PART TWO

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1.4.1 Student involvement

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2 Payload description and development

2.1 Imaging spectrograph

2.1.1 Transmission versus reflection gratings

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2.1.2 Image Intensifiers and CCD Arrays

The equipment to create spectrographic images includes an image intensifier and a charge-coupled device (CCD). The image intensifier, which is lens-coupled to the CCD, will strengthen the dim starlight so that it can be adequately detected by the CCD. Spectral images captured by the CCD will be used to determine properties of ozone above the earth.

Science-Tech, a Canadian company, can provide an intensified CCD (ICCD) for $28000 (Can). K-Space Associates Ltd. can supply a CCD for $3500 (US). Electrophysics Corp. will provide an intensifier for $4000 - $5000 (US).

2.1.3 Lens system and ray tracing

TBD

2.2 Video Sensor 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 $3000 (US). Possible suppliers are Hamamatsu and Panasonic.

2.3 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 measurment 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 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 $10000 - $20000 (US). A possible supplier is Trimble Navigation.

2.4 Data acquisition and telemetry system

Standard S-band telemetry will be used to achieve a downlink data rate of 10 Mbps.

3 Validation of the payload

3.1 Mission simulator

TBD

3.1.1 Star database

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3.1.2 Refractive atmosphere model

As light from a star goes through the atmosphere, it is bent due to the change in refractive index. The first procedure to quantize the deviation in ray direction was to calculate a final change in angle. This angle would be from the apparent look direction (tangent to the altitude) to the instrument to the point at which the ray leaves the atmosphere (outer limit of atmosphere chosen to be 120 km where refractive index is equal to one to the twelfth decimal). For worst possible conditions (lowest altitude of 10 km and tangent look direction), the deviation in angle was around 0.6°. By this method, however, it would be difficult to relate this change to other parameters of interest or calculations (*e.g.* field of view).

The second method is similar, in which at each shell interface a new direction for the ray is calculated. As well, calculations begin at the instrument and the ray is "back-tracked" through the atmosphere. The final deviation from the apparent line of sight is the summation of change in angle at each interface (i.e. the difference between the angle at which the ray strikes the shell interface and the angle at which it continues through the next shell is added together each time to give a total deviation angle). In this way, it is possible to start at any altitude with any apparent look direction. However, the worst case scenario is still the lowest tangent altitude (now at ground level). Using this method with 5 km shells, and data for pressure and temperature from CIRA (January 60° N latitude), the deviation from the initial look direction to where the starlight actually originated, was calculated to be 0.3°.

This method was verified and correlated with members of the tomographic team. Further analysis performed with continuous refraction (instead of having shells and interfaces) lead to an estimate 0.5° deviation from apparent look direction (at ground level and tangent altitude). In order for consistency in tomography, this team could include two-dimensional ray tracing (with the suggested Runge-Kutta method) as well as the algorithms that have been developed. From similar estimates of the effects of refraction by satellite studies, the estimated deviation of true look-direction may translate into only a few centimeters of deviation. With the projected positional accuracy of our instrument, this effect would then be minor.

One point that should be noted is that the ray can not be traced from space to a final tangent altitude. The light source is estimated at infinity which leads to parallel rays of light incident on the atmosphere. Thus, the stars within the field of view would appear to remain stationary if the instrument did not spin or swing. Only those stars on the extreme outer edge may drop out of sight. One can not track a ray through the descent in order to find specific changes in angle because the view is of a continuum of parallel beams.

3.1.3 Ozone absorption model

The best current ozone absorption cross sections for the Chappuis band at temperatures of 226 K and 293 K, published by Shettle, were obtained from the GOMOS project Web page. A model ozone profile spanning 0 - 50 km altitude with 2 km height resolution has been used to estimate the ozone absorption effects on a G-type star spectrum when viewing at 90° zenith distance through the atmosphere. The model is being extended to viewing angles other than 90°.

3.1.4 Optics ray tracing model, including components for

3.1.4.1 Grating

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3.1.4.2 Lenses

TBD

3.1.4.3 Intensifiers

Electrophysics Corp. has an image intensifier with the following optical characteristics:

Input Image Size	18mm diameter
Output Image Size	18mm diameter
Resolution	≥36 lp/mm
Gain	10000
Spectral Response	400nm to 850nm
Sensitivity	Higher near the infrared end of spectrum

The price for this intensifier is $4000 - $5000 (US).

3.1.5 CCD

The CCD provided by K-Space Associates Inc. is the K400CC5 High-Resolution, High-Sensitivity, Peltier-Cooled Black&White CCD. The cost for this detector is $3500 (US). Specifications that affect image quality are as follows:

Potential Well Depth	100,000 electrons
Pixel Resolution	768(H) X 493(V)
Pixel Size	11 microns X 13 microns
Sensing Area	8.8mm X 6.6mm
Spectral Range	400nm - 1100 nm without IR filter
Signal to Noise Ratio	56 dB
Sensitivity	0.5 lux at f/1.4 without IR filter
Exposure Time	1/30 sec to 5 min

3.2 Calibration, testing, etc.

TBD

4 Platform, vehicle, launch

4.1 Vehicle

The Black Brant VI meteorological rocket initially envisaged as the launch vehicle was found to be unavailable. The Orion sounding rocket has been selected as the launch vehicle. This vehicle can carry a 120 lb payload to 80 km apogee from sea level at a quadrant elevation of 85°, and thus provides both ample payload space and an adequate payload mass budget (estimated at 28 lb). The Orion can be obtained from the U.S. Navy under an end-user agreement, as has been done in the past for projects with Canadian government sponsorship.

4.2 Location

At least one launch, from SpacePort Canada/Churchill Rocket Range, is envisaged. Additional simultaneous launches from remote sites such as Gillam, MB, and Eskimo Point or Chesterfield Inlet, NWT would provide additional constraints on the ozone distribution. Sounding rockets have been launched from Gillam and Chesterfield Inlet in the past, using portable launch equipment. (Is this true?)

The launches must take place when both the Sun and the Moon are at least 15° below the eastern horizon, or 10° below the western horizon, at all launch sites.

4.3 Parachute deployment

High-altitude parachute deployment from the Orion apparently has a history (e.g., the International Ozone Rocketsonde Intercomparison, Wallops Flight Center, September 1978) and thus should not pose undue risk. The key requirements for the parachute are relatively slow descent and very slow but non-zero payload spin, of the order of 1 rpm through the stratosphere. It is additionally required to stabilize the payload beneath the parachute as early as possible.

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5 Flight operational schedule, ground support, data acquisition

Akjuit Aerospace will be responsible for provision of launch support, including finning and launching the rockets, recording and decommutating telemetry, and recovering the payloads. Full telemetry recording is required to minimize the risk of data loss.

6 Work breakdown and schedules

6.1 Conceptual design phase (Phase A)

See attached pages.

6.2 Engineering design phase

See attached pages.

7 Budgets

See attached pages.

8 Risk analysis and management plan

TBD

9 Anticipated benefits

9.1 Canadian space science

TBD

9.2 Industry

TBD

9.3 Public at large

TBD