Overview of Altus Cumulus Electrification Study (ACES) and the Altair

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Project Overview

• Study thunderstorms using General Atomic’s Altus II UAV.

• Exploit unique capabilities of Altus to conduct thunderstorm studies.

• PI-led, end-to-end experiment encompassing all aspects of mission implementation and execution.
Support and Development

Sponsor
- NASA’s Office of Earth Science (Code Y)

Program
- Uninhabited Aerial Vehicle (UAV)-based Science Demonstration Program (UAV SDP) managed by Ames Research Center (ARC)

SDP Goals
- Conduct high quality science research using UAVs.
- Demonstrate utility of UAVs for Earth science and applications observations.
- Build confidence in UAV platforms through scientifically useful demonstrations.
Key Science Objectives

• Investigate lightning – storm relationships
  – quantify connections (updraft strength, precipitation, ice mass, storm height, latent heat release, precursors to severe weather events)

• Support validation of space-based lightning sensors
  – fill measurement void (observations last collected in early 1980’s)

• Study storm electrical output
  – quantify contribution of thunderstorm to global circuit

• Benefit science relevant to NASA’s Earth Science themes
  – themes include Global Water and Energy Cycle, Climate Variability and Predictability, Atmospheric Chemistry, and Disaster Management
Technology Demonstration

• Demonstrate the utility and promise of UAVs for investigating thunderstorms and other weather phenomena.

• Provide demonstration of real-time monitoring and control of a UAV science payload.
  – e.g., electric field monitored from the aircraft during ACES flights
Aircraft Selection

Altus II UAV

Pilot Console

Ground Control Station
Advantages of Altus for Storm Observations

• High altitude flight
  – 40,000 to 55,000 feet flight level
  – “cloud top” perspective

• Continuous observation of storms
  – long-duration flights combined with slow flight speeds

• Rapid response
  – operational flexibility for changing weather conditions

• Reduced risk to personnel
  – no pilot and/or passengers are placed at risk
### ACES Payload

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Measurement</th>
<th>Performance</th>
<th>Power  (W)</th>
<th>Mass  (kg)</th>
<th>Volume  (cc)</th>
<th>Heritage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric field mills (6 sensors)</td>
<td>DC electric field: 3 axis (x, y, z)</td>
<td>&lt;10 Hz &lt;1V/m – 15kV/m</td>
<td>2.8</td>
<td>21.8</td>
<td>16,000</td>
<td>ER-2, ALTUS, other aircraft</td>
</tr>
<tr>
<td>Electric field change meters (4 sensors)</td>
<td>AC electric field: 3 axis</td>
<td>1 Hz – 100 kHz</td>
<td>3.0</td>
<td>1.81</td>
<td>7,500</td>
<td>ER-2, ALTUS, other aircraft, ground based</td>
</tr>
<tr>
<td>Optical pulse sensor (2 sensors)</td>
<td>Optical lightning transients</td>
<td>320 – 1,100 nm</td>
<td>0.8</td>
<td>2.50</td>
<td>2,250</td>
<td>ER-2, ALTUS, ground based</td>
</tr>
<tr>
<td>Gerdien conductivity probe</td>
<td>Conductivity</td>
<td>3x10⁻¹³ –10⁻¹¹ S/m</td>
<td>3.0</td>
<td>1.36</td>
<td>1,100</td>
<td>ALTUS, UAV (Navy Swallow), rockets</td>
</tr>
<tr>
<td>Magnetic search coil</td>
<td>AC magnetic field: 3 axis</td>
<td>100 Hz – 100 kHz &gt;1.3 pT@ 10 kHz</td>
<td>0.3</td>
<td>0.91</td>
<td>1,650</td>
<td>ALTUS, Swallow, rockets</td>
</tr>
<tr>
<td>Fluxgate Magnetometer</td>
<td>DC magnetic field: 3 axis</td>
<td>0 – 100 Hz &gt;10 nT</td>
<td>0.2</td>
<td>0.45</td>
<td>100</td>
<td>ALTUS</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>Acceleration 3 axis</td>
<td>+/- 4 G</td>
<td>0.1</td>
<td>0.45</td>
<td>55</td>
<td>ALTUS, other aircraft, rockets</td>
</tr>
<tr>
<td>Flight Payload Data System (FPDS)</td>
<td>N/A</td>
<td>64 Ch @ 100 Hz 16 Ch @ 100 kHz</td>
<td>368</td>
<td>70</td>
<td>156,000</td>
<td>ALTUS</td>
</tr>
<tr>
<td>Total Payload</td>
<td></td>
<td></td>
<td>378</td>
<td>163 (360 lb)</td>
<td>184,655 (6.8 cu ft)</td>
<td>ALTUS</td>
</tr>
</tbody>
</table>

Altus can accommodate payloads up to 800 W, 400 lb, and 18.6 cu ft. Payload enhanced by the addition of 3 cloud cameras (down, left, right).
The ALTUS Cumulus Electrification Study (http://aces.msfc.nasa.gov)

ACES Payload
Experiment Design

• Conduct mission from Key West, Florida to take advantage of cost and resource sharing with another NASA program.

• Study thunderstorms that form over the Florida Everglades and nearby ocean.

• Utilize a large variety of ground- and satellite-based weather data to support both real time operations and science analyses.

• Nearby ocean provides for improved safety during loitering periods and lost link or emergency situations.
The ALTUS Cumulus Electrification Study (http://aces.msfc.nasa.gov)

Location of Field Campaign

82 Nautical Mile radius arc

NAFKW

Warning W-174C

Keep Out Zone
Field Campaign Objectives

- Observe thunderstorms during August, 2002
- The duration of the observing period was approximately 4 weeks.
- Goal to complete 8 - 10 flights, each 6 - 8 hours in length (actually completed 11 science and 2 check flights).
- Altus required to be on station and at altitude (~40,000 to 55,000 ft) for 4 - 6 hours.
Weather at Florida Everglades

• Frequent thunderstorm occurrence in the early to late afternoon

• Summer thunderstorms in the Everglades area are small air-mass “pulse-type” variety

• Typical storm lifetime is 0.5 – 1.0 hours

• Typical storm dimensions are 10 km diameter, 12 km height

• Initiated by differential heating and classic sea breeze convergence (presence of Everglades suppresses activity compared to central Florida)
Distribution of Storms near Everglades

Aug 2002
### Monthly Activity (Daily Frequency)

<table>
<thead>
<tr>
<th>Flight #</th>
<th>Date</th>
<th>Take-off (UTC)</th>
<th>Duration (hr:min)</th>
<th>Storm Passes</th>
</tr>
</thead>
<tbody>
<tr>
<td>84 FCF</td>
<td>Aug. 02</td>
<td>1318</td>
<td>0:55</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>Aug. 04</td>
<td>1714</td>
<td>3:00</td>
<td>6</td>
</tr>
<tr>
<td>86</td>
<td>Aug. 06</td>
<td>1521</td>
<td>1:30</td>
<td>+</td>
</tr>
<tr>
<td>87</td>
<td>Aug. 08</td>
<td>1724</td>
<td>3:30</td>
<td>6</td>
</tr>
<tr>
<td>88</td>
<td>Aug. 10</td>
<td>1632</td>
<td>3:18</td>
<td>20</td>
</tr>
<tr>
<td>89</td>
<td>Aug. 12</td>
<td>1449</td>
<td>1:24</td>
<td>4+</td>
</tr>
<tr>
<td>90</td>
<td>Aug. 13</td>
<td>1519</td>
<td>2:36</td>
<td>0</td>
</tr>
<tr>
<td>91</td>
<td>Aug. 15</td>
<td>1505</td>
<td>5:12</td>
<td>17</td>
</tr>
<tr>
<td>92</td>
<td>Aug. 21</td>
<td>1540</td>
<td>6:42</td>
<td>41+</td>
</tr>
<tr>
<td>93</td>
<td>Aug. 23</td>
<td>1812</td>
<td>4:30</td>
<td>27</td>
</tr>
<tr>
<td>94</td>
<td>Aug. 25</td>
<td>1854</td>
<td>2:24</td>
<td>0</td>
</tr>
<tr>
<td>95 FCF</td>
<td>Aug. 30</td>
<td>1457</td>
<td>1:06</td>
<td>0</td>
</tr>
<tr>
<td>96</td>
<td>Aug. 30</td>
<td>1903</td>
<td>1:42</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13 flights</strong></td>
<td><strong>37:48</strong></td>
<td><strong>115+</strong></td>
<td></td>
</tr>
</tbody>
</table>

The ALTUS Cumulus Electrification Study (http://aces.msfc.nasa.gov)

CAMEX Science Workshop
Huntsville, AL   20-22 November 2002
Real-Time Weather Display

Supporting Data

<table>
<thead>
<tr>
<th>Product/Parameter</th>
<th>Latency</th>
<th>Primary Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar</td>
<td>WSR-88D (Miami, KW)</td>
<td>5-10+ min</td>
</tr>
<tr>
<td></td>
<td>NPOL (Ramrod Key)</td>
<td>post mission analysis</td>
</tr>
<tr>
<td>Lightning</td>
<td>Cloud-to-ground (NLDN)</td>
<td>Real time</td>
</tr>
<tr>
<td></td>
<td>Total lightning (EDOT)</td>
<td>post mission analysis</td>
</tr>
<tr>
<td>Satellite</td>
<td>GOES</td>
<td>15 min (5 min for rapid scan)</td>
</tr>
<tr>
<td>Aircraft location</td>
<td>INS/GPS from aircraft</td>
<td>Real time</td>
</tr>
</tbody>
</table>

Access

- Real time display products available to any project computer via LAN (requires Java application on local computer, display is platform independent)
Real-Time Weather Display
The ALTUS Cumulus Electrification Study (http://aces.msfc.nasa.gov)
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ACES Presentation Outline

• ACES Overview
• ACES Objectives
• Altus II and Payload
• FAA Approval Process
• ACES Campaign
• Conclusion
ACES Conclusions

• Demonstration of the UAV as a science platform flying in National Air Space
  – Minimum restrictions applied in COA (treated generally like a manned aircraft)

• Validated utility and promise of UAVs for scientific and operational weather research
  – High altitude, slow flight speed, and long duration

• Real-time weather display developed for ACES with aircraft tracking
  – Useful for precision weather research and other applications.

• Pilots and scientists co-located in Ground Control Station (GCS)
  – Improved execution and conduct of science mission
Future

• UAV capability that will enhance weather research
  – Over the horizon capability
  – TCAS (Traffic alert and Collision Avoidance Aystems)
  – Regulatory approval process to flying in national airspace
  – Reduced flight hour cost

• Altair (next generation science UAV) built by GA-ASI
  – More reliable and robust
  – Similar capabilities as the Altus
The Future - Altair

Pros

– Higher reliability, additional capabilities, greater safety
– Over the horizon capability, long duration missions
– TCAS (Traffic alert and Collision Avoidance System), ATC voice relay, redundant systems
– Larger payload (800 lbs), wing pods possible for add’l payload
– Improved regulatory environment

Cons

– Regulatory environment still uncertain
– Max altitude (52 Kft) a little lower than desirable