexibility to carry additional scientists during mission flights or to be used for educational outreach. The location allows maximum interaction between the scientists and pilot.

- Fast response to aircraft "squawks".

As with all aircraft operations, maintenance issues may arise while on location for a project. The UWKA maintenance department has been proactive in conducting routine phase maintenance when the aircraft is not deployed, and has shown incredible ingenuity and response time to aircraft issues (aka squawks) that arise while deployed. An example is the lower port door. It jumped its tracks and the pilot was unable to open or close the door from the flight station. To get the squawk resolved by an external mechanic would have taken significant time away from the project waiting for parts to arrive. Because of the in depth knowledge of the UWKA maintenance department, they were able to apply an in-house solution and have the door fully functional within a few days. The UWKA facility has also implemented procedures to avoid repetition of aircraft squawks. During the PECAN mission, the King Air experienced a dual generator failure due to condensate from the air conditioner that had accumulated in the belly of the aircraft. After this incident, a new preflight procedure was put in place to check the individual drains for accumulation. In addition, flight procedures were altered to avoid the negative loading of the aircraft, which is thought to have caused the accumulated condensate to immerse the circuit boards.

- Relationship between the program and the UW facility is strong. Two nearly identical aircraft adds value in training/experience.

An added benefit for the UWKA research facility is the availability of the 2nd King Air aircraft, owned by the Regents of the University of Wyoming, and operated by UWKA staff as a transportation aircraft. Having access to this aircraft allows for additional training and experience for the technical crew and engineers at the facility, and a measure of economy of scale.

- Real-time data back-up to mitigate loss.

While being briefed on the dual generator failure experienced during the PECAN mission, a question arose about the data, specifically how it was backed-up. During a dual-generator failure, the aircraft is operating solely on battery power, and the life of that battery is highly dependent on the electrical draw. It is vital that enough battery power remains to operate aircraft anti-icing and de-icing equipment, navigation, radios, and lights. The scientific load must be shed to preserve the battery for these functions. The pilot has the ability to shed all scientific power with the use of a single switch in the center console. When the scientific load is shed, the data must be backed-up to prevent loss of observations prior to the electrical failure. The UWKA prevents this from becoming an issue by backing up the data in real-time. This ensures the preservation of data while enabling the pilot to focus on flying the aircraft and executing emergency checklists as required.

- Open to new ideas/instrumentation. UWY shows a can-do attitude.

Although UW's strengths lie in cloud dynamics microphysics and aerosols, they are open to and supportive of projects outside their core strengths such as atmospheric chemistry. Instruments for measuring trace gases are limited at UW, but can be borrowed from NCAR. More often user-supplied instruments must be installed. For these, appropriate inlets and apertures are available. The crew has the expertise and attitude necessary to perform these integrations.

- Relationship with NCAR

Communication and cooperation with NCAR appear to be strong. If a project is too much for the King Air, transition to a more appropriate platform such as the C130 appears to be smooth. The KA has limited in house air chemistry capability but is aware of the instrumentation available at NCAR and the opportunities and challenges associated with installing it on the KA.

While a close relationship with NCAR is desirable, it is not sufficient for optimizing use of and scientific productivity from the UW facilities. NCAR facilities are more suited to teams of users and large-scale projects. UW facilities are suitable for single investigators or small teams of experimentalists and modelers. These are often scientists and engineers in an earlier stage of their career, and the NCAR communication efforts such as the web site may not reach these users.

Opportunities for Improvement

- Assessment of scientific & educational impact accomplished through use of UW facilities.

Documentation of the accomplishments, including the list of publications acknowledging UW support, needs to be kept up to date and to reflect exact nature of the support. It is especially important for NSF to see which papers arose from support of non-UW PIs. It would be useful to indicate which facilities (KA, WCR, WCL) were involved, perhaps in a table; the committee should not have to look there to find this information. The review committee was able to find a number of high impact papers that were frequently (~40-50) cited [Kotchenruther et al., 2001; LeMone et al., 2008; Roberts et al., 2006; Wang et al., 2012]. These should be presented as the lead accomplishments when describing the UW program either in a website or to visitors. The list of publications on the UW web site http://www.atmos.uwyo.edu/uwka/publications/uwka_wcr_wcl_pubs.htm is two years out of date. A database of reviewed archival publications, dissertations and theses, and outreach activities is essential to LAOF and NSF who must document accomplishments and broader impact of all facilities. The SVT recommends greater effort on assessing the scientific and educational impact accomplished through the use of UW facilities.

- Entraining new investigators. Implementing a concerted and systematic effort to make capabilities known to theorists and experimentalist for obtaining successful proposals/funding/papers.

To broaden the range of applications of the UWKA facility, concerted and systematic efforts need to be made to attract new investigators. As mentioned above, the facility provides a comprehensive set of measurements on cloud microphysics and dynamics. Such data are critical for developing process-level parameterizations to employ in cloud-resolving or regional scale models. Attracting new investigators that can utilize in situ and remote sensing cloud observational data in their models will not only increase usability of the collected datasets, but also broaden the scientific impacts of the deployments. Close interactions between the UWKA scientific staff and the new potential investigators during proposal preparation stages is encouraged to strengthen proposals' technical merit and to increase the chance of having a successful submission. Additionally, research capabilities of the UWKA facility as a single-PI airborne platform for carrying out atmospheric aerosol and chemistry measurements should be advertised more in the community. Participating in organized seminar series at institutes and departments with potential new investigators, hosting exhibitions at annual conferences (e.g., AGU, AMS, AAAR), or holding aircraft visitor days with local universities and research institutes at deployment locations are several mechanisms to advertise the facility and its capabilities to the community to attract new investigators.

- Data availability (in usable form) end-user level.

To extend usability of data obtained during the deployments to external investigators, the data should be processed and end-user level data made accessible through a public website, in a format easily adaptable by the scientific community. Successful data management can be a daunting task and may require a dedicated person. In recent years, several agencies, including NSF, NASA, DOE, WCRP (World Climate Research Program), and WWRP (World Weather Research Program), have highlighted research on clouds, aerosol, precipitation, and climate interactions as a high priority research theme. Investigators beyond those proposing to deploy the UWKA or WCR-WCL units will also benefit from the comprehensive and high-quality data obtained during a typical deployment. Data availability from these deployments should be publicized with experimentalists and modelers in the community, during annual conferences or seminar series, to encourage their utilization beyond the proposing PI's group. A method should be put in place to track and record external downloads of the data through the public website and to ask external PIs to offer co-authorship/acknowledgements for using the data.

- Outreach and education.

The SVT strongly encourages UWY to continue and intensify outreach and educational efforts. The current plan for UWY personnel to visit university campuses should be carried out systematically and vigorously. A few years ago, UWY submitted a proposal to use flight hours to visit universities that may house new investigators interested in using the UWY facilities, but it was declined. This plan should be revised and resubmitted – both to improve visibility of the program and to increase the success rate of requests. Although there were a reasonable number of requests, the number of projects awarded by NSF has been low in the past few years. There is an issue of the statistics of small numbers, but it is clear that new investigators must be entrained into the user community. These should include theorists as well as experimentalists because effective field campaigns are often planned to test a specific theory expressed in a numerical simulation.

- Work to obtain/upgrade to a KA 350ER aircraft prior to the 10,000 flight hour life limit.

The King Air 200 used for the research operations is a stable and well-maintained platform. It was purchased as a new aircraft in 1977 and currently has logged approximately 8000 hours. Typical King Air aircraft have a structural lifespan of 25,000 flight hours; however, due to the unique characteristics and added structural loading of atmospheric research missions, Beechcraft Corp. has reduced the lifespan on N2UW. At its current utilization rate, the life limit will be reached sometime in the next decade. UWKA personnel are aware of this and are investigating options to prolong the life span of N2UW or to replace the aircraft. One option is to upgrade to a King Air 350 aircraft with extended range capabilities. The King Air 350ER model will increase the scientific payload by 1800 lbs. and increase the mission endurance by approximately two hours. With the additional fuel load, missions can be extended offshore by more than 150 nm. These added benefits argue in favor of the up-grade as the UWKA would be able to expand mission capability and take on new projects. It is important to note that even if the life span of the current King Air 200 can be extended, it will eventually need to be replaced. Decisions for that replacement must be done early in the process to allow for uninterrupted service to the community. The SVT encourages UWKA facility to continue to conduct the data analysis required to determine if the life span may be extended while also preparing for possible replacement.

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