CINDY ZOOK
ASSOCIATES
Organization & Manageme
Development

3714 Richard Avenue
Fairfax, Virginia 22031

Tel. 703-591-2755
Fax 703-591-1042
e-mail: czook1@aol.com

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To: Mrs. Cheryl Yuhas, Mr. Randy Albertson and the Suborbital Science Missions (Atmospheric Composition - Troposphere) Participants

Following are the notes and completed templates from your work yesterday. In spite of the scheduling adversity before us, I think the groups produced some great quality work in such a compressed timetable.

Good luck with the rest of your mission campaign and Suborbital UAV development endeavor. It's been great working for you. Thank you and take care.

Sincerely,

Yumiko

Suborbital Science Missions of the Future

Atmospheric Composition (Troposphere)

July 21, 2004

Summary of Opening Remarks and Discussions

Cheryl Yuhas kicked off the meeting with welcome and briefed participants on the progress of Suborbital Earth Science Program and the results from last week's meeting. She also gave some highlights from Mike Luther's presentation (from the workshop as well) on Earth Science Enterprise's mission, critical science questions, current/future earth observing systems and other remote sensing technologies.

- What are the science drivers that can be put into investment? - we are getting best investment with the money
- Ask each group to think out of the box about what kind of missions can be put into place
- Collaborative partnership with aeronautics engineering community and science community
- Majority of Troposphere folks are not included in the workshop last week
- Current platform can be coordinated with these activities (UAVs)
- Traditional technologies are a part of the mix
- Highlights of Mike Luther's presentation

Randy Albertson then briefly addressed on Aeronautics Enterprise, especially its mission, vision, focus areas, latest technologies and programmatic priorities. He pointed out Code R's biases on remote areas and stressed that there are opportunities for Troposphere's input to be included in requirement gathering process of this program.

After these briefings, several participants raised concerns that the chart showing HALE ROA Science Platform capabilities is not particularly Troposphere inclusive.

In response, Jim Gleason emphasized that this meeting is in fact one of the avenues for feeding scientific needs from Troposphere back to the Aeronautics Engineers so that the input will be considered in Program's UAV vehicle capability development

There were some discussions on what particular weight of load, spatial range and endurance of UAV will be suitable for their science mission (such as hurricane tracking mission) needs.

Finally, Bill Brune briefly provided some frameworks of the template process and explained that they needed to be focused on operational aspects of scientific missions in order to work through and generate group products.

System Requirements Template (Group 1 A)

<u>Critical Observation</u>: Tracking long distance (>10000 km) transport and evolution of pollution

<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.

- We want to track plumes and measure the composition of gases and aerosols over very long distances (>10000 km), time periods (> 10 days), and multiple altitudes. Need to communicate in real time to ensure that the platform is within the plume. Need to control in real time to take any necessary corrective action.

- Inert tracers that distinctly identify plume position. Reactive tracers that allow interpretation of plume chemical evolution. Precursors and products associated with ozone formation, oxidizing potential, and aerosol interactions.

- New techniques (e. satellites, other UAV) for tracking and communication. New techniques of profiling to stay Lagrangian.

- Examples of parameters that must be monitored are:
  - Chemistry
    - ~ Ozone and water vapor
    - ~ Carbon species (CO, CO_2, CH_4, NMHC, and HCFCs)
    - ~ Reactive nitrogen species (NO, NO_2, PAN, HNO_3)
    - ~ Reactive hydrogen species (HCHO, H_2O_2)
    - ~ Sulfur (SO_2)
  - Aerosol (composition, number, size)
  - Radiation (UV radiation, IR flux)

Explicitly state how this observation and measurement supports this Earth Science focus area.

- This capability presently does not exist. Will address primary questions in ESE strategic plan.

- Explicitly state the advantage of using a suborbital platform for this measurement.

- Long duration necessary for Lagrangian sampling
  Improved targeting of atmospheric phenomenon.
  Integrates observations from other satellite and UAV platforms.

Identify other cross-cutting areas impacted by this observation.

- Climate change, carbon cycle, hydrological cycle, weather and applications

<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:

Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)

- Heavy pay load capability (>2500 lbs)
- Power (as necessary for payload)
- All environmental conditions such as Temperature and pressure control

Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.

- Should be able to be targeted globally
- Cover altitudes of 0-50000 ft.
- Range (>15000 km)
- Endurance (>10 days)
- All seasons

Communication needs such as real-time data or instrument control

- Over the horizon communications for real time control

<u>Mission Concept</u>: Describe in as much detail as possible the measurement approach:

Provide a narrative describing a "day-in-the-life" of the mission.

- identify source region
- Wait for the appropriate plume development and launch platform
- follow plume over 10-15 days

Identify any special or unique platform or mission issues

- Must have investments made to ensure readiness of lightweight measuring instrumentation.
- Near continuous air space access at all locations and altitudes targeted by the mission

Summarize the key elements of the mission concept for this measurement.

- Tracking regional pollution transport and its impact on climate and chemistry

System Requirements Template (Group 1 B)

<u>Earth Science Focus Area</u>: Cloud / Aerosol / Gas/Radiation Interactions

<u>Critical Observation</u>: The study of cloud microphysics, chemistry and optical properties during formation, evolution, precipitation and dissipation.

<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.

- The condensation, activation and evolution of the aerosol and cloud droplet spectra during cloud cycles and their effect on the precipitation, lifetime and optical properties of the could.

Explicitly state how this observation and measurement supports this Earth Science focus area.

- Clouds are the chemical processing factory of the atmosphere and have controlling influence on the hydrologic cycle and the radiative balance of the planet. This project would seek to explicitly link these roles in ways that provide greater understanding of natural and anthropogenic aerosol/gas constituents upon cloud properties, including radiative effects, along with the processing and removal of these aerosol/gas species.

Explicitly state the advantage of using a suborbital platform for this measurement.

- Clouds cycles on scales of minutes and hours to days are difficult to effectively sample from existing airborne platforms. The ability to linger and fly extended missions in cloud environements could be done by suitable suborbital platforms.

Identify other cross-cutting areas impacted by this observation.

- Aerosol geochemical cycles, hydrologic cycle, gas to particle conversion, heterogeneous chemistry, precipitation chemistry, cloud radiative effects, global radiative forcing

<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:

- Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)

- Aerosol size distributions, light scattering, light absorption, Cloud droplet distributions, droplet chemistry, short wave and long wave radiative fluxes, precipitation chemistry, imagery. Environmental variables including specific humidity, temperature (relative humidity), pressure, dew point, ice point, trace gases and ionic species. Sampling inlets uncontaminated by power sources.

- Capability for dropsonde deployment.

Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.

- Above, below and in cloud, possible coordinated with concurrent measurements from different platforms. In cloud measurements with coordinated radiation above and below cloud.
- Altitude from 0.5km to 30km for various cloud types.
- Endurance from 1hour to 2 days, depending upon mission.
- All Seasons, frequency as needed.
- Robust, watertight platform with Anti-icing capabilities.

Communication needs such as real-time data or instrument control

- Real time transmission and receiver for platform and instrument control.
- Local radio communication with dropsonde receiver and satellite communication for downlink and control.

Mission Concept: Describe in as much detail as possible the measurement approach:

Provide a narrative describing a "day-in-the-life" of the mission.

- Take off and ferry to cloud system with three aircraft. In-situ aircraft characterize cloud droplets evolution over cloud lifetime, droplet chemistry, etc.. Lower aircraft measures aerosol properties below cloud and visible and IR fluxes and aircraft above measures visible and IR fluxes. Continue over lifetime of cloud evolution.

System Requirements Template (Group 1 C)

<u>Critical Observation</u>: Long time scale vertical profiling

<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.

- High resolution vertical chemical structure of the atmosphere. These measurements in conjunction with ground based and satellite measurements will map the vertical structure of the composition. Coordination of low altitude with high altitude aircraft and satellite and ground based instruments.

Explicitly state how this observation and measurement supports this Earth Science focus area.

- Fits atmospheric composition area of ESE focus

Explicitly state the advantage of using a suborbital platform for this measurement.

- Suborbital platforms will allow for higher resolution vertical measurements and can remain at a specific site that could overlap with ground based or geostationary satellite measurements.

Identify other cross-cutting areas impacted by this observation.

- This could provide critical validation data for ground based and new satellite systems capable of tropospheric profiling.

<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:

Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)

- Large payload including:
  - Hydrocarbon measurements
  - Ozone
  - Nitrogen oxides
  - Tracers including CO, CH_4, N_2O
  - Radiation UV-VIS and IR
  - Aerosols
- Payload weight of ~1500 lbs
- Free air stream sampling for reactive species

- Unimpeded field of view zenith and nadir for radiation
- 3-4 KW power

Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.

- Measurements from surface to 60 KFT on combination of 2 platforms
- Ability to complete entire vertical profile in ~20 minutes
- Flying in the same vertical column with coordination and 5 KFT overlap
- Ability to maintain latitude and longitude for entire vertical profile

Communication needs such as real-time data or instrument control

- Real time positional data to insure single point profile
- Platform to platform coordination for overlap in vertical space

<u>Mission Concept</u>: Describe in as much detail as possible the measurement approach:

Provide a narrative describing a "day-in-the-life" of the mission.

1. Instrument preparation
2. Initial mission planning
3. Mission programming and PI briefing
4. Instrument upload and testing
5. Takeoff of high altitude aircraft
6. Real-time data transmission & updated positional information leading to low altitude aircraft takeoff when high altitude aircraft is at max altitude
7. Profiling
8. Return to base
9. Data download
10. Instrument & aircraft servicing
11. Data analysis
12. Mission objective revisions based upon flight results

Develop a diagram showing flight profile or maneuvers in time, space and/or geographic coordinates.

1. High altitude platform takes off from base
2. High altitude platform ascends to maximum altitude
3. Low altitude platform takes off
4. Platforms proceed to descend or ascend in a geostationary spiral
5. Coordination and 5KFT overlap of downward spiral of high altitude aircraft with upward spiral of low altitude aircraft.
6. Multiple profiles executed
7. Return to base

Identify any special or unique platform or mission issues

- Must be able to change altitude rapidly to insure accurate mapping of the vertical column
- Must be able maintain geostationary position for vertical profiles

Summarize the key elements of the mission concept for this measurement.

The main elements of this mission are:

1. long duration for multiple vertical profiles
2. coordinated platforms with real time command capability,
3. heavy lift (10 instruments - 1500 lbs.)
4. high reliability.

System Requirements Template (Group 2 - A)

<u>Critical Observation</u>: Global 3-d continuous measurement for environmentally important species for assimilation in global models

<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.

- Global evolution of atmospheric composition on time scales from synoptic to decadal
- Regional emissions and continental outflow
- Resolution of fine vertical structures inaccessible from satellite observations

Explicitly state how this observation and measurement supports this Earth Science focus area.

- Improved emission estimates
- Global trends
- Continuous monitoring of plumes
- Improvement in model descriptions of processes

Explicitly state the advantage of using a suborbital platform for this measurement.

- High vertical resolution
- Large suite of species non-measurable from space
- Observation in both cloudy and clear environments

Identify other cross-cutting areas impacted by this observation.

- Numerical weather prediction
- Carbon cycle science
- Climate variability

<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:

Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)

- Type: key species controlling tropospheric ozone, aerosols, greenhouse gases;
- Remote payload: Ozone/aerosol/water lidar, dropsondes, DOAS

Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.

- Fleet of ~1000 platforms (balloons, UAVs,…) globally deployed, with daily vertical profiling from the platforms enabling observation from surface to 20 km altitude.

System Requirements Template (Group 2-B)

<u>Critical Observation</u>: Processes of transport and chemical evolution in the troposphere (e.g., intercontinental transport of plumes, convective processing, lightning effects)

<u>Observation / Measurement Definition</u>: Describe the phenomenon you want to observe. Describe what you need to measure.

- Chemical evolution and transport on scales ranging from convective to global
- Ozone, aerosols, and related species affecting their evolution or providing tracers of air masses

Explicitly state how this observation and measurement supports this Earth Science focus area.

- Improved process-based understanding to guide chemical transport models
- Improved understanding of global-scale transport

Explicitly state the advantage of using a suborbital platform for this measurement.

- Process studies in the troposphere require resolution of scales and detailed chemical characterization not accessible from space

Identify other cross-cutting areas impacted by this observation.

- Numerical weather prediction
- Biogeochemical cycling
- Climate dynamics

<u>Observation / Measurement System Requirements</u>: Describe how you want to observe or measure the phenomena. Consider the following:

Instrument / Payload characteristics (type, weight, volume, environmental considerations, and access such as sampling or viewing ports)

- In situ payload: ozone, aerosols, precursors, related radicals, greenhouse gases, as well as tracers with spectrum of atmospheric lifetimes
- Remote payload: ozone/aerosol/water lidar, DOAS, dropsondes, FTS, wind profiler
- Care in avoiding contamination from UAV exhaust

Flight characteristics (location, altitude, endurance, season, frequency). Discuss number of platforms, formation flying, or other special flight characteristics.

- “Mothership” with extensive remote instrumentation directing drones with in situ instrumentation flying above and below the mothership along patterns directed by the mothership
- Balloon releases to enable Lagrangian sampling
- 1-week endurance, 15,000 km range, surface to 20 km altitude

<u>Mission Concept</u>: Describe in as much detail as possible the measurement approach:

Provide a narrative describing a "day-in-the-life" of the mission.

- Remote sensing from the mothership characterizes the spatial extent of the air mass being probed and communicates the information to the drone UAVs in real-time allowing continuous flight adjustment

Group Participant List

Group 1

Antony Clarke	tclarke@soest.hawaii.edu	808-956-6215
Scott Sandholm	scott.sandholm@eas.gatech.edu	404-984-3895
Rick Shetter	shetter@ucar.edu	303-497-1480
Hanwant Singh	hanwant.b.singh@nasa.gov	650-604-6769
Jim Podolske	james.r.podolske@nasa.gov	650-604-4853
Jim Crawford	james.h.Crawford@nasa.gov	650-269-5516

Group 2

Melody Avery	m.a.avery@larc.nasa.gov	757-864-5522
John Crounse	crounjd@caltech.edu	909-232-3234
Ed Browell	edward.v.browell@nasa.edu	757-864-1273
Cam M'Naughton	cameronm@soest.hawaii.edu	808-284-3084
Ron Cohen	cohen@cchem.berkeley.edu	510-642-2735
Xinrong Ren	ren@essc.psu.edu	814-863-8752
Paul Voss	pvoss@geo.umass.edu	413-545-0229
Huiting Mao	hmao@typhoon.sr.unh.edu	603-862-0121
Bob Talbot	Robert.Talbot@unh.edu	603-862-1546
Daniel Jacob	djacob@fas.harvard.edu	617-495-1794

For further ideas

Cheryl Yuhas	Cheryl.l.yuhas@nasa.gov	202-358-0758
Randy Albertson	randy.Albertson@dfrc.nasa.gov	661-276-7540

Appendix II

Letter from Cheryl and Randy (Post Meeting)

Dear colleagues,

Thank you for taking time out of your busy schedule to meet with us and participate in the workshop today. In a short amount of time, all of you did a very good job.

Next step is to use these inputs in program formulation and advocacy efforts starting with the engineering analysis for the national UAV roadmap.
Some of you can expect follow-on contacts to clarify the concepts, etc.

We realize that this wasn't the best time for you to meet with us, but we had to push all of these workshops in between July to August so that the results can be used in FY07 budget formulation.

An interagency workshop will be held August 3-4th at Scripps Institute of Oceanography to develop a collaborative new initiative between NASA, NOAA, DOE. At the workshop, these mission concepts will be briefed.

Throughout this formulation and analysis, we welcome your continued feedback and input. Opportunities for feedback include:

- Informally through templates to Cheryl or Randy at any time
- 2 engineering oriented venues that we will be at in fall AIAA UAV Conference in Chicago in September, and the UAV Conference in New Mexico in early November
- Formal feedback in Jan./Feb., at Suborbital Program Annual Review

If you would like to submit further mission concepts, attached is a blank mission template that you can use. Also attached is participant list that we'd like you to review for its accuracy. Please forward these to Randy at randy.albertson@dfrc.nasa.gov

Cheryl and Randy