Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Next generation onboard data networks and payload interfaces

Global Hawk Payload Data System

AMS Ikhana UAS (Wildfire)

NASDAT Network Server

Experiment Interface Panels

Telemetry and Payload Computer

Master Payload Control System
Natural Hazard Response

Collaborative Decision Environment
Real time Information Direct to First Responders
NASA Earth Science Research Capable Aircraft

Altitude (feet)

<table>
<thead>
<tr>
<th></th>
<th>10000</th>
<th>20000</th>
<th>30000</th>
<th>40000</th>
<th>50000</th>
<th>60000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Endurance (hrs)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>8</th>
<th>12</th>
<th>18</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Local flight primarily for CALIOP satellite validation, encountered different aerosols relevant to air quality.

User interpretation is required to infer geophysical parameters (pollution, smoke, dust, cloud) from measurements (backscatter, depolarization, wavelength dependence)
Measurements of Myrtle Beach Fires on April 24:

- April 23 US EPA requests HSRL overflights of SC fires using NASA B200 King Air
- Existing HSRL configuration allowed for rapid deployment from NASA LaRC on April 24
- Satisfied US EPA science requirements to measure aerosol distribution related to fire plume rise and aerosol extinction for biomass emission estimates

B-200-HSRL Overflights of SC Highway 31 Fire (17:45 – 19:20 UTC APR 24)

MODIS-TERRA AOD captures aerosols from SC fires - 15:30 UTC APR 24
Operation IceBridge

IceBridge, a six-year NASA mission, is the largest airborne survey of Earth's polar ice ever flown. It will yield an unprecedented three-dimensional view of Arctic and Antarctic ice sheets, ice shelves and sea ice. These flights will provide a yearly, multi-instrument look at the behavior of the rapidly changing features of the Greenland and Antarctic ice.
ER-2 and P-3 - Oracles

- **ORACLES**
  - Southern Africa produces almost a third of the Earth’s biomass burning (BB) aerosol particles, yet the fate of these particles and their influence on regional and global climate is poorly understood. ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS) is a five year investigation with three Intensive Observation Periods (IOP) designed to study key processes that determine the climate impacts of African BB aerosols.
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Small UAS Development
The RQ-14 Dragon Eye sUAVs were recently acquired by NASA from the U.S. Marine Corps via GSA to support this mission—good example of civilian repurposing of military hardware.

Flights occurred from March 10-13, 2013.

5 science flights with SO2 sensor and 1 science flight with thermal camera (7-12µm band)

SO2 concentrations of ~6-20 ppm were detected throughout the day.

Collected measurements in the volcano plume coincident with an ASTER overpass.

Expanded flight envelope up to 12,500 ft ASL from 8,000 ft ASL published operational ceiling.

Next deployment in 2015 will include the SIERRA UAV carrying a mass spectrometer and other instruments + Dragon Eye.

Funded by NASA Earth Surface & Interior Focus Area (John Labrecque) and the University of Costa Rica (Prof. Jorge Andres Diaz, Co-I).

US Team from NASA JPL, ARC, WFF.

Other participants/advisors:
- Applied Sciences University Düsseldorf (Germany)
- RadMet LLC (Redwood City, CA)
- Teledaq LLC (Santa Clarita, CA)
- Aerovironment, Inc. (Monrovia, CA)

Principal Investigator: David C. Pieri (JPL)
Compact Sulfur Dioxide sensor package for Dragon Eye UAS: “In situ validation and calibration of remotely sensed volcanic emission data and models” (Pieri, et al)
Too few ice crystals to effectively deplete excess H$_2$O vapor

Global models assume no supersaturation ($S_{\text{ice}} \leq 1$)

Jensen et al., PNAS (2013) 110, 2041.
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
Airborne Science Elements of Excellence

- **Airborne Science Infrastructure**
  - Next generation airborne sensor network
  - Integrated infrastructure for disaster response

- **Airborne Science Manned Aircraft**
  - B200
  - King Air
  - C130
  - ER-2
  - DC-8
  - P-3

- **Airborne Science Unmanned Aircraft**
  - Dragon Eye and Raven
  - Ikhana (Predator-B)
  - Global Hawk

- **Advanced Visualization Tools**
  - MTS - Mission Tools Suite and beyond
MTS – a suite of web based software tools to increase the efficiency and effectiveness Earth Science Airborne Campaigns

- Real time aircraft tracking and instrument telemetry
- Customized user and project workspaces
- Team communication and collaboration tools for shared situational awareness
- Integrated single and multi-user chat client
- Comprehensive ingest and streamlined display for KML, WMS, TMS data products
- Plotting and graphing
- Complementary tools for education
- Mobile tracking
Sensing Hazards with Operational Unmanned Technology
New UAS-related modeling and simulation capabilities

19 UAS mission profiles

17 UAS types

UAS models, comm. link models

SAA sensor models

DAA algorithms

Human-in-the-Loop Evaluation

NAS-wide Simulation

UAS-NAS integration concepts

Traffic displays, DAA algorithms, ATC, Ground Control Station

ACES: Flight plan and NAS-agent modeling system
NRT Airborne Science

Thank You!
Don Sullivan
donald.v.sullivan@nasa.gov
(650) 604 0526

27 September 2016