NITEOWL Proposal

Part Two

1. Mission Overview

TBD - JEG

2. Top Level Science Requirements

The NITEOWL project will use starlight to obtain images from which column ozone densities between the imaging spectrophotometer and the stars observed can be determined to within 5%. The vertical ozone distribution will then be determined within 5% with a vertical resolution of 1 km and a geographic resolution of 200 km.

More to say? TBD - JAS

3. Instrument

3.1 Imaging Spectrograph

The imaging spectrograph or imaging spectrophotometer (ISP) consists of 3 main optical elements. The first of these is a diffraction grating which is described in section 3.1.2. The collimated light from all of the stars in the field of view of the instrument is dispersed by the diffraction grating onto the second of the major optical elements, the objective lens. This lens is the element which places the most stringent constraint on the aperture diameter of the system (see section 3.1.3). The objective lens will focus the incident light from the grating onto a fiber optic taper. A description of the third optical element, the fiber optic taper, which will minify the image produced by the objective lens is given in section 3.1.4.

There are two other important parts to the ISP, the environment surrounding the optical elements which includes the entrance window, and all baffling and stops used to minimize contributions due to stray light, and the CCD detector which collects the intensity spectra produced by each star. These two portions of the instrument are explained in sections 3.1.1 and 3.1.5.

3.1.5 CCD

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3.1.1 Window and Entrance Baffling

The opening allowing light into the ISP will be a simple opening in the ôskinö of the payload which will be covered during take off. The cover will be ejected at or slightly after the payload achieves apogee. The opening will be as small as possible to acieve the necessary field of view given the position of the diffraction grating and objective lens. Between the window and the diffraction grating a series of knife edge baffles will be inserted in order to reject light outside the field of view and to decrease the amount of light reflected onto the grating from within the instrument. Finally, between the lens and the fiber optic taper a stop will be inserted in order to eliminate any reflections from the sides of the instrument before they contaminate the image at the fiber optic taper.

3.1.2 Transmission Grating

A transmission grating with a ruled area of x and a ruling frequency of y will be used to disperse the incident starlight. This results in a resolving power of z. Therefore, features of b nm or larger can be resolved over the entire frequency range of interest. The trasmission grating will allow a total of 80% of the incident radiation to pass through. By blazing the grating at c the amount of light in the first order maximum at 570 nm will be maximized with as much as d% of the trasmitted light appearing at this point in the spectrum. The incoming light is assumed to collimated, thus the spectrum from each star will be dispersed over the entire aperture of the lens.

3.1.3 Objective Lens

TBD - MH

3.1.4 Fiber Optic Coupling

A fiber optic taper is necessary in order to take the image produced by the objective lens and make it a size suitable for readout by the CCD detector. The transmission of the fiber optic taper given a length of x cm and a minification factor of y will be z. The image produced by the objective lens will be too large to fit on the CCD due to the low ª/# and large aperture required to attain a transmission high enough to achieve the desired SNR. While the minification process will degrade the SNR the advantages of having a large aperture and low ª/# were considered to outweight the disadvantages introduced by the taper.

3.1.5 CCD Detector

Light collected by the optics will be focussed onto a charge-coupled device (CCD) so that the spectral images captured by the CCD can be used to determine properties of ozone above the earth. To adequately accomplish this task the characteristics of the CCD must be known.

The CCD imager will have the nominal specifications shown in Table 3.1.5.

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Table 3.1.5: Nominal specifications for the CCD imager.

Characteristic	*Specification*
Pixel Array	1024 x 1024
Visible Array	512 x 1024
Pixel Size	24 um x 24 um
Potential Well Depth	300,000 electrons
Quantum Efficiency	55% - 85%
Wavelength Sensitivity	400 nm - 900 nm
Imaging Size	24.6 mm x 24.6 mm
Resolution	12 bits/pixel
Frame Transfer Rate	4 frames/sec
Exposure Time	1/30 sec to 5 min

Science-Tech, a Canadian company, can provide an intensified CCD (ICCD) for $28,000 (Can). K-Space Associates Ltd. can supply a CCD for $3,500 (US). Scientific Imaging Technologies, Inc. can also provide a large area CCD.

3.2 Video Camera for Attitude Determination

A video camera is needed so that the viewing direction of the instrument can be determined. The video camera will be set at a known angle with respect to the spectroscopy optics. Star images that the camera produces will be correlated with a star database so that the viewing direction of the spectrographic equipment can be computed.

The estimated cost for the video hardware is $8,000 (US). Possible suppliers are Hamamatsu, Panasonic, and Xybion.

3.3 Avionics

3.3.1 Global Positioning System

A Global Positioning System (GPS) device is required to track the position of the instrument as it goes up and as it comes down. The position of the payload must be known for two reasons: 1) so that a measurement taken by the instrument can be associated with a specific position above the earth; and 2) so that the payload can be recovered.

Constraints imposed by the US government on suppliers of GPS hardware can be overcome with differential GPS equipment. However, since the NITEOWL project does not permit a

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communication uplink to the payload ordinary differential GPS devices will not be suitable. Instead, inverted differential GPS hardware will be used. Inverted differential GPS hardware requires a standard GPS receiver in the payload, a communication downlink from the payload, and a base station.

This type of GPS equipment will estimate the position of the payload within 1m. The cost of the hardware will be approximately $10,000 -$20,000 (US). A possible supplier is Trimble Navigation. Bristol Aerospace also has a GPS-Telemetry package for approximately $65,000 (Can).

3.3.2 Telemetry system

Standard S-band telemetry will be used to achieve a downlink data rate of 10 Mbits/sec. The carrier is 1.6 Ghz with a bandwidth of 160 Hz/bit. Bristol Aerospace will supply a GPS-Telemetry package for approximately $65,000 (Can).

3.3.3 Data Rates

The data rate is expected to be 117 Mbits/sec without compression and 9.75 Mbits/sec with compression of 12:1. Compression is necessary to transmit the data collected within the 10 Mbits/sec bandwidth of the telemetry system. Information rates from data collection devices are listed in Table 3.3.3.

Table 3.3.3: Data rates for various instrument devices.

Device	*Data Rate (Mbits/sec)*
CCD	25
Video Camera	91
Avionics	1
Total Bandwidth	117

3.4 Digital and Analogue Hardware

3.4.1 Compression Electronics

A compression ratio of 12:1 is required in order to transmit all the data collected by the instrument. Electronics to perform the compression will consist of specialized integrated circuits and logic circuits. These items can be obtained from various suppliers.

3.4.2 Instrument Power Supply

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The power supply (unit provided by Bristol Aerospace) for the instrument is 45 W, at 28 Vdc and 1.6 A. This capacity is overrated by 50% to allow for a margin of safety. Power consumption for instrument devices is disbursed on the following basis:

Table 3.4.2: Power consumption versus device in the instrument.

Device(s)	*Power Consumption (W)*
CCD	1
Video Camera	4
Digital and Analogue Electronics	5
Avionics and Telemetry	5
In Flight Payload Heating	15
Total Consumption	30
Overrated by 50%	45

4. Other Required Systems

4.1 Chemiluminescent Ozonesonde?

As part of the validation of the ozone measurements, a chemiluminescent ozonesonde will be included with the payload. ***Typical dimensions*** for this cylindrical device would be approximately 11 cm in diameter and 50 cm in length, weighing 2.5 kg. This instrument uses the chemiluminescence reaction between ozone and Rhodamine B which provides an *in situ* ozone concentration once calibrated. *In situ* measurements do not depend on lighting conditions, and the detector works equally well in day as at night. Ambient air is sampled by a self-pumping technique as the sonde descends through the atmosphere. The flow rate past the detector is proportional to the pressure change in the chamber and the chemilumniescence is then proportional to the ozone flux. This technology has been used for many years, and its reliability has been tested on many flights. The vertical resolution of the ozonesonde is comparable to the ISP at 0.5-1 km, and the detector provides sufficient sensitivity for accurate measurements of ozone in the stratosphere.

4.2 High-Altitude Deployment Parachute

TBD - JAS

4.3 Radio Frequency Multiplexer

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TBD - JEG

5. Required Facilities

5.1 Available Facilities

There are five major sites which will be useful and available to provide fabrication, testing and calibration instrumentation and expertise. First, within the Institute of Space and Atmospheric Studies (ISAS) there is a fully equiped and staffed optics laboratory. Testing of the wavelength calibration of the optical spectrograph can be undertaken here. Second, the Department of Physics and Engineering Physics includes a machining shop which has undertaken diverse and physics related projects in the past with considerable expertise. Third, since the mission is to be flown and operate in temperatures down to -60° C thermal testing of the various components will be done. The mechanical engineering department at the University of Saskatchewan (U of S) has facilities which can achieve temperatures of this magnitude. Fourth, the Civil Engineering Dept. at the U of S has a vibrational testing facility which will be available for use in simulating the launch conditions which will have to be survived by the payload at take-off.

5.1.1 I.S.A.S. Optics Laboratory

The ISAS optics lab. is fully equipped and staffed by experienced personnel. One of the instruments in particular which is seen as being of great benefit to the NiteOwl project is the monochromator. This instrument should allow verification of the specifications of the CCD detector as well as characterization of the respose of the entire optical system to various wavelengths of light. With some additional mounting it is envisaged that the response of the spectrograph to various angles of incidence may be investigated and characterized.

5.1.2 Physics Shop

TBD - MH (mechanical fabrication)

5.1.3 Mechanical(?) Engineering Thermal Chamber

The thermal chamber at the U of S is more than large enough to accomidate the entire payload for the NiteOwl mission. The chamber is able to achieve temperatures of -xx C. Testing of both the electronics and the CCD detector at low temperatures is considered essential to determining the reliablility of the instrument as a whole.

5.1.4 Civil(?) Engineering Vibration Facility

TBD - JAS (shock/vibration testing)

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5.1.5 SCI-TEC Facilities

TBD - JEG (???)

5.2 Other Required Facilities

5.2.1 ???

6. Instrument and Payload Testing

6.1 Imaging Spectrograph Characterization and Calibration

TBD - JJO

6.2 Attitude Video Camera Testing and Characterization

TBD - JEG

6.3 Determination of Relative Orientation of Imaging Spectrograph and Attitude Video Camera

TBD - JEG

7. Launch and Operational Considerations

7.1 Launch Vehicle

TBD - MH

7.2 Launch Window

TBD - JJO, JAS

7.3 Launch Support

Launch support will be provided by Akjuit Aerospace and Bristol Aerospace Limited. This will include transportation of the rocket and payload to the launch site, technical expertise for the launch itself, tracking and telemetry systems implementation, decommuntation and storage of the flight data and post-flight recovery of the payload.

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The transport to the launch site should be straightforward with no problems forseen. The launch itself is a well-understood process and assuming that the payload is designed to withstand the vibrations and accelerations associated with the launch there should be no problems. In particular, the GPS equipment cannot function in the acceleration/jerk environment of the motor burn, but can be turned on after engine cutoff to acquire lock during rocket ascent. This will allow GPS tracking from the time of lock acquisition through loss of signal on descent. The rocket will be kept warm while awaiting launch by enclosure in custom-made styrofoam box with warm air blown in at several points.

The telemetry system provided by Akjuit Aerospace for tracking the payload during decent is an 8', S-band (1.6 GHz) dish. This system gives 30 dB for a 2 W transmitter 100 km away. Akjuit has also offered to provide a 6' hand-tracked dish to provide redundancy for the 8' system.

The data transmitted by the ISP and GPS will be stored on magnetic tape by Akjuit Aerospace and decommutated after the flight using several passes through the aquired data with increasingly rigorous error checking. The data associated with the AVC will be transmitted, recieved and stored seperately, but with a common time stamp to allow synchronization of the two data streams.

The post-flight recovery of the payload will be complicated by the long flight time of the instrument. The extended time the instrument is in free-fall creates trajectory dispersion problems. The area surrounding Churchill is not densely populated which is a necessary feature for the launch site, however the region is heavily wooded which could make recovery of the payload more difficult.

7.4 Data Acquisition

TBD - JEG

8. Work Breakdown Structure and Schedule, including Management Plan

8.1 Work Breakdown Structure and Schedule for Phase A

TBD - JKC, DPH

8.2 Work Breakdown Structure and Schedule for Phases B Through D

TBD - JKC, DPH

8.3 Management Plan

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8.3.1 Human Resources Deployment Plan

TBD - JKC, DPH

8.3.2 Contingency Plan

TBD - JKC, DPH

9. Project Budget

9.1 Phase A

TBD - JKC, DPH

9.2 Phases B through D

TBD - JKC, DPH

10. Risk Analysis

TBD - JJO

11. Potential Benefits

The benefits of research of the ozone layer and of studying other species are very important for humans and for Canadians especially. The significance for Canada is that it has a huge landmass and vegetation in the North that could be affected by a significant change of the ozone layer. Therefore research is of great interest for Canada, as changes happen just 20 km away from us.

Spinoffs are seen in the opportunity to establish Churchill as an important launch place. The final aim to fly an ozone monitoring instrument on a microsatellite to measure global ozone distribution in almost real time is of high importance if the ozone depletion continues. People would have the opportunity to see the thickness of the ozone layer on TV, in the newspaper, on radio and on the Internet. So they can decide by themselves if they want to expose themselves to sunlight or not at a specific day. The other advantage of publishing the data in real time on the Internet is the fact that each individual can obtain the information whenever he wants.

To provide each individual with the opportunity to obtain information about health risks he might expose himself to, should be of high priority for public financed research. A global ozone monitoring system is one step in this direction.

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Additions TBD - MH

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