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Work: 797-4271

Wednesday, June 26, 2004

Paul Israelsen
Department of Electrical Engineering
Utah State University

Dr. Israelsen,

Included is my proposal for my senior project, which consists mainly of software coding for analysis of ionoshperic data. I will be working alone on this project, and plan to have it done in August. The Space Dynamics Laboratory will be sponsoring this project. If you need to contact the Space Dynamics Laboratory in regard to this project, please contact Pat Patterson, who is my supervisor. He can be reached at 797-4112 or at pat.patterson@sdl.usu.edu.
I am open to any suggestions you may have to improve the project, and I will keep in contact with you about its status. I hope to hear from you soon about the approval of this proposal.

Thank you.

Keith Melville

Senior Project Proposal for

ATOX Data Analysis

ECE 4840 Design II

June 26, 2002

Keith Melville

Instructor Approval ______________________________ ______________

Kevin Moore Date

Electrical and Computer Engineering Department

Utah State University

Sponsor Approval ______________________________ ______________

Pat Patterson Date

Space Dynamics Laboratory

Background Information

The Coupling of Dynamics and Aurora (CODA) program is the latest in a series of NASA sponsored experiments designed to study the response of the atmosphere to auroral forcing. Strong turbulence arising in the lower E region from auroral forcing has only recently been discovered, and its magnitude and distribution remain unknown. Current models and empirical data disagree on the magnitude and scale of variation in vertical turbulence velocities.

The CODA experiment was launched from Poker Flat Research Range in Fairbanks, Alaska, in February of 2002 with the purpose of studying the effects on the wind structures associated with a diffuse aurora. The Atomic Oxygen (ATOX) sensor system on board was designed to provide diagnostics of neutral turbulence and vertical mixing of atomic oxygen in the D and lower E regions (altitudes between 80 and 130 km). The sensor is made up of two critical components: UV lamps and photometer detectors. The UV lamps provide the energy to activate the atomic oxygen, and the photometers allow for determination of the density in the activated region.

The photometers make both a resonance-fluorescence and a differential absorption measurement. Two boom-mounted photometers are deployed to measure the 130.4-nm absorption over 0.50 and 0.33 meter path lengths. This differential technique eliminates the effects of vehicle shock and off gassing. At the same time, the resonance fluorescence from each scattering volume is measured by redundant, on-board 130.4 nm photometers. The lamps were modulated at 125 Hz to provide a measurement of the background and absorption/fluorescence signals from which the atomic oxygen density is derived.

Identified Need

Data from the CODA flight has been collected, and needs to be reduced and analyzed. In its current state, the data is very difficult, if not impossible, to interpret. To become valuable, the data must be reduced and presented in a way that allows the scientific community to understand the results.

Problem Definition

Because the results of the data are unknown, it is impossible to say exactly what pieces of data are the most relevant, and to what extent and in what fashion the data needs to be reduced. As the data is reduced, certain data may prove to reveal more pertinent information than other data. For this reason, the final format of the reduced data cannot be determined beforehand. Pat Patterson of the Space Dynamics Laboratory and Dr. Charles Swenson of Utah State University’s Electrical and Computer Engineering Department will be overseeing the data reduction. Below is a description of the required data reduction, given by Pat Patterson:

Data coming from the launch of the CODA mission in February of 2002 has been collected and is awaiting analysis. Data from four on-board sensors are of particular interest to SDL & USU scientists – the sensors include the Atomic Oxygen Sensor (ATOX), 2 plasma frequency probes (PFP), and a DC probe (DCP). The data currently resides in a raw state in a PCM telemetry file. Roughly 70 payload sensor and housekeeping sensor data streams are located in the telemetry file.

One of the largest issues associated with the reduction of the data will be to pull this raw data from the files and calibrate it so that scientists can make sense of it. To do this, each stream of data must be calibrated, and fitted to NASA flight GPS data that allows researchers to determine the exact location (longitude, latitude, and altitude) under which each measurement was made.

Another major issue with the raw data is that the rocket is stabilized during flight by a slow spin about its major axis. This inputs a large modulation into the data stream that must be filtered out without affecting the actual data. The data must also be calibrated and normalized so that data streams from each of the photometers can be compared.

It is expected that many different software routines will need to be developed and implemented in a user-friendly fashion to complete this data extraction and analysis. It is expected that NASA will utilize this PCM telemetry format for the next several flights in which USU & SDL will be participating, therefore it is extremely important that the software and routines be developed in a way that makes them easily usable on follow-on programs. This will include the writing of a reference manual and/or users guide that familiarizes the scientist with the methodology for the data reduction.

Objectives and Scope

The following is a list of objectives I propose to achieve in order to reduce and analyze the telemetry data into an understandable form:

1) Extraction of Raw PCM Telemetry Data

The data collected from NASA is currently in a PCM telemetry file. To be useful, the data must be extracted for import into the data analysis software.

2) Polynomial Fit for GPS Data and Error Plots

The data taken is connected directly to the flight time, but to be valuable, the data needs to correspond to altitude, latitude, and longitude. It is desired to produce a polynomial curve fit for these three parameters as a function of flight time.

3) Filter Out Rocket Spin Modulation to Reveal Ionospheric Data

Since the CODA rocket was stabilized with a spin of about one rotation per second, this inputs a 1 Hz modulation into many of the data streams. This 1 Hz modulation must be removed in order to get a clear picture of the actual measured data.

4) Data Channelization

Because the lamps are oscillated at 125 Hz, there is a transient curve to the UV output as the current to each lamp is turned on and off. Each sample taken of the photometer output should correspond to this transient curve, and therefore each successive sample from the photometer output cannot be compared directly to the previous or the next sample. The photometer output should be treated as a time division multiplexed signal, where the input for each signal comes from a *constant* UV output. The photometer output needs to be split up into channels which contain readings of a constant UV output.

5) Data Calibration

The data will be calibrated with a differential technique. Two lamps excited two regions of atomic oxygen on opposite sides of the rocket. Since the two lamps may have put out different intensities of UV, the lamp output must first be compared. The resonance-fluorescent photometers for each lamp are the same distance from their respective sample volumes, and since we can assume that the density of each is the same, the output of these photometers can be used to determine the variation in output between the two lamps.

Knowing the relative variations in output of the two lamps then allows us to normalize and compare the output of the absorption photometers. One absorption photometer boom was 0.50 meters long, and the other 0.33 meters long. The output of these absorption photometers, once normalized, allows us to make a differential measurement of the density of atomic oxygen.

Deliverables

This project will result in four distinct deliverables:

- Data Reduction Tree
- Software Code
- Reference Manual
- Data Book

Since the raw telemetry data needs to remain intact for possible future analysis, the data reduction process will be shown in a tree format, called the **Data Reduction Tree**. Each node in the tree will represent the data in a certain reduced form. With the Data Reduction Tree, the process of data reduction will be described, so that in the future, the raw telemetry data can easily be reduced again in the same fashion, or other reduction processes could be employed branching off of the existing Data Reduction Tree.

Fully functional **Software Code** that implements the Data Reduction Tree will be provided. The Software Code will be written and commented such that someone unfamiliar with the data reduction process can understand and modify it as needed.

Each function and procedure of the Software Code provided for data reduction will be documented and described in a **Reference Manual**. This will be done so that future users of the system will understand how to reduce the data according to the data reduction tree, or in other ways allowed by the functions.

For quick reference to the reduced data at any point on the data reduction tree, a **Data Book** will be provided, which will include graphs and plots of the data in its reduced form. Plots of the data at each node in the Data Reduction Tree will be provided.

Tasks

1 - Data Extraction
- 1.1 - Determine Data Extraction Process
- 1.2 - Extract Required Data Streams

2 - GPS Data Curve Fitting
- 2.1 - Find Polynomial Fits for GPS Data
- 2.2 - Produce Error Plots for Position Curve Fits

3 - Data Reduction Tree
- 3.1 - Draw Data Reduction Tree
- 3.2 - Describe Each Node in Data Reduction Tree
- 3.3 – Revise Data Reduction Tree

4 - Data Reduction
- 4.1 - Write Function to Highpass Filter
  - 4.1.1 - Design Highpass Filtering Scheme
- 4.2 - Channelize the Data
  - 4.2.1 Determine Channel Offsets from Beginning of Data Stream
- 4.3 - Data Calibration
  - 4.3.1 - Determine Variance in Lamp Output
  - 4.3.2 - Normalize Absorption Photometer Output per Lamp Variance
  - 4.3.3 - Make Differential Data Stream Between Two Absorption Photometers

5 - Reference Manual
- 5.1 – Clarify Software Code with Additional Comment
- 5.2 - Write Descriptions and Document each Software Function

6 - Compile Data Book
- 6.1 - Produce Plots of Reduced Data
- 6.2 - Write Description of Each Data Plot

Engineering Approach

The required data reduction includes channelization, filtering, and calibration. In order to obtain offsets for channelization, and the channelized signal, there will be user interaction required, because the exact time that certain data streams begin is unclear, or a user may want to see the data in some new way. A function to strip out a TDM stream will show the original data in the TDM stream, and allow the user to select a sample which is a member of the desired stream, and the sample interval of the TDM stream (i.e, the number of streams contained in the TDM stream). Selected offsets should be optionally saved, so that various offset configurations can be quickly used for channelization.

Data filtering will be done in the frequency domain. The data will be taken in small segments, transformed into the frequency domain via the FFT, where the designed filter will be applied. The filtered frequency data will then be transformed back into the time domain.

The filtered data will be calibrated so that each data stream can be compared. Using the data from the resonance-fluorescent photometers (also called the calibration photometers) the data from the absorption photometers will be adjusted to show the output for equal UV output from both lamps. The adjusted output of the absorption photometers will be compared by subtracting the output of the short-boom photometer from the output of the long-boom photometer.

After the software code is complete and well commented, I will write a description of each function stating what it does, and describing input and output parameters. I will compile these descriptions along with hard copies of the Software Code into the Reference Manual. I will also plot the reduced data at each point in the data reduction tree, and write a text description of each plot. I will include full, zoomed-out views and close-up, zoomed in views of interesting points. I will compile the plots and descriptions on a word file to produce the Data Book.

Alternate Approaches

Assuming that the TDM data consists of an oscillating input, like the one we have in this system, a way of automatically detecting the channels might be employed. Using the frequency of the oscilating system, we could determine the number of channels per oscillating cycle, determine where the peaks are in that cycle, and then channelize accordingly. The downfall of this type of system is that, along with being more difficult to implement, the data format of future systems will not necessarily conform to the assumptions made in order to implement the system.

An alternative for data filtering would be to selectively sample the data stream output at the peaks. The peaks should occur once every second, and such a sample would give a general idea of the shape of the output. The disadvantage to this filtering method is that the sampling rate effective is reduced to 1 Hz, and

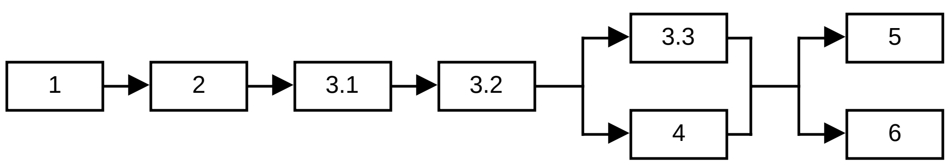
999 out of 1000 sample points would be discarded. Another associated problem is in ensuring that the sample selected of the 1000 available is truly representative of the atomic oxygen density.

Project Management

I will be working on this project alone, but I have the background and skills necessary to complete the project. I have experience with signal processing, which will play a major role in the data analysis and reduction. I will need to implement software functions to transform the data into the frequency domain, apply digital filtering, transform back into the time domain, and other procedures associated with signal processing. I have experience with programming which will be required to write software routines. It is expected that the software routines will be implemented with Matlab, which is a package that I have programmed for in the past. For more details on my back round and skill, see the attached resume.

Pert Chart

The following pert chart shows which tasks must be done in order to begin others. (Refer to the Tasks section for a description of task numbers.) All of task one must be done before task 2 can begin. When task 2 is done task 3 can begin. Once task 3.2 of task 3 is done task 4 can be started, and task 3 and 4 should end simultaneously. At that point both tasks 5 and 6 can be done. Each of tasks 3, 4, 5 and 6 produce one of the deliverables.



Gantt Chart

This Gantt chart shows each task, and the assumed amount of time each will take. Each cell represents working on a particular task for 12 hours. Since I will be working about 24 hours a week on this project, every two cells are about a week's worth of work, so each column is named after a week number and either A, for the first part of the week, or B for the last half of the week. Each task has been given at least 12 hours, but some of these may take less than 12 hours, so this Gantt chart is a worst-case scenario. The amount of time to complete the project will be at most 9.5 weeks (204 hours). If we assume a starting date of June 26, 2002 for this project, it will be done by Aug 23, 2002.

Task\Week	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A
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Budget

The main expense the Space Dynamics Laboratory will incur to bring this project to completion is my pay, which for 204 hours of work, is $2091. The Space Dynamics Laboratory already has the equipment necessary to complete the project, which mainly consists of a workstation and Matlab. Up to about $100 may be necessary for the material required to produce all of the documentation and data books, either in hard copy format, or on CD-ROM. The maximum required expenditure for this project is $2191.

Conclusion

In summary, the data collected from the February 2002 CODA flight is currently in a format that is very difficult to interpret. The data needs to be reduced in order to be analyzed further. Further analysis of the data will help build a model on the magnitude and scale of variation in vertical turbulence velocities in the ionosphere.

I will be willing to modify my proposal for objectives and approach in reducing the data taken on the CODA flight if necessary, but my basic approach consists of the following:

To reduce the data, I will extract the raw PCM telemetry data for importing into a software package. I will make polynomial fits for the GPS data, so that the rest of the data can be referenced to location rather than mission time. I will separate the various data channels by creating a function that separates a TDM signal into distinct data streams. I will filter the data by transforming it into the frequency domain and applying a highpass filter to eliminate the effects of rocket stabilization. I will calibrate the absorption photometer data with the data from the calibration photometers, so that those data streams can be compared, and a clearer picture of neutral turbulence and vertical mixing of atomic oxygen in the D and lower E regions can be obtained.

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EDUCATION

Candidate for BS/MS Electrical Engineering, Expected December 2003
Utah State University, Logan, Utah
- 3.85 GPA, University Honor Roll

Bachelor of Music, Composition, May 2000
University of Utah, Salt Lake City, Utah
- 3.42 GPA

PROFESSIONAL SKILLS AND EXPERIENCE

Signal Processing
- Experience designing digital FIR and IIR filters and analog filter s
- Able to design and analyze discrete and continuous time systems
- Experience with sampling theory, DFT, and Z transforms
- Able to design and analyze hardware realizations of transfer functions

Programming
- 2 years experience with C/C++ using Visual C++ and Codewarrior
- 50 hours working with Matlab and Simulink
- Experience with SQL, TCL, HTML, Java, and JavaScript
- Experience with assembly level programming (Intel 80x86)
- Familiar with UNIX, Windows, and Macintosh platforms

Digital System Design
- Design team leader for RISC processor in Verilog and for PAL device design
- Able to test and debug hardware

RELEVANT WORK EXPERIENCE

Web Programmer, November 2000 - Present
Space Dynamics Laboratory, Logan, Utah
- Develop Internet and Intranet sites using SQL, TCL, HTML, Java, and JavaScript
- Build code libraries to decrease development time and improve code readability

Teaching Assistant, ECE 3260 Science of Sound, Aug 2000 - Dec 2001
Utah State University, Logan, Utah
- Substitute taught class in physical, psychological, and electronic acoustics
- Tutored students individually and in groups on course material

LEADERSHIP AND VOLUNTEER EXPERIENCE

Church Volunteer Service, Kyushu, Japan, 1994 - 1996
- Held leadership positions; supervised other volunteers
- Translated meetings into Japanese for Japanese volunteers