Feasibility Analysis 2/14/06

PASE

Title:	Pacific Atmospheric Sulfur Experiment (PASE)
P.I./Institution:	A. Bandy et. al. / Drexel University
Location:	Christmas Island
Period:	1 August – 5 September 2007
Date of feasibility:	2/3/06
Facilities:	C-130

Summary:

This project is a comprehensive study of the chemistry of sulfur in the lower regime of the remote marine troposphere. The experiment will be conducted east of the island of Kiritimati (Christmas Island), which past experiments have shown is an ideal location for such studies. State of the art instruments will be used to make accurate and high speed airborne measurements of sulfur dioxide, dimethyl sulfide, dimethyl sulfoxide, dimethyl sulfone, methane, sulfuric acid, hydroxyl radical, ammonia, water vapor, ozone, hydrogen peroxide, liquid water, temperature, pressure, wind velocity, cloud condensation nuclei, and the size, composition and thermal properties of aerosols. PASE will be performed using the NSF C-130 aircraft with flight profiles conducted in a Lagrangian framework similar to that used in the DYCOMS I & II programs.

Review: Various field support costs and ground support options can change significantly over time. The same can be said for technical innovations in state of the art scientific equipment. A review of this initial feasibility analysis will be conducted in January of 2007 to address any new technical or support issues and to adjust the deployment pool budget, as required.

Resources requested:

C-130: A total of 121 research flight hours are requested to support this program. An additional 10 hours would be needed for preliminary flight testing along with 39 hours of ferry. RAF has also included 8 additional ferry hours to cover one overnight trip to Hawaii, mid-project to facilitate the required crew rotation. Thus, a total of **178 flight hours** will be required. RAF has the needed staff to support the requested project.

Scheduling Requested:

The PIs have requested a field deployment interval extending from **1 August to 5 September 2007.** The targeted research conditions will not allow the project to move to an a earlier deployment date, but the PI's have indicated that a shift of up to one month later in the year could be accommodated if necessary.

C-130 Preparation: The user-supplied instrumentation package is extremely complex and will require an extended integration and flight test period. **Two full months** will be needed for the initial project setup to be followed by a **two week test flight period** before the start of research flight operations. The aircraft must therefore be assigned to the program by 15 May 2007 in order to meet the requested deployment interval. By its very nature, the user-supplied instrumentation package will have to be installed on the aircraft in pre-planned stages. Systems located in the forward cabin will have to go in first and remain onboard as the remainder of the installation progresses. This can be a hardship for users, especially those with systems currently under development, but it is the only way the installation can proceed in any sort of controlled fashion. RAF will work with the PIs to develop a detailed schedule for the integration of the user-supplied systems. Note that RAF does not pre-plan for overtime during the installation period. Except by special arrangement with RAF management, user access to the JeffCo facilities is limited to standard working hours (Mon. – Fri. / 0730 – 1700).

C-130 Conflicts: There are no direct field project conflicts with this proposed time interval. However, there is another request for the C-130 in early 2007. If this earlier project is approved, there may be difficulty in getting the necessary support equipment to the PASE deployment site in time.

Location: The PI's have requested the use of the island of Kiritimati (Christmas Island) as the base of research flight operations. Christmas Island has very limited support for any type of aircraft. Pretty much all of the required ground support equipment will have to be shipped to the site and the RAF will have to make prior arrangements for fuel in the quantities required. Not much information is easily available regarding overall ground support at the proposed airport. Specifically, we have no information on office, storage or lab space that will be needed to support the on-board equipment. A site survey trip will be required to finalize costs and arrangements.
The project is operationally feasible, but the remote location carries several risks:

1) The island is only serviced by one commercial airline flight per week. Access to "emergency" spare parts will be very limited. Maintenance delays or delays due to unexpected scientific hardware issues could be protracted.
2) There is no access to heavy equipment on the island if it became necessary to change out an engine. In addition, the combination of overall payload weight and distance to Hawaii will not allow a three engine ferry in case of a major engine problem. A significant portion of the research payload would have to be removed in the field to allow such a transit, terminating the experiment.

Personnel Needed:

C-130 staffing recommendations: 2 Pilots; 1 Flight Engineer; 3 Mechanics; 3 Technicians; 1 Project Managers / Scientists; 2 Chemistry Technicians; 1 Aerosol Scientist; 1 Software Engineer; 0.5 RDP System Administrator.

The basic request for flight hours (ferry & research) will exceed the long term crew duty limitations of the flight crew. A crew rotation will be required. Due to the remote location and poor commercial airline access to the island, RAF recommends the C-130 and crew ferry to Hawaii mid-project to facilitate this staff exchange. The resources for this activity have been included in the project budget.

Technical and Operational Issues:

A diplomatic clearance will be required to conduct flight operations.

Due to the extended duration of the deployment and the remote nature of the site, RAF has included a mid-project ferry to and overnight stay in Hawaii to perform the recommended crew rotation. The aircraft will have to depart JeffCO on 26 July 2007 in order to make the transit to Christmas Island and have enough time to set up prior to the start of schedule research flight operations.

The PI's have requested research flight durations of 9.3 hours. With such a large payload, RAF's ability to routinely provide flights of this length will depend upon the flight profiles specific to each mission. Extensive operations in the boundary layer use more fuel. There may be some flights when the duration is reduced. At no time should the duration drop below 8.5 hours, however.

The request asks for night time flight operations. While the airport normally closes at night, RAF has received assurances from the local authorities that such operations will be approved.

The project calls for low altitude flight legs. The normal RAF policy regarding these types of flight operations will apply: VFR conditions and over ocean water - 100 ft AGL minimum altitude during daylight hours and 500 ft AGL minimum altitude during nighttime hours; VFR or IFR conditions over any land mass, populated or unpopulated areas- 1000 ft minimum altitude day or night. As always, all specific low altitude operations remain at the discretion of the pilot in command.

A large contingent of support equipment will have to be shipped to the site. This includes several major components such as the RAF ground power cart (GPU), spare tires, air conditioner cart, and heavy maintenance work stands.

The PIs are advised that all EOL crew duty limitations will apply and may affect

the scheduling of back-to-back flights on consecutive days or switching between daytime and nighttime flight operations. Due to the heavy flight load and the need for extensive ground support of the user-supplied systems on non-flight days, extra staff will be required in the field to ensure adequate support of the project. For details on crew duty access the Technical Bulletin #6 on the RAF web site (www.eol.ucar.edu/raf/Bulletins/).

EOL does not provide any weather forecasting products or personnel to aid in monitoring local weather conditions or guiding the research. These activities will be the sole responsibility of the PI and the primary research team.

Instrumentation:

The standard RAF instrumentation can be provided without difficulty but there are some issues with certain of the special request RAF sensors that are noted below.

RAF Instrumentation:

Measurement of turbulent water vapor fluxes will be an important aspect of PASE. Currently the EOL does not provide such a capability as a consequence of the inability to acquire spare lyman-alpha lamps. However, this is an area of active development at the RAF with test flights of the next-generation fast response humidity system being planned for early 2006. The RAF is also actively pursuing several other means of high-rate water vapor measurement. It is our expectation that the ability to measure turbulent water vapor fluxes will be available in time to support PASE flight operations.

One of the adjunct investigators has requested access to the RAF Low Turbulence Aerosol Inlet (LTI) on this project. This unit is not currently being supported by the RAF. In place of the LTI, this investigator has indicated that they can use one of the RAF solid diffuser inlets (SDI's). However, this change would impact their science by limiting the passage of very large particles (> 3 um) through the inlet system.

The PIs have requested the RAF high and low rate ozone (O3) analyzers. The RAF can provide these systems, and support them in the field. A dedicated operator will be required on every research flight. Additionally, a RAF scientist must be added to the general support staff for system integration, pre-flight and post-flight preparation and data analysis. Note that the fast ozone system requires regular access to a source of dry ice. With the limited commercial access to the island, it is not clear how this requirement will be met.

The PIs have requested high rate wind data in support of their research. It has recently been determined that the high rate wind gust measurements collected by the C-130 radome gust probe in a turbulent boundary layer do not conform to established theory. Specifically, the ratios between the transverse spectra and the

longitudinal spectrum do not take the expected value of 4/3 in the inertial sub-range. There appears to be some damping of the pressure fluctuations in the plumbing to the attack and sideslip differential pressure ports at higher frequencies. The RAF, in conjunction with NCAR and university scientists, is investigating possible means of correcting this situation (see the RAF web site – raf.atd.ucar.edu for a link to up to date status reports on the progress of this effort). It is unclear whether or not this issue can be resolved in time for this project. In the mean time, the performance of the radome gust probe is very consistent and well characterized. Mean wind field data are unaffected by this problem.

User Supplied Instrumentation:
Physically the RAF can accommodate the list of first priority User instrumentation. However, the stated power load (110 VAC / 60 Hz) from this payload is too large for the C-130 to handle. RAF is working with the PI to confirm the needs of the individual sensors and to see if any of the systems can be shifted to an alternate power source (110 VAC / 400 Hz). None of the systems in the secondary priority list can be accommodated in the projected payload layout: Georgia Tech AMS and the Univ. of Hawaii PC-BOSS. RAF will work with the PI to have a fully supportable payload defined by the OFAP meeting.

The external wing stores proposed by the University of Hawaii duplicate measurements already requested from RAF instrumentation and could be removed to alleviate some of the overall payload issues. Specifically: DMT Cloud Droplet Probe and the Gerber Cloud Droplet Probe. Also, the data from the User systems cannot be recorded on the RAF Airborne Data System (ADS). Using the RAF instrumentation will free up rack space and place the resulting data directly into the RAF data files for broader access.

All user-supplied equipment will have to be examined for compliance with RAF safety policy on suitable materials and the structural integrity of user-supplied mounting racks. The RAF will work directly with the users in the design and fabrication of the interface hardware needed to mount their equipment in the C-130.

Chemically clean inlet ports on the C-130 are at a premium. The top of the aircraft is considered to be unsuitable due to turbulence and flow shadowing caused by the normal “pitch – up” attitude of the aircraft during flight. Side apertures aft of the propeller line are susceptible to contamination from the engine exhausts. That leaves the side apertures in the forward cabin and the full length of the aircraft belly. Both have been proven to be chemically clean. However, most of the proposed chemical measurements are to be made on reactive species. This requires special inlets and a close proximity between the inlet and the analyzer. Due to the limited number of the apertures in these locations and their relative positions along the airframe, it is clear that some

compromises on sampling line lengths will have to be made by some of the users. It should be noted that RAF has only a basic set of simple "goose neck" curved inlets available for use from a belly location and access to, or sample tube routing paths from, the belly apertures are quite limited. Users requiring special inlet systems will be responsible for providing their own hardware. Those users so affected should contact the RAF aeronautical engineer for design help and for final approval.

Many of the user systems will require the presence of hazardous materials either onboard the aircraft or for the preparation and ground support of their instruments. **Full disclosure of any changes to the list of hazardous materials submitted with the original request form must be made to the RAF and the NCAR Safety Office and must be approved in advance.** A full set of MSDS documentation must be provided to the RAF. Users will then be briefed on the required safety practices onboard the aircraft and within the support labs. Containment boxes with overboard venting will be required for any hazardous compressed gases. Any such materials brought to the RAF facility or the field deployment site must be disposed of by the users prior to their departure from these sites at the end of the field program.

As part of its in-house support infrastructure RAF has cylinder racks that are located in the aft bunk areas on both sides of the C-130. Each rack can hold up to six cylinders with diameters ranging from 7 – 9 inches and does not use up any cabin floor space. Most of the user-supplied cylinders will have to be mounted in this fashion. The proposed floor plan leaves little room to accommodate alternate cylinder mounting options.

The power needs of the user-supplied payload are roughly 65% of the total research power available on the aircraft. RAF requires approximately 2 KVA for our systems with the remaining buffer needed to handle pumps that will have even higher start up surges. A particular start up sequence for user-supplied equipment may have to be imposed to keep the power requirements within the specified limits. RAF will work with the users to try an alleviate some of this problem.

One or more user groups have asked for a real time feed of certain RAF parameters. RAF outputs a serial ASCII data feed available to all onboard users. This system provides the means for integrating the various user-recorded data sets during the post flight analysis processes and serves as the list of variables that are included in the real time data feed to the ground. There is currently a maximum limit of 22 variables, plus time, associated with this data feed.

Each user is responsible for obtaining all of their own expendables, specifically liquid N2, butanol and dry ice. Given the complexity of the cabin layout, only a small supply of these materials can be transported on the C-130 out of JeffCo or

on the research missions. RAF recommends that prior arrangements be made for access to these materials at the deployment site.

In the past RAF has found that many users fail to include laptop computers in their descriptions of the equipment to be used onboard the aircraft. Research operations are not like commercial flights and are often quite turbulent. RAF will require all laptop computers to be secured to some piece of support structure, most likely a standard rack. Roll out trays work very well and minimize the amount of rack space required. The top of a rack is also suitable for this purpose.

Communications Issues:
EOL will provide a small local area network (LAN) suitable for linking EOL ground station computers and user systems intended for sharing preliminary data. A secure exposed host will be included in the LAN to provide basic Internet access for email and general communications. RAF has included a remote satellite uplink station in its planning to provide this access to the outside world. This link may or may not be capable of large data file transmissions, depending on the performance of a system suitable for use from such a remote location.

Real-Time Data Requirements: The communication of data to and from the aircraft and of chat messages will be done using satellite communication. Experience shows these systems to be prone to occasional and sometimes lengthy drop-outs. These systems will not function with 100% up-time. The PIs have not specified a need for this type of service.

DFS Services:
The research payload is extensive with many systems that have not previously flown on the C-130. Extensive assistance from DFS will be required to fabricate interface hardware.

Logistical Issues:
The PASE campaign will require a substantial amount of logistical effort. Diplomatic clearance and Visas are required**.** Available housing and work space will be limited.

Shipping: There are significant issues related to shipping equipment to Kiritimati. The poor commercial access (one flight per week) to the island means that all science and operational support equipment will have to be shipped out well in advance of the flight test period. Due to the large instrumentation payload expected for this project, no space on the C-130 will be available for carrying user spares or other support equipment to the deployment site.

Aircraft Safety:
Most of the scheduled flight operations will take place over the tropical Pacific

Ocean. The C-130 is fully equipped with the gear necessary for water survival. Due to the warm water temperatures in the targeted area, immersion suits will not be required. All onboard observers must undergo a full RAF safety briefing prior to their participation in any C-130 flights. Training with key systems and the identification of all survival gear will be covered in this briefing.

Both RAF and user-supplied chemistry measurements require the use of compressed gases, some of them fall into the hazardous materials category (NO, etc). All compressed gas cylinders carried on the aircraft must be current on their DOT certification. Any hazardous materials must include a suitable containment vessel attached to the cylinder and vented in such a way that an accidental leak cannot contaminate the cabin area. Emergency monitors must be included in the instrumentation package that can alert onboard personnel to any elevation in cabin concentration levels. MSDS sheets will be required on any hazardous materials included in the user-supplied instrumentation. **Maintenance to or modification of these containment systems or the plumbing associated with the hazardous gases while the aircraft is in flight is strictly prohibited.**

The requested instrumentation package contains one or more systems that require the use of dry ice and Butanol, a flammable liquid whose vapors can be a respiratory irritant. The exhausts from all such systems must be vented overboard. Special handling will be required during the servicing of the instruments and any stored quantities must be sealed in an airtight container.

Due to flight safety considerations, system operators will not be allowed to maintain station at systems with no operator seat while the aircraft is in flight. Short periodic checks are approved.

Data Processing Requirements:

Data processing and basic quality assurance reviews will be conducted in the field using an RAF computer ground station shipped to the base of operations. This system is fully capable of providing "quick look" data to the PIs within a few hours of each flight. Data will be provided in the standard RAF netCDF data format which is MATLAB compatible. RDP has been asked to supply a local server to link RAF to the internet for basic email support and potentially to user computers for data transfer. The RAF is not aware of any plans for an overall project operations center at this time. Close coordination will be required to incorporate the RAF "data center" within the computer support structure for the project.

Final data processing and distribution of the data will take place from JeffCo three to six months after the deployment is complete. Archived data, suitable for formal distribution, are only provided in the final data products which have under gone post project calibration and QA data review. Data from the state parameters will be sampled at 25 or 250 sps, as appropriate, to provide good resolution of the various atmospheric structures and a data set suitable for use in flux calculations. Due to the many and varied ways of making flux calculations, no such products will be included by RAF in the official data set. This activity is considered to be scientific analysis and will be left up to the individual users. The final data products will be output in two formats: at the standard (LRT) rate of 1 sps and as high rate data (HRT) with an output rate of 25 sps. The PMS probes will be set to their maximum recording speeds (10 sps for PMS 1-D).

Development Impacts:

HIAPER: Based on the current schedule of projected G-5 upgrades, there should be no conflicts with the current request.

Conclusion:

There are logistical challenges associated with this project and more information on local services needs to be obtained. Noting the possible operational risks associated with this remote location, and with the inclusion of the mandatory mid-project crew rotation noted in the Personnel section of this review the project is supportable.