ROBOTIC SEARCH FOR ANTARCTIC METEORITES: 1997 TECHNOLOGY DEMONSTRATION AT PATRIOT HILLS

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1. Introduction

To address technological and operational issues related to very remote planetary exploration, robotic demonstrations in analogous environments on Earth are highly useful. Antarctica presents a close analog to planetary exploration with regards to issues of environmental survival, communication, power, navigation, and scientific research. An ideal context for robotic Antarctic demonstrations with relevance to planetary exploration is the search for meteorites and in particular for those of Martian origin.

Through tireless investigation in the harsh Antarctic environment and using computer sensing to search above and below the ice surface, robots could explore regions of Antarctica to find otherwise undetected meteorites. The use of robots could augment the human search for meteorites by working full-day cycles in the deep cold, and by detecting surface meteorites obscured to the human eye by blowing or drifting snow. In a few years, robots could find meteorites not visible to humans, overlooked by humans, or in areas challenging to the human search.

This program will demonstrate the robotic technologies developed by the Antarctic Meteorite Search Technology task in Antarctica in calendar years 1998, 1999, and 2000. In 1998, humans will validate robotic component and meteorite classification instruments. In 1999, a winterized Nomad robot developed by the Atacama Field Trial task in FY97, will explore Antarctic icefields in search of stranded meteorites and under human supervision. In 2000 a solar-powered robot and the 1999 robot will perform collaborative autonomous searches for meteorites and demonstrate control from remote scientists.

2. Objectives

The overall goal of the program is to demonstrate robotic operations with planetary analogs of environment, communication, power, control, navigation and scientific research, and is driven by the urgency for the development of robotic technology to serve near term planetary exploration. This program will produce convincing demonstrations of planetary analog robots and will promote a terrestrial scientific agenda as well.

The purpose of the first season’s demonstrations are to validate component technology relevant to future planetary missions and to evaluate sensors for automatic classification of meteorites from native rocks and not visible to humans. Carnegie Mellon proposes to perform field work in Antarctica in January 1998 associated with range and vision sensing, direct ground-to-satellite communications, and solar collection for propulsion. In the proposed Antarctic demonstration, sensor-based meteorite search experiments will validate optical reflection spectroscopy, imagery, and combined metal/magnetic anomaly detection instrumentation.

3. Justification

The proposed FY98 experimental demonstrations are justified by the need to evaluate technologies of significance to NASA's planetary exploration program in a terrestrial environment analogous to the Moon and Mars. Antarctica's lengthy diurnal cycle and remote location simulate conditions and transmission delays encountered in a mission to the poles of the Moon or the ice caps of Mars, making an Antarctic robotic exploration the ideal planetary paradigm of robotic search.

Moreover, the Antarctic demonstrations are also justified by the need to increase the rate of collection and number of collected samples of Antarctic meteorites that may be of Martian origin, in order to provide additional information on the chemical and physical composition of the surface of Mars and allow examination for additional evidence of any past Martian life. Of the 15,000 meteorites collected to date only 12 are believed to be of Martian origin. The most interesting ones have been found in Antarctica; specifically ALH84001 and EETA79001 were collected from the Allan Hills ice field and Elephant Moraine, respectively. Robotic search in Antarctica will support and dramatically extend the human search for meteorites. This program will set the foundation for complementing ANSMET's search for Antarctic meteorites by identifying meteorites in areas not visible to humans or challenging to human search using robotic techniques.

Development and evaluation of mobile robots capable of extended search for meteorites in Antarctica will further NASA's search for planetary life. Such a robotic expedition will serve as a driver for robotic technologies, a forum for demonstrating results, and a clear step toward exploration of the planets. The technical objectives of scientific exploration, environmental survival, and self-sustained mission performance are fundamental to NASA's charter in exploration and are directly relevant to the joint NASA / NSF initiative to operate in the Antarctica as an analog to the Moon and Mars.

4. Approach

This task will build upon the technologies and demonstrations of the Atacama Desert Trek and the Lunar Rover Demonstration programs. This year's top demonstration, is:

Demonstration of robotic and meteorite classification technologies in Antarctica: The goal for FY98 is to deploy, experiment, and quantify the performance of individual robot components in Patriot Hills, an Antarctic site suitable for the proposed demonstration and the deployment challenge. This effort will leverage 1997 field demonstration results of wide angle imagery and meteorite detection using magnetic and eddy current instruments. This year's demonstration includes, a new design of an ultra wide FOV camera for landmark-based navigation and sun / star tracking, a radar sensor for navigation and buried object identification, a high-resolution imaging sensor and optical spectrometer for meteorite identification, and a solar panel assembly for rover power generation. The validation of such components is deemed critical in the development of planetary analogous robots for search of Antarctic meteorites.

The following paragraphs review the technical approach of the program and detail the plans for the Antarctic demonstration of 1997-98:

4.1 Search for Antarctic Meteorites

For over four decades, scientific search teams from around the world have endured Antarctica's harsh climate and treacherous terrain in ventures that are tedious, often dangerous, and always unpredictable. Search teams can spend weeks with little or no yield — or discover hundreds of meteorites within a few square kilometers.

Today, the meteorite search strategy is based on a sound understanding of probable sites. Using satellite and aerial imagery, scientists target exposed ice bedrock migrating from the central to the coastal regions. Of particular interest are areas where this bedrock has collided with the massive transantarctic mountains to create new landscapes.

In the field, however, the human search for meteorites is largely confined to visual inspection of the surface of ice and moraines. Researchers identify meteorites, mark their locations with flags, map reference areas, and carefully collect the meteorites. Critical to this process is absolute protection against contamination; the meteorites are preserved in their frozen state and sent to ANSMET facilities at NASA’s Johnson Space Center for analysis and classification.

Meteorites vary in size, shape, and composition. While typically 2 cm to 15 cm across, meteorites as large as 1 m across have been discovered. Generally, their shape is flat elliptical or near spherical, with extruded features and a glossy brownish to black color attributed to a fusion crust. The majority of the discovered meteorites are stony meteorites, some of which contain iron or other magnetic elements. Some iron meteorites have also been found.

To detect both metallic and non-metallic meteorites, a meteorite-search robot or meteorobot, would use a variety of sensing modalities including metal detectors and magnetometers to detect iron, infrared to detect silicates, multi-spectral close-up imagery, and optical spectrometers to distinguish meteorites from native rocks. In a compact, mobile package of sensors and onboard computing, a meteorobot would acquire a complete field of data and process size, depth, geometry, and elemental composition of potential meteorites.

Once the meteorobot detected a meteorite candidate, its onboard computers would fuse sensor data and record meteorite depth, position, size, and geometry. The meteorobot would then plant a flag or place a visible marker denoting the location of the rock for subsequent retrieval by the ANSMET team. If the initial search yielded a significant number of meteorites, the robot will repeat the search of the same field for multiple seasons.

The human field team would collect the meteorites identified by the meteorobot, using electronic data (GPS location of the find, hardcopies of sensor measurements, *in situ* photograph of the meteorite, flag number, etc.) and physical marks, such as flags.

4.1.1 Meteorite classification

Humans rely primarily on vision to recognize surface meteorites. Researchers are trained to recognize meteorites by example: by reviewing samples of meteorite and non-meteorite rocks, they fine tune visual skills for on-site identification of meteorites. Meteorobots could be trained to have similar capabilities using color imagery of meteorite and native Antarctic rocks, neural nets, and other machine learning and classification techniques. Color, texture, and shape would serve as important visible features. Several of the needed vision techniques already exist and have been used in planetary exploration programs.

For Antarctica, meteorobots would be trained to use vision sensors to scan a cluster of rocks on blue ice, segmenting rock images into individual objects for automatic classification. By relying on constrained visual search, the meteorobot would cover a wider area and quickly eliminate the vast majority of surface rocks. Having down-selected the possible meteorites, the robot would closely examine each candidate and use its non-visual sensors to provide more reliable estimates of their composition.

4.2 1997-98 Antarctic Demonstration

The main demonstration for FY98 is the field testing and validation of robotic components and sensors for identification of meteorites at Patriot Hills, Antarctica, in January 1998 (Attachment A). A field team from Carnegie Mellon University, NASA Ames Research Center, University of Pittsburgh, and the Antarctic Chilean Institute (INACH) will establish a base camp at approximately 80 deg 18' South - 81 deg 16' West and operate for four weeks. Field work and experiments will be carried out primarily in areas of exposed blue ice.

4.2.1 Robotic Component Experiments

Wide-Angle Imagery: This experiment will validate the performance of a 360 deg FOV panospheric camera in Antarctic conditions. The camera will be evaluated based on the quality of acquired panoramas in low contrast and high brightness. The use of such a camera as a sun tracker for absolute heading, a means for acquiring skylines for position estimation, and a visual means to track local terrain features for use as landmarks for navigation appear promising. During the field experiment, panoramic images will be acquired with the camera placed at appropriate locations.

Radar: The Antarctic environment can be treacherous for navigation, with ice fields of unknown stability and rigidity. A radar sensor can map ice and snow terrains, and unseen features under the surface such as crevasses. The depth of penetration and the echo profiles can provide needed traversability information to the navigation subsystem. As well as mapping out the nearby region for navigation purpose, a radar sensor can be used to detect buried objects. This capability is needed to locate potential meteorites beneath the ice surface, both for purposes of scientific study and navigation. This experiment will evaluate the resolution and accuracy of a radar sensor in detecting obstacles and localize stony artifacts buried into the ice. The current sensor configuration incorporates antennae of two different frequencies. The depth of penetration and the echo profiles will be recorded for each type of surface. It will also be tested to detect unseen features under the surface, such as crevasses.

Solar: The solar power experiment intends to quantify the solar power output in Antarctica. To do that, a small device will characterize power output vs. time of day, solar panel angle and different loads. It will also estimate the snow accumulation effect on the performance of the power system. The experiment will be set at close proximity to the base camp and will run continuously for the duration of the expedition. The solar illumination environment in polar regions is a challenging one. Power levels can be influenced by local terrain features, atmospheric conditions, and snow accumulation. A solar power system that can function in this environment will be developed.

Communications: The transmission and reception of digital data through a low-orbit satellite constellation will be evaluated in terms of data rate, duty cycle, and power consumption. Technology that will enable the meteorobot to communicate directly with satellites will be developed. This independence from a fixed lander platform will become necessary as planetary missions increase their range requirements. This experiment will determine satellite coverage and data transmission rates. The digital transmission and reception of digital data through a low-orbit satellite constellation will be evaluated in terms of data rate, duty cycle, and power consumption.This experiment involves setting up a portable transmitter at close proximity to the camp and monitoring data transmission rates.

GPS Positioning and Orientation experiment: GPS receivers will be tested to evaluate the availability and accuracy of their readings. Also, a differential GPS-based system to provide high precision readings. The attitude (pitch, roll, yaw) will be sensed with a multi-antenna system, to be compared to a magnetic compass readings.

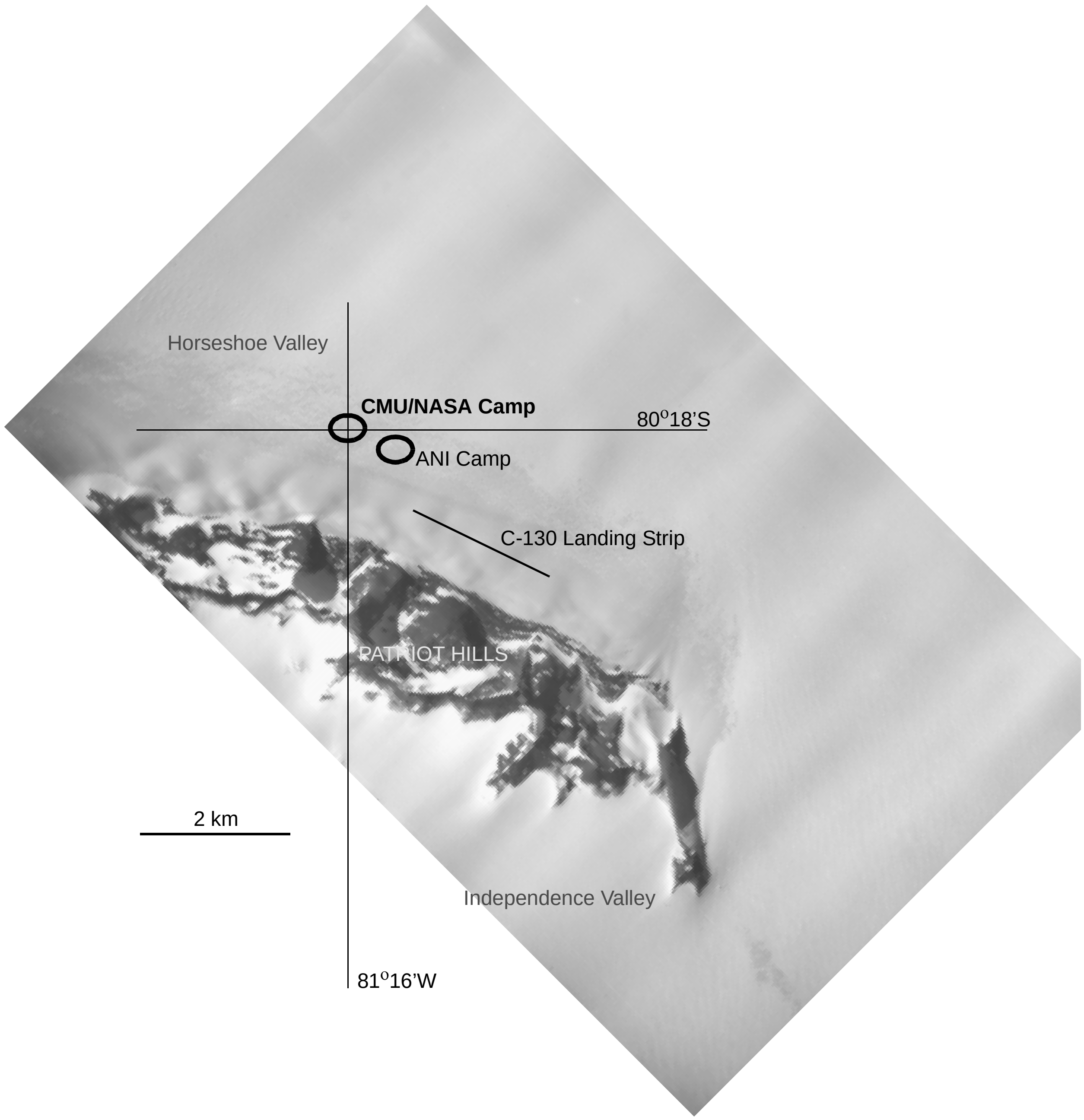
4.2.2 Automatic Meteorite Search Demonstration

To detect metal bearing meteorites (this includes most stony meteorites), meteorobots will use a suite consisting of a variety of sensing technologies. In a compact, mobile package of sensors and onboard computing, a robot could acquire a complete field of data and process gradient, total field, or magnetic tensor data. In FY98 this task will validate the selected sensors for detection and classification of meteorites, and will ruggedize them to be deployed by a mobile robot. The proposed expedition at Patriot Hills includes the following experiments:

Reflection Spectroscopy: This experiment will evaluate the viability of field reflection spectroscopy for the purposes of discriminating meteorites from other Antarctic rocks and remote sensing of rock mineralogy. The spectrometer foreoptics and a digital camera will be mounted on a pan-and-tilt mechanism at the top of a tripod. The spectra-radiometer will be contained in a flight box. Every time a sample is identified, the team will use the spectrometer to acquire spectral data and collect the sample.

High-resolution Imagery: The purpose of this experiment is to verify the ability of robotic-relevant cameras to acquire images of low contrast, dark objects (rocks and meteorites) in the bright conditions of Antarctica, and gauge ice and debris accumulation on optical surfaces. The digital camera will be set up at a permanent outside location, continuously powered and kept at operating temperature.

ANTARCTIC DEMONSTRATION 1997-98
PATRIOT HILLS FIELD CAMP PLAN



Antarctic Meteorite Demonstration for January 1998

Experiment	Base Camp vs. Field	Time	Power & Other Needs
SOLAR	Camp- Outdoors	2 hr set-up 0.5 hr/day	Self-contained Battery continuous Flight box on ice
PANOSPHERIC	Field: 10 panoramas x 500 m Camp: 300 panoramas x 0.3 m	1 hr set-up 1 day - field 7 days - camp 7 hrs/day	300 W @ 120 VAC Generator or battery Flight box on Banana sled Camera on tripod
RADAR	Field 1 km from camp, many sites	0.5 hr set-up 10 days - field 8 hrs/day	Flight box on 2nd Banana sled. Generator or battery
COMMUNICATIONS	Camp - Indoors	7 days - tent 8 hrs/day TDRSS availability	30 W continuous Battery continuous
GPS	Camp - Outdoors	10 min set-up 2 days 8 hrs/day	Equipment on Mountainsmith sled 7.5 W + computer Battery continuous
SPECTROSCOPY	Camp: Calibration Field: Data Collection; 200 samples	20 min/sample 14 days in the field 7 days w/ Field Search 7 days - 1 km from camp	730 Whr @12 VDC 190 Whr @ 120 VAC Flight box & battery pack on Banana sled
IMAGING	Camp - Outdoors	2 hr set-up	26 W continuous Camera on tripod
FIELD SEARCH	Field	7 days w/ snowmobiles	Field equipment. Fuel for snowmobiles.

Antarctica97-98 SOLAR Experiment

Stewart Moorhead, Ben Shamah

Purpose

To characterize the operations of solar panels for power generation in the Antarctic environment where sun elevations remain fairly constant and low and temperatures are in the -20 to -10 degree Celsius range. The characterization will be performed in preparation for the construction of a solar powered robot for use in the Antarctic Meteorite Search program in Dec. 1998.

The experiment will characterize the power output vs. time of day under three loading conditions: regular resistive load, high current resistive load (i.e. low resistance), and battery charging. The experiment will also investigate the rate of snow accumulation on the solar panels as well as the effects on power generation with varying thicknesses of snow.

Deliverables

The experiment will return the following pieces of data:

- recording of the average power output at 30min intervals for 5 days on each load (i.e. the power will be averaged for 30min and recorded with a date/time stamp, ambient temperature and load used. Each load will be tested for 5 continuous days)
- the rate (mm/hour) of snow accumulation on the solar panels due to natural mechanisms
- the power vs. snow thickness relationship

Setup

The experiment will use 4 Siemens SM10 (10W) solar panels connected in s square to collect solar power. The square will allow power to be generated 24 hours a day without any re-alignment from a human operator. The solar panels will be connected to a control box which contains the 3 loads (including the batteries), a Motorola 6811 controller board for data collection, a temperature sensor, user interface (i.e. 4 switches, a button and serial port) and possibly a heater.

The 6811 controller board will read the voltage level generated by each panel across the currently selected load using a built in A/D port. These 4 voltages will be recorded along with the ambient temperature, the date, time of day and load in non-volatile RAM or EEPROM. Sufficient memory will exist to store all data collected.

The user interface will be quite simple. Three toggle switches will be placed to select the load (regular, high current, or battery). Another toggle switch will exist to turn the experiment on and off. A serial port will allow a laptop or other PC to be connected. The contents of the 6811 memory can be downloaded by pressing the push button.

It may be necessary to include a heater in the control box to regulate the temperature for the electronics. This will be controlled by a thermostat or another temp. sensor and the 6811

Procedure

The experiment has been designed to minimize the need for human intervention. The first day of the mission will have the solar panels set up and test data recorded and downloaded to an external PC for analysis. Once the system has been checked out, the regular load toggle switch will be selected and the unit will commence collection of data. For the snow gathering experiment a human will need to come and check the thickness of snow coating the panels every hour (this may be reduced if the field team feels it necessary). The snow will be cleared off at this time. After 5 days with the regular load it will be switched to the high current load. The same procedures will be followed. Finally after another 5 days the load will be switched to battery. After 5 days of battery, the field team will then deliberately put snow on the panels at varying thicknesses. The snow thickness will be recorded and the power output can be read from a PC connected to the serial port. readings will be with the regular load selected.

The contents of the 6811's memory will be downloaded every 5 days and verified on site or in Pittsburgh to ensure that it is still working. This frequency can be increased time permitting. However, the non-volatile nature of the 6811's memory means that all of the data collected will remain intact, even when power is lost during shipping and thus serves as a backup.

Antarctica97-98 RADAR Experiment

Alex Foessel

Objectives

- Evaluate the utility of radar for use as tool for detecting buried meteorites and objects in ice, and to characterize the surface and subsurface compositions, detecting ice and snow layers.
- Evaluate the utility of radar as safeguarding and navigation tool, by its ability to detect obstacles and crevasses, and providing information to map the terrain ahead.

Description

The experiment consist in bringing a radar transducer to Antarctica, where it will be tested against buried objects and meteorites with know characteristics and depths in a known area. Radar echo profiles are recorded to construct subsurface object maps. Each profile is a set od echo recording over the test area.

The sensor will also be used to characterize the subsurface composition, detecting layers of ice, snow, and rock where this composition is known. Also profiles will characterize a known area.

Finally, tests with different incidence angles will allow to evaluate the detection of obstacles and crevasses in front of the sensor.

In each test, the test area is known, and the data will be analyzed (fully after the experiment) and compared to the reality to obtain a measure of performance of the sensor at object detection, and safeguarding tool.

Deliverables

The Antarctic phase of the experiment will return the following data:

- Profiles of radar echo over a known area with precisely located buried objects, specifically meteorites and rocks, at different depths. The antenna will be placed at different heights with respect to the surface to characterize signal coupling.
- Profiles of radar echo over areas with known subsurface layer composition, and different configurations of ice, rock and snow layers.
- Profiles of radar echo with non perpendicular angles against snow/ice obstacles. And also against crevasses.

The profiles are defined as a set of data taken at equal intervals in a 2D grid. The pattern is repeated to obtain data with different polarization, to evaluate its relevance in object detection.

Setup

Radar hardware:

- Radar antenna
- Antenna mounting kit
- Radar transducer
- Radar acquisition system
- Preprocessing computer and storage media
- Differential GPS system for ground truth
- Attitude system

Field elements:

- Measure tape and sticks
- Shovels
- Bamboos and flags to mark a test area

- Markers to define test points

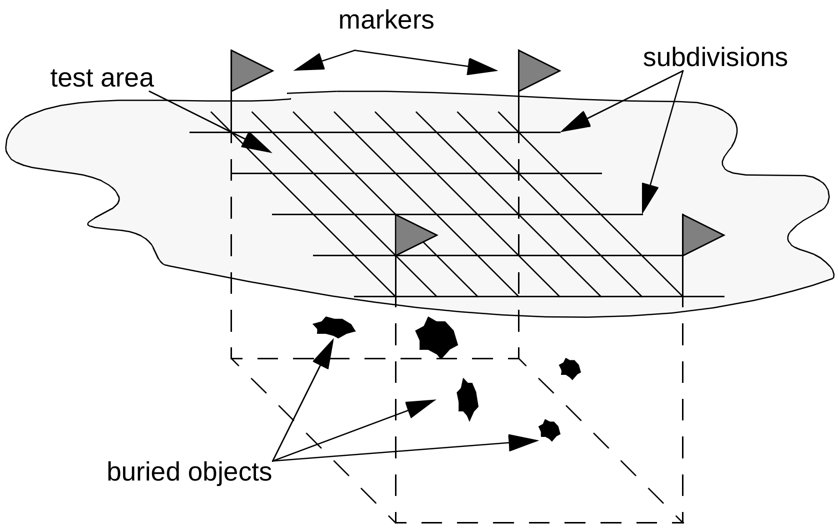
Procedure

Buried Meteorite and Rock Detection:

A test area is defined in a place with soft composition (snow). This area is divided into equal squares. The dimensions of the area and subdivision are defined according to the beamwidth, and the distance resolution of the radar equipment. Objects are buried at know depth and positions. These objects should consist of meteorites and rocks of different sizes. The position, size, and composition of each item are recorded.

The radar emits over each point defined in the test area, with a fixed antenna height over the surface. Each echo is recorded in digital form, and the full set of recordings is considered a test area profile, that has information of very point defined in the area. The same procedure is performed at different heights to evaluate antenna-surface coupling.

All the information is copied in to another storage media as a backup measure.



Subsurface Composition:

Another test area is defined over an ice field with a snow layer in top of it. Core samples are taken to characterize the layer structure of the area. The results are recorded for later use.

A similar subdivision is defined, and the radar is operated over each point, thus obtaining profiles of this area. The height is also changed to study the changes in sensitivity with respect of radar signal coupling.

Obstacle Detection

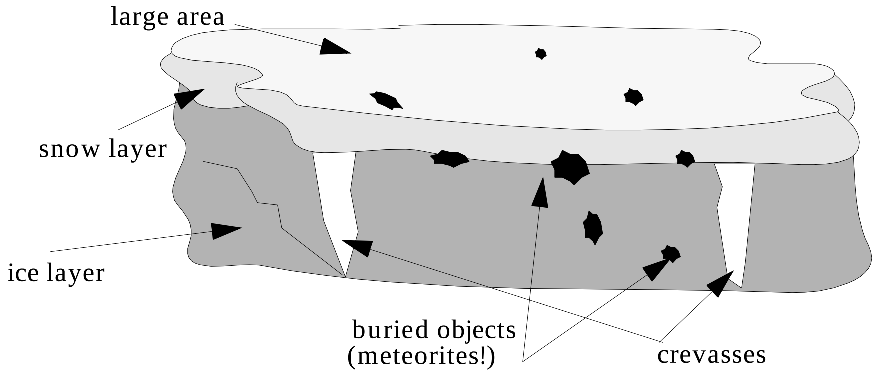
The radar is used this time against objects at a known distance. The usual wavelength will be reflected at the same angle of incidence, therefore a flat surface will be invisible to the radar signal. However, obstacles as crevasses, holes, and ice walls present a surface that will reflect some of the beam energy, thus being detectable.

For this experiment, suitable obstacles are selected. Points at different distances are defined, the distance, size and any noticeable features are measured. This data is recorded for later use.

The radar is positioned at each test point, and aimed ar different angles towards the obstacle, to characterize its performance at detection.

Antarctic Meteorite Search with Radar

How to *3D* map THIS in Antarctica?

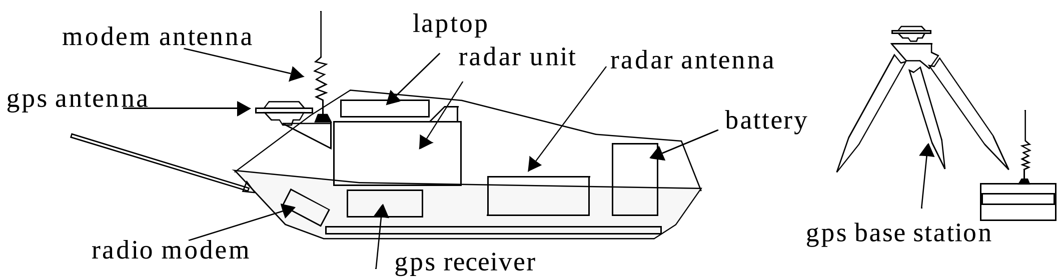


Use Ground Penetrating Radar

- Penetration with cm resolution to detect meteorites and objects
- Precise radar data positioning with cm accuracy GPS system.
- Radar data stamped with position and time to build 3D maps
- Detection of strata composition (glaciology) and voids
- Crevasse detection (robot safety on the ice field!

Equipment: Sled

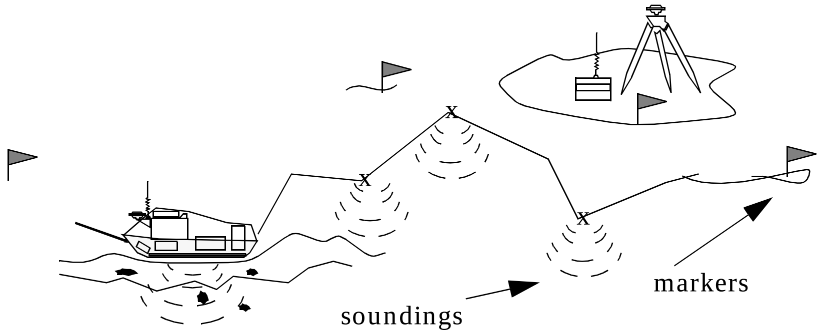
- Pulled by a person or snowmobile
- Bottom and top insulation for cold environment operation
- Carries Ground Penetrating Radar (1GHz)
- Differential GPS, base station within 10 Km
- Battery power (10 hours of operation)
- Radar acquisition: radar A/D sampling, 500 samples/radar pulse, 5 pulses/s



- GPS acquisition: serial, 1 Hz update rate, accuracy 1 cm hor, 2 cm ver, 1 ms time
- Data storage: 10 hours limited, transfer to file server at camp, tape backup

Field Operations (this season)

- Identify area of interest, mount base station, mark area
- Man powered or snowmobile powered operation according to extension
- Characterize visually the terrain
- Core samples in test points for data comparison, location of crevasse



Post field activities, data processing

- Data filtering (noise out)
- 3D map data integration (using positioning)
- Deconvolution of radar data
- Object recognition, crevasse recognition
- Strata characterization

Other related experiments for this antarctic season

- GPS characterization
- GPS as heading sensor
- Magnetic compass performance
- Inclinometer and vertical gyro performance

Integration to Robot (98)

- Integrate system with Nomad, next generation Nomad
- Feed obstacle (crevasse) detection to autonomous navigation
- Feed radar data to science system
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Antarctica97-98 PANOSPHERIC Experiment

Matt Deans, Eric Rollins

Objectives:

- Evaluate the utility of the panospheric camera for use as an imaging system for use in the Antarctic Meteorite Search project in 1998 as a tool for teleoperation, autonomous landmark based navigation, skyline position estimation, remote science or other purposes.
- Evaluate the utility of the panospheric camera for use as a sun tracker or visual compass to provide a means of computing absolute heading at any time.

Description:

This experiment will occur in two phases. One phase will occur stateside, and includes extensive camera calibration, tests of compression schemes, tests of skyline extraction and position estimation, and tests of autonomous position estimation by tracking natural landmarks in panospheric images. The other will be a data collection phase in the Antarctic.

Deliverables:

The Antarctic phase of the experiment will return the following data:

- Light levels at various times during the day, in shadow and direct sunlight, on blue ice and in moraine areas. Dynamic range of ambient light will be measured and recorded.
- Quantitative measures of image contrast using an entropy measure calculated from the histograms of images acquired by the panospheric camera. Measurements will be made with various filters or filter combinations in an attempt to improve image quality.
- Quantitative measures of the blooming effects of the CCD used in the camera, as well as quantitative measures of the glare induced by internal reflections within the cylindrical glass housing and more importantly glare from reflections off of blue ice. Measurements to be made for various integration times, especially some with extremely short exposures for sun tracking.
- Images tagged with position ground truth and archived for use in tests of skyline based position estimation. These archived images will also be used in testing of compression/ decompression algorithms. Sequences of images will be tagged with position ground truth and archived for use in testing landmark based position estimation.

Setup:

The Panospheric experiment will require the following hardware:

- DALSA CA-D7 12-bit digital monochrome CCD camera
- Panospheric imaging optics and mounting hardware:
  - camera lens
  - spherical mirror
  - cylindrical glass housing
  - aluminum enclosure
- Filter kit
  - ND 3.0 and ND 2.0 for sun tracking
  - Polarizers (linear and circular) to cut glare
- Bitflow Data Raptor PCI framegrabber
- Dual pentium PC (atacama.frc.ri.cmu.edu)
- Dual axis inclinometer with M68HC16 based serial interface
- Trimble differential GPS

- Light meter
- Tripod

Procedure:

- On the first two days of testing with the panospheric, images will be acquired and several measures of image quality will be made from the histogram, including histogram entropy and populations of saturated and underexposed pixels. Exposure times and filter combinations will be varied to determine the ability to improve contrast and dynamic range. Polarizing filters will be used to collect panoramas with the filter on and off axis to determine the usefulness of a polarizer for reducing glare due to specular reflections off of ice and internal optics.
- After initial configuration testing with the camera, ten different panoramas will be recorded and tagged with position ground truth from dGPS, Each panorama should be at least 500 meters from all other panoramas. These panoramas will provide data for testing of skyline position estimation.
- Ten different sequences of panoramas will be recorded, five on relatively clear blue ice and five in feature rich moraine areas. Each sequence will contain 100 images, collected 0.3 meters apart, for a total traverse of 30 meters. Each frame will contain position ground truth from dGPS.
- Panoramic images will be acquired using a high index neutral density (ND 5.0) filter and fast shutter in an attempt to minimize blooming in imaging the sun’s disk. This is crucial for accurate localization of the center of the sun’s disk for use in sun tracking.

Issues/concerns:

It is likely that the change from warm moist conditions to extreme cold will cause heavy condensation inside the camera optics. This problem can only be dealt with by keeping the camera warm and dry in an environmentally closed container with dessicant and waiting for the lenses to clear.

Antarctica97-98 SPECTROSCOPY Experiment

Liam Pedersen

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PATRIOT HILLS