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MODIFICATIONS OF AIRBORNE OCEANOGRAPHIC LIDAR FOR THE LONG RANGE P-3 MISSIONS

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This has been an extraordinary series of Airborne Oceanographic Lidar (AOL) missions. The AOL was flown over the North Pole on three low altitude sea ice mapping flights. These flights were followed by six Joint Global Ocean Flux Study (JGOFS) flights based from Hawaii and Christmas Island to measure chlorophyll along the equator. On return to the west coast, there were several terrain mapping flights in Nevada and Arizona. This was followed by mapping of the Greenland ice cap from the airport at Sondresstrom Greenland.

This research proposal was developed to support the AOL instrumentation research that prepares the AOL for each science mission. Saint Vincent College physics professor, Dr. Richard Berry, is engaged in LIDAR instrumentation research to improve the AOL. Dr. Berry's participation in the AOL mission was to implement the instrumentation modifications that optimized data acquisition.

LIDAR is a relatively new field of remote data acquisition. The components of LIDAR are: a laser, a telescope with optical instruments and a computer controlled data system. The laser is usually pulsed and brightly illuminates a distant target for about five nanoseconds. Light from the illuminated target is detected with a telescope equipped with optical instruments. The system computer controls the experiment and records data. NASA has a great deal of interest in the development of LIDAR applications for satellite observations of the earth. Each LIDAR application requires a unique configuration of instruments to measure a specific type of science data. This AOL was originally conceived as a flexible oceanographic research tool that could operate from an aircraft rather than a research ship. The science objectives of the original NASA design team were bathymetry and spectroscopy.

Mr. William Krabill is the principal scientist for a series of ice cap and glacier studies using the bathymetry configuration of the AOL. Bathymetry is a term for water depth measurement and is usually done from ships. Optical measurements of water depth using LIDAR take advantage of several laser properties. Lasers can illuminate both the entry point on the water surface and the bottom in shallow water. The pulsed nature of LIDAR is used to measure the time interval between surface reflections and bottom reflections. The depth is calculated from this time interval. With appropriate modifications the bathymetric configuration can be adapted to map terrain elevation, sea ice and the arctic ice cap.

Global warming trends have generated an international effort to determine the rate of melting of the polar ice caps. The accuracy desired for ice surface mapping was higher than the accuracy specified for ocean bathymetry. Dr. Berry worked on improving measurements of the scanning geometry and on developing range calibration procedures to improve accuracy for sea ice and ice cap measurements. Preliminary results of two ice mapping missions are confirming that the required accuracy has been achieved.

Dr. Frank Hoge was on the original AOL design team and has developed many science applications of the spectroscopy configuration. Laser stimulated spectroscopy is a widely accepted laboratory tool because lasers produce many kinds of energy changes in the sample material. An aircraft overflying bays, rivers, coastal regions and open ocean has access to all of the water conditions of interest. Operating an AOL to map the biologically significant components of the water is a very efficient way to collect the data needed to predict the fertility of various regions of the ocean. Fluorescence spectra and Raman scattering have proven very useful in the study of ocean composition. Laboratory measurements of ocean water samples have identified the laser induced fluorescence of naturally occurring substances as well as contaminants. The AOL has acquired an international reputation for the quality of the airborne measurements of chlorophyll concentrations. Intense interest in preserving the ocean food chain and understanding the factors that control chlorophyll concentrations have stimulated international missions such as JAGOFS. The NASA P3-B aircraft has a 4000 mile range which allow for long flight lines to cover a much greater ocean surface area. Surface vessel laboratory measurements confirm the quantitative accuracy of the AOL chlorophyll data. Airborne chlorophyll measurements have received widespread international acceptance.

The modifications necessary to change the configuration of the AOL from bathymetry mode into spectroscopy mode involve changing lasers, mirrors and instrumentation. The science missions and some of the specific modifications occurred in the following sequence.

The 1992 Arctic Ice Deployment required the increased range of the P3-B. The first installation of the AOL on any aircraft is very time consuming. Because of the additional complexity of installing the scanning mirror, this mission was flown with stationary mirrors in the non-scanning configuration. The mission plan included cooperative missions with U.S. Navy's ICEX-92, underflights of ERS-1 European Earth Resources Satellite, and the Danish Hans Tausen ice-core drilling site in Greenland. The instrumentation changes included the first use of a commercial TRF diode-pumped laser. The optical contrast between open water and ice required a large dynamic response range from the receiver. The photomultiplier tube detector and the pulse amplifiers were configured to accommodate as wide a range of signal strength as possible. Timing thresholds of the electronics are affected by variations in signal strength necessitating a range calibration procedure. These procedures were developed and used before and after each flight.

The next research flight was a chlorophyll fluorescence flight to demonstrate that the AOL spectrometer had sufficient sensitivity to measure low chlorophyll levels typical of the south Pacific. This mission was also to develop the MODIS algorithm using data from overflights of the TAMBEX II's cruise in the Gulf of Mexico. There was a great deal of interest in confirming the performance of the AOL with very low chlorophyll concentrations before departing for participation in Pacific JGOFS. The AOL lasers were changed and the instrumentation was prepared for laser induced fluorescence measurements.

The Joint Global Ocean Flux Study (JGOFS) steering committee developed plans for the Equatorial Pacific Experiment (EqPac). This project required the maximum range of the P-3B and the highest power laser configurations. Dr. Berry participated in the modifications to the AOL instrumentation to prepare for the flight and was invited to accompany the mission. In order to more efficiently power dual lasers on this flight, the DCR 10 laser power supplies were modified to work directly from the 400 Hz aircraft power. The AOL recorded chlorophyll data from the California coast line to Hawaii. The AOL recorded data on many equatorial flight lines south of Hawaii for the EqPac experiment.

Upon return to California, the AOL was converted to the bathymetry mode for terrain mapping projects in Nevada and Arizona. This combined mission began 8-17-92 and was completed 9-18-92.

The most challenging experiment was the June 22,1993 mission to make additional ice cap measurements over several interesting regions in Greenland. The maximum elevation error from all sources was specified as eleven centimeters. The aircraft position was to be measured to the accuracy limit of the new global positioning system. Preparations for this flight were extensive. The attitude of the aircraft must be known to accurately predict the illuminated spot on the ice cap. Scan geometry angles became a significant issue following the 1992 mission. Much of the research effort of the past year has been devoted to improving techniques of measuring the scan angles and verifying the stability of the scanning system. Calibration flight legs over water and over surveyed runways was used to confirm the scan geometry. For the 1993 mission, improved and redundant measurements were made on the scanning geometry. Scan ellipticity was predicted by computer simulation and compared to observations. Portable measuring systems and procedures for improved post flight calibration were developed and used during the 1993 mission to Greenland. Data from these flights is being analyzed and satisfactory elevation errors were achieved. At the present time, this experiment is at the limit of resolution and performance of the AOL.

The budgeted funding for this proposal was exhausted during the June 22,1993 to July 11,1993 Greenland mission. Saint Vincent College and Dr. Richard Berry appreciate the opportunity to participate in NASA research and thank the many persons who make this association possible.