## SITE TESTING FOR A FAR-NORTH OPTICAL/INFRARED TELESCOPE

Brad Wallace,

Defence Research and Development Canada

# Eric Steinbring, Greg Fahlman, Brian Leckie, Tim Hardy, Murray Fletcher, Marcel Pennington, Kris Caputa

National Research Council of Canada, Herzberg Institute of Astrophyiscs

# **Ray Carlberg, Bryce Croll**

University of Toronto

# Dell Bayne, Bruce Cole

Environment Canada

## **Paul Hickson, Thomas Pfrommer**

University of British Columbia

# **Stefan Thorsteinson**

Royal Military College

#### ABSTRACT

Earth-observing satellites are often placed in sun-synchronous, polar orbits. Such orbits converge near the Earth's poles, allowing a high latitude space surveillance sensor to perform high-cadence monitoring of the orbit and status of these spacecraft. A high latitude optical/infrared sensor would complement existing space surveillance radar sensors, but has not been seriously considered due to the lack of a potential site. Recently, a small number of astronomical observing sites, possibly suitable for placement of optical and infrared sensors, have been identified on Ellesmere Island in Canada (latitude 82 degrees North). Three of these sites, located above the local inversion layer and on mountains near the coast, are undergoing initial assessments using wind-powered environmental sensors and sky monitoring cameras. This paper will discuss the site testing equipment and plans, review some initial results, and briefly discuss the potential benefits for both astronomy and surveillance of space.

#### 1. INTRODUCTION

The infrared (IR) spectrum provides information on resident space objects (RSOs) that is complementary to data obtained from the optical, ultraviolet, and radio wavelengths. While the use of the IR for observing during daylight is an advantage ([1], [2]), the true benefit comes from the use of the IR data to help characterize and monitor the objects. Work in this area has used both space-based ([3][4][5]) and ground-based ([6][7][8]) sensors. While space-based assets have significant advantages due to being above the atmosphere, ground-based observatories have other significant benefits, including the ability to relatively easily repair and upgrade instruments.

The most capable ground-based IR sensors are astronomical observatories located at a handful of mid-latitude sites such as Chile and Hawaii. The benefits of these sites come from rising above the inversion layer, sitting above most of the atmosphere, and being under cold, dry skies. It has long been noted that regions of the Antarctic should also have these characteristics, and also have the added benefit of long uninterrupted nights [9] and a lack of high-level winds; as a result, the potential of the Antarctic for astronomy has received significant attention over the last several years. The expectation that the cold, dry air in Antarctica would be conducive to unparalleled seeing has been validated at Dome-C [10], and studies have shown that the infrared background and infrared transmission are also

exceptionally low (see [11] and references therein). The conditions are, in fact, such that an infrared telescope located at Dome-C would provide data comparable to a telescope 2-3 times larger that is placed at the best midlatitude sites.

Given the benefits of infrared sensors for Space Situational Awareness (SSA), it is logical to ask whether there are any benefits to placing IR SSA sensors in Antarctica. This line of speculation is pre-empted, however, by the Antarctic Treaty which states "There shall be prohibited ... any measure of a military nature" [12] and could have ended there except that many of the desirable observational qualities of the Antarctic are likely also found in the Arctic.

An initial investigation of cloud cover over the Arctic regions [13], using a coarse (1 km) spatial resolution, encouraged a group of astronomers to begin a campaign to better characterize the sky and environmental conditions of a small number of sites on Ellesmere Island in northern Canada. While the initial results of these efforts will be discussed later in this paper, it is worthwhile to note that - in addition to any advantages these sites might have for astronomy – they offer two benefits from a SSA point of view: there are no treaty obligations that limit use of the Canadian arctic for military purposes, and Canada has a long and continuing history in Surveillance of Space (SofS) [14].

So, returning to the question of whether there may be value to placing an IR SSA sensor at a high latitude site, it is useful to note that Earth-observing (EO) satellites are often placed in sun-synchronous, polar orbits. These Earth-observing satellites – often termed reconnaissance satellites when used for military purposes – offer both strategic and operational benefits to the user, and may pose threats to those being observed; as such, there is a benefit to being able to regularly monitor the position, status and actions of EO satellites. Since polar orbits converge near the Earth's poles, high latitude space surveillance sensors are able to observe these spacecraft nearly every orbit. Such sites are therefore ideal for high-cadence monitoring of the orbit, status, and actions of these spacecraft; as such, the answer to the question "is there value to a high-latitude IR SSA sensor" is undoubtedly "yes," although the practicalities of its operation are still uncertain.

This paper will discuss the current efforts related to placing an optical/IR sensor in Canada's Far North. The paper will begin with a brief discussion of the astronomical justification for placing an optical/IR telescope at such a site, and will be followed by a discussion of some of the issues specific to placing a SSA sensor at such sites. The paper will then segue to an overview of the initial efforts and results in site characterization, and will end with a discussion of the current strategy for going forward.

# 2. JUSTIFICATION FOR A FAR-NORTH SITE

The effort to characterize the candidate sites is being conducted jointly by astronomers from the National Research Council of Canada, Canadian academia, and Defence Research and Development Canada (DRDC), with assistance from Environment Canada and Natural Resources Canada. Before discussing the effort and its results, though, the benefits – and some of the challenges – of a high latitude IR telescope for astronomy and SSA will be discussed.

#### 2.1 ASTRONOMICAL CONSIDERATIONS

The proposed sites offer two main benefits to astronomers – extremely long nights offering continuous observing, and exceptionally low IR sky background from a ground-based observatory. These themes can be seen to reoccur in the list of scientific objectives summarized below:

*Cosmology*: The understanding of cosmology – the origins and evolution of the universe – requires the ability to obtain data form objects at cosmological distances – redshifts of z = 1 -2 or higher. At these redshifts the spectral lines that are commonly observed in the optical regime are pushed into the IR, requiring a large IR telescope to detect.

*Exo-planet research:* Exoplanet research has two facets: the discovery of planets surrounding other stars, and understanding of the physics of the planets and the system origins. Discovery of the planets can be done in several ways, one of which is to monitor candidate stars and look for low-level brightness variations that correspond to passage of a planet in front of (and behind) the star, or to reflected light from the planet(s). These

observations can be enhanced by observing a candidate star for extended periods of time and looking for periodicity in the brightness signature that would correspond to the orbital period of the planet. Such observations can be conducted from space, but are limited from a ground-based observatory; a high-latitude site would enable significantly more candidates to be tested.

*Origins:* Stars and galaxies are born out of dense clouds of dust and gas. Many of the spectral lines for the molecular gas fall in the IR and sub-millimeter range and thus require IR sensors. In addition, the emission from warm dust peaks in the IR, allowing an analysis of the distribution of the dust and how it forms into stars and galaxies.

Of particular interest from an astronomical point of view is that the population of objects potentially observable from a Far North site has no overlap with the populations visible from the South Pole, and so a high-latitude site would be complementary to Antarctic observatories.

#### 2.2 SPACE SITUATIONAL AWARENESS CONSIDERATIONS

As indicated in the Introduction, the proposed location has three main benefits for SSA – a location within Canada with exceptionally low-background IR skies, high-cadence access to polar-orbiting and high inclination spacecraft, and (for half the year) long nights. In this section we highlight the benefits of a Far-North site and discuss competing practical considerations that need to be taken into account when deciding the overall value of the site.

### 2.2.1 ACCESS

As discussed above, a high latitude site is advantageous for observing polar-orbiting objects, but the satellite catalog (SatCat) contains many non-polar orbiting objects. A very basic question must first be asked: what fraction of objects in the SatCat can be viewed from the proposed sites?

To answer this question the entire SatCat for a single day – arbitrarily chosen to be March 21, 2007 - was imported to Satellite ToolKit (STK). Simple site access statistics were computed for each object as seen from a site located at 82.3 degrees North, 82.3 degrees W, and an altitude of 1400 m ("Site 12", see below). Of the 10444 objects listed in the SatCat for that day, a total of 8132 (78%) were visible with an elevation of 15 degrees or higher. The remaining objects – the ones not visible from the site – were: 1) all objects in geosynchronous orbits (roughly 700 in total), 2) about half of all mid-Earth orbit objects, and 3) 700 low inclination LEO objects.

Having access is not simply enough. Having long-duration access, enough to gain information beyond basic orbital metrics, is rather more important; Fig. 1 illustrates the range of access times. The mean access times range from a maximum of almost 800 minutes for Molniya and high inclination satellites and unsurprisingly, decreases with decreasing maximum elevation. Polar orbiting LEO objects have maximum access times that are close to 15 minutes.

The advantages of a high-latitude sensor can be seen when analyzing the access times for certain orbital classes. For example, from a high latitude site Molniya satellites can be observed both when they are located over North America and while they are over Asia, while lower latitude sites can only see the object while it is over North America.

In a similar way, both the GPS and GLONASS navigation satellites can be well tracked from the high-latitude site. Due to the semi-synchronous nature of the orbits, the GPS satellites will be seen first on one side of the sky, then the other, on successive orbits. However, while the maximum elevation of one pass will increase with decreasing latitude, the maximum elevation of the next pass decreases with decreasing latitude, quickly becoming unobservable. The high-latitude site, however, is able to observe both passes, albeit at lower maximum elevations. For example, at the site considered here, the GPS satellite SSN 25933 has maximum elevations of roughly 35 degrees on one pass and 45 degrees on the next. The same satellite observed from southern Canada has a maximum elevation of roughly 60 degree on one pass, but less than 13 degrees on the next.



Figure 1: Mean access duration vs. maximum elevation angle for all SatCat entries on 21 march 2007

Finally, consider the case of Radarsat-1, a polar-orbiting LEO. While the high-latitude site sees every pass, the southern Canada sensor sees less than half the passes. Further, the low latitude site sees passes in groups of typically three, with one high elevation and two lower elevation passes. Finally, while each of the passes at the high-latitude site are 15 minutes in duration, the lower latitude passes range from 15 minutes down to zero, depending on the maximum elevation. As a result, not only is the cadence of potential observations greater at the high-latitude site, the total observation time is significantly greater.

### 2.2.2 ANGULAR RATES

Observing an object in LEO can present a challenge for an optical/IR sensor, and even more so for a remote Far-North site. The main issue is the high angular rates associated with these objects which, if tracked, strongly impacts the complexity of the sensor.

An optical sensor optimized for deep-space objects often observes in sidereal stare mode, where the sensor tracks the sky at the same rate and direction as the background stars, and the RSO is allowed to streak through the image. For a LEO object this can present two issues. First, the high rate means that the light from the RSO spends only a short time on any given image pixel, reducing the signal-to-noise ratio (so-called "trailing losses"). Secondly, either the sensor must have a significant field of view, or the position of the object must be known to high precision, to keep the RSO in the field of view for the entire exposure. Alternatively, if the sensor tracks the RSO and allows the stars to streak ("track rate mode"), the stars will suffer strongly from trailing losses and require the RSO position be derived instead from mechanical measurements of the pointing position of the sensor. It will also require the sensor be able to track the RSO position quickly, smoothly and precisely, placing significant requirements on the sensor.

While any decision regarding the design of a sensor at these sites will largely hinge on the environmental and infrastructure issues, the angular rates cannot be neglected. The distribution of angular rates derived from the same access study as above can largely be split into two categories: LEOs, and everything else. The LEO objects – both polar orbiting and otherwise - have mean rates of typically a few hundred to 1000 arcseconds per second. Even the minimum rates (when the object is above 15 degree elevation) are typically 100-200 arcseconds per second. While certainly not impossible rates, a system that could actively track such rates would doubtless require significant power, and would be a challenge for a remote, unattended site.

The MEO and higher objects have more reasonable rates – on the order of 100 arcseconds per second or less. Such rates are easily trackable and would likely require less power. A passive "fence" type architecture may, however, make more sense as options are considered.

### 2.2.3 ILLUMINATION

Illumination issues will also play a major consideration in sensor design, but even a basic analysis appears to yield a fairly robust conclusion: specifically, that an IR sensor is favored over a purely optical one. This conclusion comes from two considerations: the distribution of dark skies during the year, and the phase angles that can be seen from the site.

The obvious first issue is the prevalence of dark skies during the year. The length of winter nights increases with increasing latitude, as does the length of summer days. At the latitude in question, astronomical twilight (sun 12 degrees or more below the horizon) is first achieved in early October and ends in Early March, while full night (sun 18 degrees or more below the horizon) is achieved in late October and ends in late February. Thus, for 4 months of the year the sensor would be in total darkness, but it would also spend an equal time in total daylight. Since optical observations require reflected sunlight from the RSO and dark skies above the sensor, optical observation would be possible in good weather anytime during the winter, but would not be possible at all in the summer months. This dichotomy would limit the utility of the sensor for regular use.

The other factor is related to phase angles. The phase angles that are available to a given object are highly dependent on the object's orbit, and are often not ideal. For example, an object in a dawn-dusk sun-synchronous orbit will have sun-object-sensor phase angles that are typically near 90 degrees (a fully illuminated object would have a phase angle of 180 degrees). Alternatively, a LEO in a noon-midnight sun-synchronous orbit would have a maximum phase angle near 180 degrees just as goes over the horizon, but this would be at the greatest slant range and through the maximum airmass. When the object is at the minimum slant range, the phase angle would be closer to 90 degrees. GPS satellites would follow a similar pattern, but the increased distance to the GPS satellites would increase the severity over LEO objects.

Reviewing these results, the annual illumination effects (i.e. the 4 months darkness and 4 months daylight, with 2 month transitions between) argue strongly – indeed all but demand – an IR sensor that can observe during daylight. The phase angle considerations also argue for IR, since in the thermal IR the objects are self-illuminated and do not depend upon reflection from the sun, but the argument here is less strong since LEO objects are relatively close. This result is neither surprising nor a deal-breaker. Indeed, the best use of such a site is one that best exploits the unique capabilities of the site. As such, from a simple utility point of view, it would be best to place an IR sensor at the site to obtain SSA information instead of e.g. simple orbital metrics.

#### 3. SITE SELECTION

As noted in the Introduction, the initial impetus for investigating the Arctic for potentially suitable sites for astronomy came from the growing recognition of the excellent skies in the Antarctic. The Canadian Arctic – particularly the Northwestern coast of Ellesmere Island - has many mountains with summits rising above 1000m, and at 2616 m the highest peak, Mount Barbeau, is almost as high as Cerro Pachon in Chile (2715m). An investigation of the height of the inversion layer in the Arctic thermal inversion height [15] measured this as 1400 m or less, below many of these peaks. The clear-sky fraction estimated by [13] – although coarsely sampled – suggests that many of these sites could be clear 70% of the time or more.

Beyond the dark IR skies and long Arctic nights discussed previously, other considerations that make these sites potentially attractive include:

- A solid (rock) foundation on which to locate a sensor, unlike the Antarctic or Greenland glacial plateau
- Remarkably consistent weather patterns, with winds almost always from the west.
- From continuous weather records going back roughly 50 years (available for Eureka (80N) and Alert (82N) on Ellesmere Island) daily temperature normals are very stable: -40C for winter and 5C in summer. In addition, the whole of the High Arctic is polar desert, with annual precipitation less than 9 cm (occurring primarily in summer). For Alert, precipitation is less than 10 mm on average in February [16].
- Ellesmere Island is generally situated inside a hole in the aurora, with the aurora generally appearing in the southern sky

Although the infrastructure available is predictably sparse, Ellesmere Island is not without human habitation. The most Northerly settlement is at Grise Fiord (76 degrees N, population c. 100). Environment Canada operates a Weather station at Eureka (80 degrees N) which is able to communicate via Geosynchronous communications satellites, and the Canadian Forces has a station at Alert (82 degrees N) which is linked via microwave transmitters to Eureka. Civilian access to these locations is typically by turboprop airplanes, Twin Otter bushplanes, and Bell 206L and 407 helicopters; each of these modes of access can carry up to about 500 kgs (passengers + cargo). Larger military aircraft are active in the region but are not typically available for civilian use.

Fourteen mountain peaks on Ellesmere Island were initially identified from digital elevation maps as being "of interest" based on three criteria: 1) they had latitudes greater than 80 degrees, 2) they were within 100 km of the coast, and 3) they were not within ecologically protected areas. Since the winds on Ellesmere Island come predominantly from the West, attention was focused on peaks on the western edge of Ellesmere Island. Four sites were identified, the highest of which is almost 1900m in altitude (Table 1). A preliminary clear-sky analysis suggests that the sites may be available as much as 70% of the time.

An initial visual site survey indicated that the true peaks of the mountains did not provide safe access. Safe locations were identified near Sites 11, 12 and 14; Site 13 was viewed as not as attractive and financial issues limited the number of sites that could be equipped. The sites that were chosen for the equipment were identified based both on safe access and on the ability to safely anchor the testing equipment (described below). Sites 11 and 12 have long ridges running from the peaks to the Northwest, and it was decided to place the equipment on these ridges. Equipment was initially placed on Sites 11 and 12 in 2006, with similar equipment placed at site 14 in 2007. In addition to the standard suite of equipment, Site 14 was also populated with an all-sky camera, identical to that being deployed for Thirty Meter Telescope site testing.

## 4. SITE TESTING EQUIPMENT

The site testing philosophy is straightforward: take the measurements that are (relatively) easy to make first and then, if results are promising, add equipment as justified. This approach has the added benefit that lessons learned from previous field years can be used to improve the equipment being fielded for future years. Following this philosophy, the site testing process has begun with the collection of simple environmental information (temperature, winds, etc) along with sky images; more sophisticated measurements, such as seeing etc, will be considered for future years.

The logistical and environmental challenges posed by the sites themselves are significant. Given the transport helicopters available, the equipment could mass no more than about 200 kg, has to be loaded internally within the helicopters, and be movable by two people. Further, environmental protection considerations dictate that the environmental footprint be minimized. These constraints led to the development of a very basic and compact system that would run on batteries that would be charged up by wind power (solar panels being useless during the 4 month long winter nights).

Each site testing station includes:

- A Campbell Scientific CR10X weather monitoring system with probes for temperature, relative humidity, barometric pressure and wind direction and speed. This system measures samples every 5 seconds except for pressure, which is sampled every hour. Every hour the 5 second samples are averaged and stored to flash memory.
- An Axis 221 wide-angle, horizon-pointing, optical/near-infrared camera in a Pelco enclosure with window defroster. The camera has 640×480 pixels and automatically adjusts exposures up to 2 seconds. Power is applied to the defroster 5 minutes before a planned image sampling (every hour) and stores the image to flash memory.
- A "hardened" computer for system control,
- A flash-based data drive,
- A Motorola 9522A 2400 baud Iridium modem with antenna for communications, and
- An Ampair 100 wind-turbine recharged central glass matt battery pack for power.

All the equipment is packed together with the batteries to help keep the batteries warm. The stations are designed to be modular so that equipment is field-swappable with another station, and are able to be extended with additional equipment.



Figure 2: Two of the Inuksuk stations, one on rock, the other on snow.

When fully assembled the stations have an appearance reminiscent of stone way-markers used by the indigenous people in Canada's north; these way-markers gave the stations their names – Inuksuks (Fig. 2). The equipment on each Inuksuk station is mounted on aluminum tripods that are anchored with piles of boulders at Sites 11 and 12. At Site 14 the tripod is anchored via a 1 m  $4\times4$  that is placed into a hole in the snow and ice that is created using a powered ice-auger; as the snow that is tamped around the  $4\times4$  freezes the post becomes secure. For additional support during windy conditions guy-wires were attached from the tripod to snow pickets. The snow at Site 14 was measured to be between 1 and 2 meters deep over hard ice, with rock probably not far below, suggesting that a small telescope or seeing monitor could be anchored into the rock at this site.

The stations at Sites 11 & 12 had a wiring flaw that led to battery failure just as nautical twilight began in 2006, drastically reducing the available data for that year. As the sites are inaccessible during the winter, the problem was fixed for the 2007 campaign.

Site 14 – the highest site – had an additional piece of equipment – an all-sky camera that has been dubbed "Ukpik." The Ukpik instrument consists of a  $1024 \times 1024$  pixel SBIG STL-1001E CCD camera mated to a Nikon F2.8 8mm fisheye lens, with a cold-hardened PC with two external 80GB hard drives. The images are collected once per hour and are stored on separate hard drives on alternating days.

Name	Longitude	Latitude	Peak Altitude	Equipment	Inuksuk	Ukpik	Status
	(degrees W)	(degrees N)	(m)	Altitude (m)			
Site 11	82.12	83.4	1720	1098	Yes (2006)	Yes (2008)	Operating
Site 12	82.3	82.3	1402	777	Yes (2006)	No	Decommissioned
							2008
Site 13	81.9	80.7	1696	N/A	No	No	N/A
Site 14	82.3	80.5	1868	1639	Yes (2007)	Yes (2007)	Ukpik Failed

Table 1: Locations	and sta	tus of test	sites
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Completely cloudy

Mostly cloudy

Mostly clear

Completely clear

#### Figure 3: Examples of horizon camera images and associated classification.

The stations are designed to "phone home" once per day, and the weather data and a low-resolution version of the horizon camera image is transmitted. The stations are configured to call out during windy conditions, but during calm periods the radios are put into sleep mode to conserve battery power. Using weather data from nearby weather stations, a computer model was developed to predict when the stations should call out again; this model was used to monitor the basic status of the stations. Lack of a call-out does not presage disaster, however; during the winter of 2006 the Iridium modems failed, but the Inukshuk data was saved to the flash drives until the batteries failed. There was a similar occurrence in mid-winter of 2007 when the modem at Site 11 became too cold to operate for about a month. Again, all data were stored, and retrieved the following summer.

For the 2008 field year additional equipment was added to the sites. A methanol fuel cell was added to Site 11. In addition, an "Ukpik" instrument was added to the station at Site 11. The Ukpik instrument for Site 11 was improved over the previously fielded one in that it has a mechanical sliding door for weather protection, and includes a narrow-field pole-viewing camera.

## 5. PRELIMINARY RESULTS

As mentioned above, the site testing stations have over-wintered at two or more sites in 2006-2007 and 2007-2008, with new equipment being put in place for 2008-2009. The sites are currently accessible only during the summer, with the summer-2008 visit having been completed during the writing of this paper. As such, the data from the 2007-2008 winter have been collected but not analyzed. However, some general conclusions can be made even on the basis of the incomplete 2006-2007 dataset.

The very first and, in retrospect, obvious conclusion is that the equipment setup itself introduces a bias into the data. As noted, the weather data is collected all the time, but the horizon camera only takes data when there is power from the wind turbines. This introduces a strong bias to take sky imagery during windy periods. The general trend seen in the weather data is that – roughly weekly - there are two days of strong westerly winds (roughly 27 m/s) with associated inclement weather followed by low winds and favorable weather. The bias towards taking images during windy periods results in a bias to taking images of cloudy skies. However, since the weather data is taken all the time, this bias can be taken into account.

The hourly horizon-camera images from Site 12 were inspected by eye on a frame-by-frame basis. The images were classified as "completely cloudy," "mostly cloudy," "mostly clear," and "completely clear;" foggy conditions were classified as completely cloudy. Sample images are shown in Fig. 3.

The clear sky statistics are plotted versus wind-speed in Fig. 4. From this plot it is clear that there is a correlation between low wind-speed near the ground and clear skies. Specifically, even including the bias towards taking data during cloudy periods, skies would be mostly or completely clear almost 70% of the time that the winds are below 1.5 m/s, and completely clear 40% of the time that the winds are below this cutoff.



Figure 4: Sky condition distribution as function of wind speed.

Expanding on this trend, 97% of the clear-sky images were taken when the wind-speed was less than 1.5 m/s. Given that the cloudy skies (high wind conditions) are seemingly much better sampled than the clear skies (low wind conditions) it seems very likely that the un-sampled skies are highly likely to be clear. This gives us confidence that the true clear-sky fraction is significantly greater than shown here. At the very least, these data support the expectation, from the satellite data, that the clouds clear very quickly after a weekly two-day windstorm, suggesting a clear-sky fraction of perhaps 70%.

#### 6. FUTURE PLANS

The immediate plans are to analyze the recently retrieved winter 2007-2008 datasets from the three sites. As noted previously, the system at Site 12 was damaged during the last winter, so it is not clear how much useful data was collected and survived. The dataset from Site 11 appears to be complete though, so this should allow a baseline to be determined.

Perhaps the most eagerly anticipated dataset, however, was the all-sky imagery form the Ukpik sensor at Site 14. Weather conditions made it difficult to retrieve the data, and when it was retrieved it was discovered that the heated window cracked in early October; images after that point are obscured by ice and snow. It is expected that the mechanical enclosure used for the Ukpik sensor at Site 11 should fare better this upcoming winter.

The fuel cell at Site 11 has exhibited unexpected signs of being fussy, so it is not clear whether it will function as planned. That said, the station has been augmented with extra batteries, and with evidence that the wind turbine is charging them it is likely that at least a minimum dataset can be expected.

In the meantime, a turbulence monitor – using lunar scintillometry - is being developed for deployment in 2009. A small, scientifically productive telescope could potentially be envisioned for 2009, but may be delayed until 2010 depending on the operations through the 2008-2009 winter. The ultimate long-term goal, of course, is a moderate to large telescope optimized to work in the thermal infrared.

#### 7. SUMMARY

A small number of locations in the Canadian Arctic are being assessed for their viability as sites for infrared astronomy and space-surveillance facilities. The high-latitude location and clear, dry skies make the site attractive for high-cadence IR observations of high inclination spacecraft, especially objects in Sun Synchronous polar and Molniya orbits. The high latitude makes the sites attractive from a contact point of view, but the high angular rates

of objects in LEO will present a challenge. While the design of a sensor that can exploit the near-unique nature of the site at the same time as it copes with the environmental conditions will be difficult, the expectation is that the sky conditions are sufficiently good to justify the effort.

A staged approach is being employed to reduce the cost of confirming the site conditions, with basic weather and clear-sky information being gathered initially with more detailed information being gathered as justified. Initial results are in line with expectations from satellite data that the clear sky fraction could be as high as 70%.

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