NiteOwl

Part Two

1. NiteOwl and the Small Payloads Program Objectives

The NiteOwl project should be considered in a broad perspective. The parachute-borne spectrographic images of ozone absorption taken while descending through the lower stratosphere and upper troposphere simulate the observations that could be acquired from a satellite in low Earth orbit (LEO). While a rocket borne experiment cannot provide global coverage, it is an important validation step toward a future micro-satellite experiment. These innovative and cost-effective measurements will provide specific data regarding ozone in the upper troposphere and lower stratosphere (UTLS) during the Arctic winter, with the spatial resolution required by current predictive ozone models

The NiteOwl project will provide ample opportunities for graduate students and, in some instances, undergraduate students to be involved in all stages of the project due to the type and scope of the instrument involved. The participation of eight graduate students in preparing the NiteOwl proposal is a clear indication that this work can be performed, and performed well, with young researchers. Graduate student participation will continue during the hardware specification, design and integration phases of the project. Subsequent data analysis and calculation of the ozone vertical and horizontal distributions require expertise from researchers in various disciplines such as software engineering, computer tomography, theory of inverse problems, geochemistry, geophysics of the upper and lower atmosphere, and image analysis. The project will demonstrate the synergy of a multidisciplinary team of university scientists working closely with an industrial partner.

The NiteOwl project is very important for the industrial partner, SCI-TEC Instruments Inc.. Currently, SCI-TEC manufactures world class optical instruments for ground-based monitoring of the ozone layer. SCI-TEC's participation will give the company an opportunity to extend their product line to include optical instrumentation for micro-satellite/satellite measurements of ozone concentration. More importantly, data obtained from orbit by the stellar occultation technique can be used to generate near-real-time ozone maps with regional, national, or global coverage. This is a first step for SCI-TEC toward the development of a high value-added data product and will strengthen their ability to compete internationally. Rocket experiments are also important for Bristol Aerospace Ltd. (BAL) and Akjuit Aerospace Inc. (AAI). Their participation in this project allows them to enhance their industrial capabilities in the manufacture and launch of rocket payloads.

The NiteOwl project will address key scientific requirements for an improved understanding of ozone trends and will also take a key step toward meeting future information needs of Canadians. All participants in the project recognize that improved ozone measurements are timely, and are an appropriate response to increasing public concern over ozone depletion. This phenomenon is of vital

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importance to Canada because of its vast Arctic and sub-Arctic regions. Global ozone monitoring by stellar occultation will make an important contribution to international efforts to understand the nature of ozone variations in the upper troposphere and lower stratosphere.

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 ozone distribution within a radius of 600 km will then be determined with 12% RMS uncertainty, with a vertical resolution of 3 km, a radial resolution of 200 km, and an azimuthal resolution of 10°, over a 45° azimuth sector.

3. Instrument

3.1 Imaging Spectrograph

The imaging spectrograph (ISG) consists of two main optical elements: a transmission diffraction grating (§3.1.2) and an objective lens (§3.1.3). The collimated light from each star in the instrument field of view is dispersed by the diffraction grating into a spectrum, which is focussed onto a CCD detector by the objective lens. The objective lens defines the entrance pupil and hence the light grasp of the ISG, and is thus the element on which the requirement for 100:1 SNR (Part I, §2.3) places the most stringent demands (cf. §3.1.3). The other components of the ISG are the entrance window, baffles, and optical filters preceding the diffraction grating which, respectively, define the instrument field of view, minimize stray light incident on the grating, and define the wavelength passband, and the CCD detector which records the irradiance produced by each star. These two sections of the instrument are described in §§3.1.1 and 3.1.4.

3.1.1 Window, Entrance Baffles, and Optical Filter(s)

The entrance window of the ISG will be a simple opening in the payload skin that will be covered during launch. The window cover will be ejected just after the payload reaches apogee. The size of the opening will be determined by a tradeoff between minimizing the window area (to simplify the engineering of the window cover) and minimizing the solid angle subtended by the window at the center of the transmission grating (to reduce the vignetted portion of the sky from which stellar energy reaches the grating). Between the window and the diffraction grating a series of knife edge baffles will reject light from outside the field of view and minimize the amount of light reflected onto the grating from within the instrument. Finally, a stop between the objective lens and the CCD detector will eliminate internal reflection and scattering that would otherwise contaminate the image at the CCD.

Blocking filters will be used to define the limits of the wavelength passband of the NiteOwl ISG. These will reject wavelengths shorter than 400 nm and longer than 780 nm, in order to avoid spectral overlap on the CCD between adjacent orders of diffraction.

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Because the launch site at SpacePort Canada (Churchill, MB) lies at the center of the statistical auroral zone, the ISG may view auroral emissions at times during the mission, even when viewing the prime target stars to the south. Certain airglow emissions from the upper atmosphere will also be seen. The emission wavelengths of primary concern are the [OI] emissions at 557.7 nm and 630.0 nm, as these lie near the center of the ozone Chappuis absorption and are prominent in the spectra of both the nightglow and the aurora. We have considered the wavelength passband options described in Table 2-1. Option 1 is favoured but a final decision will be taken on the base of detailed instrument modelling to be carried out in Phase A.

Table 2-1. Wavelength Passband Options for Imaging Spectrograph

Option	**1**	**2**	**3**
Filter Type	Bandpass: 400 - 780 nm	Notch: reject 557.7 nm and 630.0 nm	Bandpass: 560 - 620 nm
Number of Components	One bandpass or (one highpass + one lowpass)	Same as Case 1, with two notch filters	Same as Case 1
Advantages	Measure whole visible spectrum, no data lost	Reject only airglow and auroral spectrum; rejection bands mark wavelengths	Minimal background auroral contribution - "dark sky"
Disadvantages	Strong aurora may compromise data	Wide rejection bands and out-of-band "ripple"	Limited wavelength band (60 nm)

3.1.2 Transmission Grating

A transmission grating with a ruled area of 100 × 100 mm and a ruling frequency of 75 lines/mm will be used to disperse the incident starlight. This results in a spectral resolution of 3.4 nm/pixel in first order, and spectral features wider than 8 nm will be resolved over the entire wavelength range of interest. The grating will be blazed at 520 nm in first order, giving as much as 90% transmission at that wavelength in the first order spectrum. Since the incoming light is perfectly collimated, the spectrum from each star will be dispersed over the entire aperture of the lens. Vertical dispersion will be obtained by aligning the grating rulings horizontally, to prevent payload spin (about the longitudinal axis) from degrading the spectral resolution. Space-qualified gratings meeting these specifications are available from Richardson Grating Laboratory.

3.1.3 Objective Lens

A 15° × 11.6° field of view on the sky has been selected for the ISG, which permits the use of an entrance aperture large enough to image 3rd magnitude stars with 100:1 SNR, and is wide enough to keep a given star within the field of view during the entire 1-s exposure time, even while spinning at the nominal rate of 6°/s or 1 r.p.m. In the vertical dimension (*i.e.*, that of wavelength dispersion), a field stop will limit the acceptance angle of the ISG to 11.56°, allowing the remaining 3.44° to be occupied by the first-order spectrum of a star seen at the edge of the field of view. In order to use the entire area of the square CCD detector (24.58 × 24.58 mm), the first order image

of the longest wavelength (nominally 800 nm), incident from the vertical limit of the field of view, will be focussed onto the last row of the CCD. Thus the objective lens will receive light rays over a 15° full field both horizontally and vertically.

The 15° field of view and the 24.58-mm size of the CCD determine the properties of the lens. The requirement that the zeroth-order image of a star at the vertical limit of the field of view be imaged at the edge of the CCD fixes the focal length at $f = 24.58mm/2\tan(7.5°) = 93.35mm$.

Signal-to-noise ratio calculations indicate an entrance aperture of 100 mm is required, so an f/# of 1.0 is indicated. Lenses satisfying these requirements are not readily available commercially, and the procurement of a suitable lens may be costly. Various options have been considered, including modifying a video projection lens, and obtaining a custom-manufactured lens from Applied Physics Specialties. The most cost-effective approach will be taken.

3.1.4 CCD Detector

Light collected by the optics will be focussed onto a charge-coupled device (CCD) detector with the nominal specifications shown in Table 2-2. Data sheets and prices for suitable large-area CCD detectors have been obtained from Scientific Imaging Technologies, Inc. (SITe) and English Electric Valve (EEV) Canada. The specifications in Table 2-2 are those of the SITe SI-003A device.

Table 2-2. Nominal specifications for the CCD imager.

Characteristic	Specification
Visible Pixel Array	1024 × 1024
Pixel Size	24 μm × 24 μm
Fill Factor	100%
Potential Well Depth	300,000 electrons
Quantum Efficiency	55% - 85%
Wavelength Sensitivity	400 nm - 900 nm
Imaging Size	24.58 mm × 24.58 mm
Resolution	14 bits/pixel
Readout Rate	1 frame/s
Exposure Time	1s (nominal)

In the event that a non-MPP CCD is selected for use, it will be important to cool the CCD to minimize dark current. This can be done by means of a cold finger thermally coupling the CCD to a radiator plate in the payload skin, which will conduct heat away from the CCD and reject it to the cold ambient environment.

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3.1.5 CCD Readout System

A custom CCD readout system will be required to meet the specifications on frame transfer speed, digitization precision, readout noise, power consumption, and overall payload mass and volume. Routes Inc. (Kanata, ON) can modify the design for the OSIRIS readout system to meet the specifications for NiteOwl. As well, Prof. Gordon Walker and his colleagues in the Department of Geophysics and Astronomy, University of British Columbia, have expertise in the development of compact, low-power readout systems that can be adapted to space applications.

3.2 Avionics

3.2.1 Video Camera for Attitude Determination

An image-intensified analog video camera will be used to determine the viewing direction of the ISG. The orientation of the video camera with respect to the ISG will be precisely measured during payload integration. Star images acquired by the video camera during the mission will be correlated with a star database to resolve the orientation of the video camera, and identify the stars in the ISG field of view. BAL will supply a Xybion intensified camera of the same type as that used successfully in the GEMINI and OEDIPUS-C missions. The analog output of the camera will be downlinked over the telemetry antenna and captured by a dedicated receiving antenna on the ground. The knowledge base for accurate interpretation of the video data stream with high time resolution was developed at the University of Saskatchewan [Moorhouse 1994] and is available for application to this mission.

3.2.2 Global Positioning System Receiver

A Global Positioning System (GPS) receiver is required to track the position of the instrument during the mission. The position of the payload must be known in order to associate a measurement with a specific three-dimensional position, and to facilitate payload recovery. Civilian use of GPS technology is normally limited to altitudes below 10 nautical miles (18.5 km) and flight speeds less than 600 knots (1100 km/hr), but these limitations can be defeated with appropriate authorization. BAL will provide a GPS position determination capability as part of the payload.

3.2.3 Telemetry system

Standard S-band telemetry will be used to achieve a downlink data rate of 10 Mbit/s. This channel will transmit data from the ISG, the GPS receiver, a temperature sensor (§4.1), and a chemiluminescent ozonesonde (§4.2), if flown.

3.2.3.1 Radio Frequency Multiplexer

A radio frequency (RF) mixer is needed to mix the AVC analog video signal onto the S-band carrier of the telemetry system. Standard RF mixing circuits can be used to perform this task. It is expected that the bandwidth of the mixed signal will be less than 105 MHz on a single-side-band (SSB) transmission system.

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3.2.3.2 Data Rates

The total data rate from the sensors mentioned in the preceding subsection is expected to be about 17 Mbit/s without compression. Information rates from data collection and transmission devices are listed in Table 2-3.

Table 2-3. Data rates from various sources.

Data Source	Data Rate (Mbit/s)
Imaging spectrograph	16.8
Temperature sensor	0.01
Chemiluminescent ozonesonde	0.01
GPS receiver	0.1
Total Bandwidth	<17

3.2.4 Compression Electronics

Lossless compression with a ratio approaching 2:1 will be required in order to transmit all the data collected by the instrument. This can be done by exploiting the expected redundancy in the images from the ISG, which will show horizontally blurred stellar spectra in which adjacent columns will differ little, if at all. Transmitting data by columns, and transmitting differences between adjacent columns when these can be represented in less than 8 bits, is expected to achieve significant savings in the total data rate. The image analysis and compression will be implemented with a digital signal processor (DSP).

3.2.5 Instrument Power Supply

The power required by the instruments is estimated as 30 W at 28 Vdc and 1.07 A. This capacity is overrated by 25% to allow for a margin of safety. System power at 28 Vdc will be available on a bus from system batteries provided by BAL. We will provide power conditioning hardware to convert the system power to the voltage levels required by our instruments. Estimated power consumption is listed by device in Table 2-4.

Table 2-4. Instrumental power consumption

Device(s)	Power Consumption (W)
CCD and Readout System	5
Chemiluminescent Ozonesonde	7
Avionics	7
In Flight Payload Heating	5
Total Consumption	24
Overrated by 25%	30

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4. Other Required Systems

4.1 Temperature Sensor

It is desirable to include a simple ambient temperature monitor in the payload to provide an independent atmospheric temperature reference. A thermistor-based sensor such as that used in the Super Loki Datasonde [Schmidlin 1986] is proposed, as it is small, lightweight, proven, and well understood. Integration of the atmospheric density downward from apogee, using the measured temperature profile, will also provide a reliable pressure/density profile. This will be useful as a check on densities and temperatures inferred from measurements of the Rayleigh scattering component of the stellar irradiance attenuation.

4.2 Chemiluminescent Ozonesonde

To provide *in situ* validation for the ozone profile inferred optically, it is desirable to include a chemiluminescent ozonesonde [Hilsenrath and Kirschner 1980] in the payload. The device is cylindrical, 10.5 cm in diameter and 51 cm long, weighing 2.4 kg. This instrument uses the chemiluminescence reaction between ozone and rhodamine-B to measure the ozone concentration *in situ*. Ambient air is sampled by a self-pumping technique as the sonde descends through the atmosphere. The reliability and accuracy of this technology have been tested on many flights. The vertical resolution of the ozonesonde is comparable to or less than that of the ISG (1.1 km at 60 km; less than 100 m below 40 km), and the detector provides sufficient sensitivity for accurate measurements of ozone from 65 km down to 20 km altitude.

4.3 High-Altitude Deployment Parachute

The instrument must rotate as it descends to provide data from all azimuths. The payload descent rate and spin rate will be determined by local atmospheric conditions and parachute characteristics. The descent rate and spin rate within the ozone layer are critical to the acquisition of an adequate data set for tomographic reconstruction. The descent rate and spin rate above the ozone layer are critical to obtaining baseline spectral data for each star and thereby fulfill the self- calibrating feature of the instrument. Parachutes which control the spin rate of the payload are an existing technology. The literature [Silbert 1980] suggests that such parachutes provide a constant number of revolutions per distance travelled. In order to obtain the target 1 km vertical resolution, the instrument must rotate at least once per kilometre in the ozone layer. Because the descent speed above the ozone layer is quite high, the rotation rate will be high also. The rotation rate of 1 rev/km combined with the descent speed just before the ozone layer is reached yields a rotation rate of 4.5 rpm. This is the maximum rotation rate at which spectral data will have to be acquired.

ALERT .... Does this rotation rate conflict with what was specified elsewhere regarding blur....?????

Do we have to consider a non-spin parachute and some other mechnical/optical means to scan the horizon?????

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5. Required Facilities

5.1 Available Facilities

Several major facilities within the University of Saskatchewan and at SCI-TEC Instruments Inc. are available to provide instrumentation and expertise for fabrication, testing and calibration. The Institute of Space and Atmospheric Studies (ISAS) has a fully equipped optics laboratory where wavelength calibration of the ISG can be carried out. The Department of Physics and Engineering Physics has a machine shop whose staff have successfully completed numerous instrumentation development projects. The Department of Chemistry has facilities to create a low-temperature, low-pressure environment suitable for simulating conditions in the stratosphere, to allow thermal-vacuum testing of the various components. The Department of Mechanical Engineering has a vibrational testing facility which could be used to simulate the conditions to which the NiteOwl instruments will be exposed during launch.

5.1.1 ISAS Optics Laboratory

The ISAS Optics Laboratory is fully equipped with equipment for generating, manipulating, and measuring light at wavelengths from the near UV to the near IR. Of particular value to this project is a scanning 1-m Ebert-Fastie monochromator, which can be used for acceptance testing of the CCD detector and the grating as well as characterizing the response of the entire optical system to light as a function of wavelength and angle of incidence.

5.1.2 Physics and Engineering Physics Machine Shop

The machine shop in the Department of Physics and Engineering Physics is available for mechanical fabrication and assembly. This facility is staffed by three highly qualified machinists, who are Canadian Interprovincial Journeyment Machinists and fully accredited Canadian Instrument Makers. Because they are employed by the Department, fabrication services can be provided at highly competitive rates. Recent work has included the preparation of space research instruments meeting very tight tolerances, for NASA projects and the Odin satellite.

5.1.3 Chemistry Thermal Vacuum Facilities

Instrument testing before launch must simulate the cold near-vacuum of the mesosphere to ensure proper instrumental operation in the expected low temperatures and pressures, and to verify that heat absorbed by the CCD can be radiated to space efficiently enough to cool the CCD and reduce dark current. The expected conditions can be simulated readily using facilities in the Department of Chemistry. A bell jar large enough to house the instrument, evacuated with a fore pump, can be used to reduce the pressure to 2×10^{-3} torr, the expected pressure 5 km above apogee. A plywood enclosure constructed around the jar, lined with 15 cm thick styrofoam and cooled by a controlled flow of nitrogen gas boiled off from a dewar at 77 K, can be cooled easily to the 200-250 K ambient temperatures found throughout the stratosphere and mesosphere. The interior of the bell jar can be appropriately blackened to absorb the thermal radiation from the CCD radiator plate.

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5.1.4 Mechanical Engineering Vibration Facility

A Brüel & Kjær vibration exciter with a stroke of 0.75 in and a maximum head speed of 50 in/s can be used for vibration testing at oscillation frequencies up to 4 kHz. The product of loading mass and peak acceleration that can be produced is 143 kg·g or 1400 kg·m s^{-2}. This will allow vibration testing of the NiteOwl instruments, but not the whole payload, at vibration levels characteristic of launch conditions.

5.1.5 SCI-TEC Facilities

SCI-TEC can provide facilities, resources, and services including ordering, receiving, and storage capabilities of SCI-TEC for instrument parts, the use of computers for instrument control and data analysis, Brewer ozone spectrophotometer data for reference and correlation with data received from the NiteOwl, space for instrument assembly and storage, and a machine shop. Pre-flight instrument testing can be undertaken using SCI-TEC's dark room, optical tables, laser alignment jigs, gas calibration unit (capable of ozone generation), and calibrated light source. It may be possible to conduct ozone absorption tests with SCI-TEC's resources.

5.2 Other Required Facilities

5.2.1 Bristol Aerospace Limited Payload Test Facilities

BAL have facilities for conducting electrical, mechanical, thermal, and vacuum tests on rocket payloads. Electrical tests that will be required include those for electrical compatibility and electromagnetic interference. Mechanical tests will include those for payload spin balance and vibration tolerance. Payload operation can be tested under conditions of temperature or pressure representative of those expected during flight.

6. Instrument and Payload Testing

6.1 Imaging Spectrograph Characterization and Calibration

The ISG will have to be characterized in terms of the sensitivity of the instrument to light of different wavelengths and in terms of the effect of the optics on the path taken through the instrument by light of various wavelengths and at various angles of incidence. These tests are expected to require some 50 person-days of effort at a cost of $nnK. The sensitivity of both the CCD and the ISG as a whole as functions of wavelength will be measured with the ISAS 1-m monochromator. This instrument can be used to produce monochromatic light over the entire passband of the NiteOwl ISG with a spectral resolution of less than 0.1 nm, if required.

The stellar occultation experiment as performed by the ISG is self-calibrating, provided the relative instrument sensitivity as a function of wavelength and position on the CCD. Knowledge of these characteristics renders an absolute calibration of the instrument unnecessary, and affords a considerable saving in calibration time and expense.

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6.2 Attitude Video Camera Testing and Characterization

A comprehensive and conclusive test which characterizes and indicates the correct operation of the video camera will involve aspects of light sensitivity, mechanical strength, and functionality. These tests, which are expected to require 10 person days at a cost of $n, will determine the wavelength passband of the camera and the threshold brightness for a reasonable quality image. Appropriate tests will verify instrument integrity at the expected levels of vibration, stress, and acceleration. Finally, a data validity test will determine the capability of the camera to represent accurately the image that it sees in an analog waveform.

The sensitivity and intensity tests can be performed by placing a calibrated source of collimated light of known wavelength in front of the camera. By noting the gain response of the camera as wavelength, intensity, and position are varied the properties of the camera become known. These tests should be preceded by a simple functional test in which the camera views the clear night sky from a dark location on a moonless night, to allow a quick assessment of the image quality and the number of detected stars.

A key requirement is to determine the mapping from the ($r\theta$) object space of the attitude video camera to the (xy) image space. This can be accomplished most simply by suitable analysis of the starfield video data discussed above.

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

The orientation of the Imaging Spectrograph (ISG) with repect to the Attitude Video Camera (AVC) will have to be evaluated before launch. Note that it is not necessary to align the two subsystems precisely to a known relative orientation. It is only necessary to determine what the relative orientation is. It is proposed to do this in three stages.

During payload assembly the two subsystems can be coarsely oriented during systems integration. During initial testing of the payload optical tests can be performed (using facilities in the ISAS Optics Laboratory) to determine whether the coarse orientation specification was met. During final verification of the payload, and during testing of the Attitude Video Camera, determination of the orientation angle between the two subsystems can be performed at night using known star patterns.

7. Launch and Operational Considerations

7.1 Launch Vehicle

The launch vehicle will be the Orion, an American vehicle. This single stage, unguided, fin stabilized rocket with a 14" diameter and a 110" length can reach an altitude of 80 km with a 55 kg payload. This rocket uses a two-phase burn: the first phase provides an acceleration up to 15 g for a few seconds. The second phase provides 6-8 g acceleration. The total burn time is approximately

32 seconds. Three nominally canted fins provide a spin rate of four revolutions per second at burnout. The expected mass distribution is shown in Table 2-5.

Table 2-5. Expected Payload Mass Distribution

Item	Mass (kg)
Payload skin section	18.7
Separation system	9.1
Nose cone	10.0
Parachute	12.2
Despin hardware	3.6
Telemetry system	12.3
Experiment	10.9
Total	**76.8**

The 'Experiment' item includes all required on-board systems: optics, power supply, batteries and mounting structure. The estimated vehicle cost is $80,000. In order to use the Orion, an End User Agreement will be negotiated with the US Navy, as has been done in the past for projects with Canadian government sponsorship.

7.2 Launch Window

In determining an optimal launch window, the positions of the sun and moon as well as the distribution of stars on the celestial sphere must be taken into account. To minimize contamination by scattered light, ground-based astronomical observations are usually carried out when the sun is at least 12° below the horizon, and the moon is also down. We adopt the conservative approach of requiring these conditions to hold from apogee (nominally 80 km altitude). The corresponding depression angles at ground level are 21° and 9° for the sun and moon, respectively.

Between October 1, 1998 and February 28, 1999, there are five periods of ten to thirteen days when these conditions are met for at least six hours each night. Table 2-6 lists these times, along with the length of the longest dark period in each month, and the range of local sidereal times (LST) covered during each period.

Table 2-6. Launch Windows Between October 1, 1998 and February 29, 1999

Launch Campaign Dates	Maximum Dark Period	LST range (hrs)
17-27 Oct 1998 (11 d)	9 hr 10 min	21.27 - 6.95
14-26 Nov 1998 (13 d)	10 hr 50 min	22.11 - 09.76
13-25 Dec 1998 (13 d)	11 hr 40 min	23.68 - 12.16
11-22 Jan 1999 (12 d)	11 hr 10 min	01.92 - 13.84
10-19 Feb 1999 (10 d)	9 hr 30 min	04.72 - 14.84

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A very favourable sector for star observations at southern azimuths occurs during the December - February launch windows at 9^h30^m - 10^h00^m LST. Over a

A Brewer ozone spectrophotometer will be used to measure ozone total column densities and profiles before and after the mission, to provide further validation for the measurements derived from the NiteOwl data. Provided that the moon is at least 20° above the horizon for one hour while the sun is at least 12° down, total column ozone can be measured using moonlight on the night of the mission. Thus it would be ideal to pick a launch date when the moon either sets before the launch or rises after the launch. Failing this, validation measurements can be obtained during the daylight hours bracketing the launch.

7.3 Launch Support

Launch support will be provided jointly by AAI and BAL. This will include transportation of the rocket and payload to the launch site, facilities and personnel for rocket and payload processing, assembly, and test, technical expertise and facilities for the launch itself, tracking and telemetry systems implementation, decommutation and storage of the flight data and post-flight recovery of the payload.

By the spring of 1998 AAI expect to have available two 5-m antennas for payload tracking and telemetry acquisition. These antennas provide 38 dB gain at S-band frequencies, which is more than adequate to record telemetry from a 2 W transmitter at ranges up to 100 km.

The data transmitted by the ISG, GPS receiver, environmental sensors and chemiluminescent ozonesonde will be recorded on magnetic tape by AAI and decommutated after the mission. The data associated with the AVC will be transmitted, received and recorded separately with a common time stamp to allow synchronization of the two data streams. **(Is this a correct understanding of how the analog video would be transmitted?)**

Post-flight recovery of the payload is highly desirable but will be complicated by the long parachute time of the payload, which creates trajectory dispersion problems. The land area surrounding Churchill is sparsely populated but heavily wooded, which could make complicate the actual recovery of the payload. Monthly mean zonal winds in the stratosphere over Churchill are strongly eastward, making it probable that the payload will land on the ice of Hudson Bay. GPS data during descent and a low-power beacon on board the payload will be used to locate and recover the payload promptly after completion of the mission.

7.4 Data Acquisition

Data acquisition is the process by which data is collected from the NiteOwl instrument. This information consists of GPS coordinates, the signal from the video camera, images from the CCD, temperature, and pressure. Rocket and payload tracking, which will be performed by Akjuit Aerospace, will provide supporting position information.

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The CCD images, temperature and pressure data are compressed and multiplexed with the 2 MHz video signal onto an S-band (1.6 GHz) carrier with a bandwidth of 10 Mbits/sec. The GPS data is sent on a different carrier (Bandwidth? Carrier?). All this information will be collected on the ground by a system of antennas. Subsequently, the data will be demultiplexed, decompressed, and decoded before being stored.

The complex nature of the data transmission system can be alleviated with a GPS-Telemetry package from Bristol Aerospace. This system will address most of the issues related to data transmission from the instrument to the ground station.

8. Work Breakdown Structure and Schedule, including Management Plan

8.1 Work Breakdown Structure and Schedule for the NiteOwl Project

A work breakdown structure and plan for the entire NiteOwl project is given in Fig. 2-1 *(not yet in place)*, outlining the major tasks required in each phase of the work. The planned duration of the project, from the start of work on Phase A to the completion of the data validation after the mission, is 474 days, or just under 23 months. This includes a waiting period of one month after the Preliminary Design Review before the decision to proceed to launch is received, and a somewhat conservative estimate of the time required for payload design and integration. If work begins on May 1, 1997 and time is saved during the Payload Design and Integration activities, the Mission Readiness Review will be held in December 1998 and launch will occur during January or February 1999.

8.2 Work Breakdown Structure and Schedule for NiteOwl Phase A

A fully-detailed work breakdown for Phase A is shown in Fig. 2-2 *(not yet in place)*. We have estimated 6.5 months for Phase A activities, which will include the required preliminary design studies as well as a detailed specification and description of all aspects of the experiment. The design studies will address many issues common to both the parachute-borne version of the NiteOwl experiment and the follow-on satellite experiment.

8.3 Management Plan

8.3.1 Human Resources Deployment Plan

The NiteOwl Team consists of a number of highly qualified personnel from the University of Saskatchewan and the project's industrial partner, SCI-TEC, as previously described in the Science Team section of Part I. Four graduate students in science and engineering will take part in the project, and financial and other management responsibilities will be undertaken by appropriately qualified graduate management students under the supervision of Prof. M.J. Painter of the College of Commerce. The detailed task descriptions of the students are provided below. With the exception of student 3 (J.A. Steele), graduate students have not yet been selected.

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Student 1 (Electrical Engineering) will be registered in an M.Sc. program under the supervision of Prof. R.J. Bolton circuits, with support from a graduate scholarship. During Phase A this student will work on electrical/electronics aspect of the experiment, including data compression methods and their implementation in digital.

Student 2 (Mechanical Engineering) will be registered in an M.Sc. program under the supervision of Prof. J.D. Bugg, with support from a graduate scholarship. The student will study parachute and payload dynamics and perform structural and thermal modelling of the experiment in Phase A.

Student 3 (Mechanical Engineering) will be registered in a Ph.D. program under the supervision of Prof. A.T. Dolovich, with support from an NSERC Postgraduate Scholarship. The student will be involved in the synthetic data preparation and algorithm development during the experimental modeling in Phase A, and will work on tomographic analysis of synthetic data during the remaining phases. The tomographic analysis of the NiteOwl data set will form part of this student's Ph.D. dissertation.

Student 4 (Engineering Physics) will be registered in an M.Sc. program under the supervision of Dr. D.P. Steele, with support from a graduate scholarship. The student will be involved in most aspects of the Experiment Modeling activity, and in work on the optics and detector system within the Experiment Specification and Description, both in Phase A.

Student 5 (College of Commerce) will be registered in the MBA program and will work under the supervision of Dr. M.J. Painter, with support from a graduate scholarship. The student will serve as Assistant Project Manager (APM), assisting with the financial and human resources management of the project.

Students 1, 2, and 4 will also gain hands-on experience at SCI-TEC as term employees during portions of Phase B, the implementation, integration, testing, and calibration of the instrument. In addition, these students will have limited involvement in the Launch Operations, Phase D.

8.3.2 Project Monitoring and Control

Control on both budget and human resources must be applied, to ensure all aspects of the project run smoothly. All tasks, and expecially those on the Critical Path (see Appendix X), must be finished on schedule, per the Work Breakdown Structure (WBS), and on budget. Time overruns in Critical Path tasks risk delaying the entire project.

The APM will have responsibility for monitoring the progress of the project overall, and each task in particular, to ensure all tasks are proceeding on schedule. The APM will work closely with the PI (and the responsible person at each subcontractor) to anticipate scheduling or budget difficulties. In cases of time or cost overruns during the project, the APM will report the situation to the PI, who will decide with the science team and SCI-TEC how to resolve the situation with the least adverse impact on both the science objectives and the project budget.

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9. Project Budget

9.1 Phase A

9.2 Phases B through D

See pages 14ff.

10. Risk Analysis

This section addresses aspects of the NiteOwl Risk and Reliability Assessment. The primary focus is on a risk analysis of the various subsystems associated with the instrument and the mission. The reliability of these subsystems will, for the most part, be determined by the sub-contractors involved in the implementation of each component.

The entire payload will undergo acceptance tests appropriate to determine the suitability of the systems and subsystems. These will be undertaken in cooperation with the sub-contractors involved or the industrial partner. There can be no provision for redundancy in the flight subsystems in the experiment due to cost constraints.

The general categories for risk and reliability analysis are discussed below.

- **Science:** The major concern here, and one that will have a major impact on the success of the project, is overlooking some aspect(s) of the experiment that would lead to failure. This can be mitigated by close scrutiny of all aspects of the experiment as well as by external review. Possible areas of concern are: incorrect assumptions, error in modeling, and error in simulation.

- **Pre-Launch**: Since a number of the subsystems will be sub-contracted, it is important to monitor closely the specification, delivery, and documentation associated with these subsystems. This is included in the management plan for the project. A major mitigating consideration is that the launch window can be over a number of days each month allowing (to some extent) delivery dates to slip. This will, however, increase the cost of launch. Possible areas of concern are: failure to meet schedule, faulty design, payload weight overrun, destructive testing, incomplete documentation

- **Launch:** The launch of the payload will be coordinated by BAL and AAI. They will be responsible for all aspects of the launch operation and initial manual tracking/capture. Possible areas of concern are: vehicle failure, manual tracking failure, bad weather, safety conditions.

- **Payload Dynamics:** It is necessary to have the payload decelerated by parachute and to have a stabilized flight (spin rate <1 rpm below 30 km altitude; swing amplitude < 5°). Areas of concern are: parachute deployment, de-spin, stabilization against pendulation.

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Optical System: It is possible for the optical system to become damaged or mis-aligned during the launch portion of the experiment. The mounting and alignment of this system will have to be checked during manufacture and assembly. Possible areas of concern are: G forces, vibration, grating or optics contamination.

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Electronic Systems: This will include the power supply, power converter, data compression hardware, and miscellaneous monitoring circuitry. Possible areas of concern are: incorrect power estimates, incorrect interfaces, physical failure, EMI, thermal problems, GPS subsystem failure, antenna failure. Outside expertise will be accessed whenever appropriate.

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On-Board Data: The major component of this system is the data compression hardware subsystem. Since this will not be a commercially available unit, past performance of the system is not available for analysis. Areas of concern are: inadequate compression ratio.

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Ground-Based Data: Aspects of this area include telemetry, data recovery and data storage. Areas of concern are: power failure, software failure, recorder failure, antenna failure.

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Post-Flight: This aspect is related to the recovery of the payload. Possible areas of concern are: on-board data storage (if used) is lost, payload is lost.

In determining the "risk" involved with each of these mission aspects, the following were considered:

System Risk Level - depends on knowledge and experience with each particular system

- Low: Use of flight qualified system, well understood considerations and methods
- Medium: Possibility of error, incorrect specification
- High: New systems, inexperience, inherent risk

Probability of Occurrence - depends on how successful each subsystem has been in past missions

- Low, Medium or High based on past experience, reliability and input from team leaders.

Impact on Mission - depends on how a problem with each subsystem affects the mission

- Low: Threatens optimal success
- Medium: Threatens schedule or acceptable success
- High: Threatens cost or minimum success

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Difficulty in Mitigating - depends on whether a problem with the subsystem in question can be resolved and what else can be done if this is not possible

- Low: Well understood approach to minimize/identify/correct problem
- Medium: Some opportunity to minimize/identify/correct problem
- High: No opportunity to minimize/identify/correct problem

Based on the assessment of each system (summarized for illustrative purposes in Table 2-7 below), an aggregate averaging has made it possible to rank each mission aspect according to the risk level associated with it. From highest to lowest risk:

1. Launch
2. Vehicle Dynamics
3. Optical System
4. On-Board Data
5. Electronic Systems
6. Ground-Based Data
7. Science
8. Pre-Launch
9. Post-Flight

The launch and the vehicle dynamics are the two riskiest aspects. However, given that the payload survives the launch and is put in a position to begin taking data, we are quite confident that the rest of the mission will be successful.

Shown below is a summary of the risk level estimations for some of the key issues associated with each mission aspect heading discussed previously.

Table 2-7. Risk Analysis of Various Aspects of NiteOwl Mission

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Mission Aspect	System Risk Level	Probability of Occurrence	Impact on Mission	Difficulty in Mitigating
Science				
Initial instrument design faulty or not proven	Medium	Low	High	Low
Scientific variable assumptions not correct	Medium	Low	High	Low
Pre-Launch				
Improper testing	High	Medium	Medium	Low
Parts are unavailable or aren't received	Medium	Medium	Medium	Low
Launch				
Invalid initial trajectory	High	Medium	High	High
Vibration during launch causes wires to break or intermittent connections	High	Medium	High	High
Vehicle Dynamics				
Parachute deployment	High	Medium	High	High
De-spinner doesn't deploy	High	Medium	High	High
Optical System				
Instrument optics misaligned due to mounting tolerances	Medium	High	High	Medium
Stray light in instrument	Medium	High	High	Low
Electronic Systems				
Problem turning instrument on at apogee	Medium	Medium	High	Medium
Subsystem interfaces not correct	Medium	High	Medium	Low
On-Board Data Handling				
Data compression hardware failure	Medium	Medium	Medium	High
Antennae failure	Medium	Medium	High	High
Ground-Based Data Handling				
Antennae failure	Medium	Medium	High	Low
Power failure	Medium	Medium	High	Low
Post Flight				
Vehicle recovery	High	Low	Low	Low

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 above our heads.

We can provide an opportunity to measure ozone by using a low cost method.

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. An experiment to measure ozone distributions at night is a first step to global ozone monitoring system is one step in this direction.

Technical benefits: For this company it is an important step further and the chance to make use of scientific research without delay. This concept yields a twofold situation: 1)The scientist gets confirmed that scientific research can immediately be transformed into technical development (and public wealth). 2) industry realizes that it is worthwhile to participate in projects with university and governmental organizations (CSA).

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