The Next-Generation Wyoming King Air Aircraft: Research modifications and Capabilities

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Presented at the annual meeting of the Science Committee for Oceanographic Airborne Research, NCAR RAF, 4 Oct ‘22
History of Airborne Research at Wyoming and the current University of Wyoming King Air (UWKA)

1965 Twin-Beech (C-45) 1971 Beech Queen Air 1977 Beech King Air 200T

Focus: atmospheric science (cloud physics, dynamics, surface and boundary layer, turbulence, air quality, trace-gas chemistry, airborne remote sensing, education and training)
History of Airborne Research at Wyoming and the current University of Wyoming King Air (UWKA)

The UWKA …

- has been operating under Cooperative Agreements between UW-NSF since 1988
- is one of the three aircraft in NSF Lower Atmospheric Observing Facilities (LAOF) Fleet
- fills a ‘niche’ within LAOF as smaller, more agile, more accessible aircraft
- was retired in Sept 2022
The Next-Generation Wyoming Research Aircraft
University of Wyoming King Air (UWKA-2)

• Effort to replace UWKA began in 2015 with investigations of potential platforms, emerging needs within the community, and new instrument/measurement capabilities
  o exploring funding opportunities
  o meetings/discussions with UW administrators, possible donors, and NSF
  o development of technical plan

• NSF 10 Big Ideas
  #4 – Mid-Scale Research Infrastructure: RFP in 2019
  “aimed at transforming scientific and engineering research fields as well as STEM education … by making available new capabilities, …(and) training early-career researchers in the development, design, and construction of cutting-edge infrastructure.”
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NSF Mid-Scale Research Infrastructure (MSRI-1) Award

The Next Generation UWKA-2

Oct 2019 – Sept 2024
The Next-Generation Wyoming Research Aircraft
University of Wyoming King Air (UWKA-2)

Project 1: Acquisition, Modification, and Certification

Project 2: New Cloud Profiling Radars

Project 3: New Airborne Lidars

Project 4: Trace Gas and Aerosol

Project 5: Immersive Environment for Science and Training
Project 1: Acquisition, Modification, Certification of Aircraft

_Five-Phase Implementation_

Phase 1: Acquisition of Baseline Aircraft (*purchased by Univ. Wyoming*)
Phase 2: Special Mission Enhancements (Vendor Contract)
Phase 3: Research-Specific Modifications (Vendor Contract)
Phase 4: Final Certification (Vendor Contract)
Phase 5: Integration & Testing Instruments (Univ. Wyoming)

_Single STC for Certification in Restricted Category_

✔ Payload configuration certified for ‘flight envelopes’
✔ Removal of equipment returns aircraft to Normal Category
**Project 1: Acquisition, Modification, Certification**

**Special Mission Enhancements**

- **Upgrade to Blackhawk XP67A engines**
  - ✔ Increased rate of climb
  - ✔ Improved single-engine & takeoff performance

- **Upgrade to 400 AMP Generators**
  - ✔ Increase from 600 to 800 Amp
  - ✔ Mission specific Electrical Bus

- **Increased max takeoff weight landing gear**
  - ✔ Heavy-weight landing gear increases MTOW from 15,000 Lbs. to 16,500 Lbs,
  - ✔ and ZFW from 12,500 Lbs. to 13,000 Lbs

- **190 G Centex fuel tanks**
  - ✔ Increase flight endurance to at least 4 hrs

**Research-specific Modifications**

- Design and complete 53 research-specific modifications to special-mission aircraft
- Development includes 3 new STCs
Project 1: Acquisition, Modification, Certification

Research modifications

- nose extension, and boom with gust probe
- hardpoints near wingtip for PMS cans (4)
- two large nadir ports
- two large zenith ports, in blue
- dropsonde chute
- inlets
- several smaller ports
- satcom antennas
The Next-Generation Wyoming Research Aircraft
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Project 1: Acquisition, Modification, and Certification

Project 2: New Cloud Profiling Radars

Project 3: New Airborne Lidars

Project 4: Trace Gas and Aerosol

Project 5: Immersive Environment for Science and Training
Project 2: improved cloud profiling radars

WCR-4 W-band cloud radar:
- Utilize 4 antennas: near Nadir, Down-fore, near Zenith, Up-fore
- Enables Vertical-Plane Dual-Doppler above and below aircraft
- New and upgraded RF hardware, including new W-band modulator
- Improved internal calibration sub-system
- RF unit repackaging for optimal antennas connection
- Upgraded Data Acquisition System and Display Software

KPR-2 K_a-band precipitation radar:
- Larger passive array antennas (2.2° HPBW)
- Upgrade RF for higher duty cycle of the solid state transmitter (up to %50)
- New Quadratic Phase Code Mode for higher sensitivity and weak side lobes
- New hybrid acquisition mode combining short pulse, compression chirp, and QPC

Both radars can be deployed on the NSF/NCAR C-130
The Next-Generation Wyoming Research Aircraft
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Aerosol Lidar Scattering Ratio (LSR)
Depolarization Ratio (Dep)
Temperature (T)
Water Vapor Mixing Ratio (WVMR)

Project 1: Acquisition, Modification, and Certification
Project 2: New Cloud Profiling Radars
Project 3: New Airborne Lidars
Project 4: Trace Gas and Aerosol
Project 5: Immersive Environment for Science and Training
Project 3: airborne atmospheric profiling lidars

MARLi-2 Multi-function Airborne Raman Lidar:
- Temperature and water vapor profiling below aircraft
- A new diode-pumped laser: reduces power consumption and weight
- Uses a novel 355nm Raman/fluorescence module
- A new set of filters for warm boundary layer measurements

Both lidars can be deployed on the NSF/NCAR C-130

ADL Airborne Doppler Lidar (new):
- Fine-scale (sub-km) three-dimensional wind profiles in clear air
- Prototype design and test key technology completed
- Single beam on stabilized platform completed, tested aboard van
- Five-beam system in development, testing on ground in early 2023
- Airborne testing and validation in 2023 (probably on C-130)
- STC development and certification for UWKA-2 in 2024
The Next-Generation Wyoming Research Aircraft
University of Wyoming King Air (UWKA-2)

Project 1: Acquisition, Modification, and Certification

Project 2: New Cloud Profiling Radars

Project 3: New Airborne Lidars

Project 4: Trace Gas and Aerosol

Project 5: Immersive Environment for Science and Training
Project 4: New trace gas capabilities

- NO\textsubscript{x} analyzer: Laser-Induced Fluorescence (LIF – NCAR) or Cavity Attenuated Phase Shift (CAPS - Aerodyne) (2023)
- Picarro G2401-m in-flight analyzer
  - CO, CO\textsubscript{2}, CH\textsubscript{4}, and H\textsubscript{2}O @ 0.3 Hz
- Two Aeris MIRA Ultra sensors
  - CH\textsubscript{4}, C\textsubscript{2}H\textsubscript{6}, and H\textsubscript{2}O
  - CO, N\textsubscript{2}O, and H\textsubscript{2}O
- O\textsubscript{3} detector, O\textsubscript{3} calibration unit and recommended flight upgrades
- Brechtel Model 1204 CVI inlet
The Next-Generation Wyoming Research Aircraft
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Project 1: Acquisition, Modification, and Certification
Project 2: New Cloud Profiling Radars
Project 3: New Airborne Lidars
Project 4: Trace Gas and Aerosol
Project 5: Immersive Environment for Science and Training
Project 5: Immersive environment to enhance science, flight decisions, and student training opportunities

- Engaging more investigators given limited space
- Training and captivating students (virtual immersion)
- Complimentary situational awareness on the ground
- Maintaining an interactive platform
UWKA – 2 Timeline

- Develop and Finalize Contract with Vendor for Modifications, Select Suitable Aircraft
- Special Mission Enhancements AND Design, Installation, Certification of Research-specific Modifications
- Research Configuration Certification
- Integration/Testing of Research Instruments

Timeline:
- 10/1/19: Start of NSF MSRI-1 Award
- 1/1/20: Allocation of State of Wyoming funds for aircraft purchase
- 1/1/21: Base Aircraft Acquisition (July 2020)
- 1/1/22: June 2022 Modifications mostly complete
- 1/1/23: UWKA-2 Delivered to UW
- Sept 2022 UWKA Retired
- 1/1/24: UWKA-2 Operational

UWKA-2 ‘transition’ period
CAESAR: C-130 over the Norwegian Sea

P/Is: Zuidema, Geerts, McFarquhar, Bailey, Cassano, DeMott, French, Wang

CAESAR aims to study how heat and momentum fluxes from the sea surface, boundary layer circulations, and cloud processes interact over the far northern Atlantic to produce the iconic cloud structure during cold-air outbreaks over open water.

The heat loss during CAOs in the near-surface ocean layers may be sufficiently strong in some areas for the surface waters to become negatively buoyant, sink to depth and form deep ocean water. Therefore, changes in frequency and intensity of CAOs in a changing climate and changing Arctic sea ice extent may have profound feedbacks on the climate system.
## CAESAR science traceability matrix

<table>
<thead>
<tr>
<th>observational category</th>
<th>instruments</th>
<th>specific objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D along-track wind (u,w)</td>
<td>WCR</td>
<td>1. surface fluxes &amp; BL growth</td>
</tr>
<tr>
<td>2D cloud &amp; precipitation structure and properties</td>
<td>WCR, KPR, WCL, MARLi</td>
<td>2. mesoscale structure</td>
</tr>
<tr>
<td>2D aerosol structure and properties</td>
<td>WCL, MARLi</td>
<td>3. clouds &amp; precipitation</td>
</tr>
<tr>
<td>2D along-track q_v, T in clear air</td>
<td>MARLi</td>
<td>4. aerosol</td>
</tr>
<tr>
<td>LWP, WVP</td>
<td>GVR</td>
<td>5. polar lows</td>
</tr>
<tr>
<td>soundings</td>
<td>AVAPS, plus Met Norway (hourly, Bear island)</td>
<td></td>
</tr>
<tr>
<td>state variables, pressure perturbations, wind, TKE</td>
<td>VCSEL, RFT, radiometric T, gust probe, HADS</td>
<td></td>
</tr>
<tr>
<td>broadband hemispheric radiation</td>
<td>SW &amp; LW radiometers</td>
<td></td>
</tr>
<tr>
<td>surface fluxes</td>
<td>VCSEL, RFT, gust probe</td>
<td></td>
</tr>
<tr>
<td>sea state, SST</td>
<td>MARLi, nadir camera, Heimann IR sensor</td>
<td></td>
</tr>
<tr>
<td>bulk condensed water</td>
<td>Nevzorov, CVI, King, Rosemount</td>
<td></td>
</tr>
<tr>
<td>droplet size distribution</td>
<td>CDP</td>
<td></td>
</tr>
<tr>
<td>precip size distribution</td>
<td>2D-S, 2D-C, PIP</td>
<td></td>
</tr>
<tr>
<td>hydrometeor spatial structure</td>
<td>HOLODEC-II</td>
<td></td>
</tr>
<tr>
<td>hydrometeor imaging</td>
<td>PHIPS-HALO, 2D-S, 2D-C, PIP, HOLODEC-II</td>
<td></td>
</tr>
<tr>
<td>δ18O isotope ratios of q_v and bulk condensed water</td>
<td>CVI/SDI, cavity enhanced laser absorption</td>
<td></td>
</tr>
<tr>
<td>aerosol size distribution</td>
<td>PCASP, UHSAS</td>
<td></td>
</tr>
<tr>
<td>black carbon concentration</td>
<td>SP-2</td>
<td></td>
</tr>
<tr>
<td>INP concentration &amp; chemical make-up</td>
<td>CFDC, IS filters</td>
<td></td>
</tr>
<tr>
<td>CCN concentration</td>
<td>CCN counter</td>
<td></td>
</tr>
<tr>
<td>carbon monoxide conc.</td>
<td>cavity enhanced laser absorption</td>
<td></td>
</tr>
<tr>
<td>mapped cloud/precip structure</td>
<td>met.no radar network, satellite imagery</td>
<td></td>
</tr>
</tbody>
</table>

### Priority greyscale
- not needed
- useful
- essential
Initially only F1 flights will be flown, until SLW (esp. large supercooled drop) content is well understood.
### Local CAO cloud and polar low sampling

<table>
<thead>
<tr>
<th>ref</th>
<th>Flight Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Level legs <em>across</em> the prevailing wind and cloud streets, @ multiple levels, ~150 km</td>
</tr>
<tr>
<td>L2</td>
<td>Porpoising legs <em>across</em> the prevailing wind, long enough to transects several cloud bands (two rises above BL and two dives to SL, ~150 km)</td>
</tr>
<tr>
<td>L3</td>
<td>Spirals from ~500 m above cloud top to near-surface, slow ascent/descent rate</td>
</tr>
<tr>
<td>L4</td>
<td>Large circles, drifting with the wind, two levels (just above cloud top &amp; in-cloud)</td>
</tr>
<tr>
<td>PL</td>
<td>A rosette pattern of 200-300 km long traverses across a polar low, at multiple levels</td>
</tr>
</tbody>
</table>

### Quasi-Lagrangian sampling

<table>
<thead>
<tr>
<th>CAO Type</th>
<th>Flight Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak winds</td>
<td>Resampling the BL air on next-day flight</td>
</tr>
<tr>
<td>Strong winds</td>
<td>Resampling on the same flight (illustrated below)</td>
</tr>
</tbody>
</table>

Background: WRF at 03/17/2016 10:50 UTC
C-130 take-off at ~8 am LT, return 8.1 hours later

![Map showing flight patterns and reflectivity at 500 m (dbZ)]
Questions?