MARS Exploration Design Challenge

Sub Module 2:
Remote Sensing

The technology of modern remote sensing began with the invention of the camera more than 150 years ago. Although the first, rather primitive photographs were taken as "stills" on the ground, the idea and practice of looking down at the Earth's surface emerged in the 1840s when pictures were taken from cameras secured to tethered balloons for purposes of topographic mapping.

What is Remote Sensing?

It's any technique for measuring, observing or monitoring a process or object without physically touching the object under observation. Optical and radio telescopes, cameras, even eyesight, are types of remote sensing.

Remote sensing instrumentation is not in contact with the object being observed, remote sensing allows the monitor to:

- Avoid hazardous or difficult to reach regions, such as inside nuclear or chemical reactors, in biological hot spots, behind obstacles, in ocean depths, mountain tops, on other planets, or directed close to the sun.
- Measure a process without disturbance, such as monitoring flow around an aircraft model in a wind tunnel or measuring temperature, humidity and pressure during an experiment
- Probe large volumes economically and quickly, such as providing global measurements of aerosols, air pollution, agriculture, human impact on the environment, planet surface roughness and large scale geographic features.

Active vs. Passive Remote Sensors

There are two classes of remote sensors: passive remote sensors and active remote sensors. Passive remote sensors do not include the energy source on which the measurement is based. The eye and optical telescopes are passive remote sensors: they rely on an external light source. You cannot see at night if the room lights are not turned on.

Active remote sensing instrumentation includes the energy source on which the measurement is based. RADAR is a widely known form of active remote sensing. In radar, the instrument emits a radio wave and senses the returned energy which is reflected from the target. Since the speed of radio waves and the time delay between emission and return are known, the distance to the target can be determined. Lidar (Light Detection and Ranging) is the optical analogue of radar. Lidars emit a concentrated light beam onto the target and measure the energy reflected back to the lidar receiver.

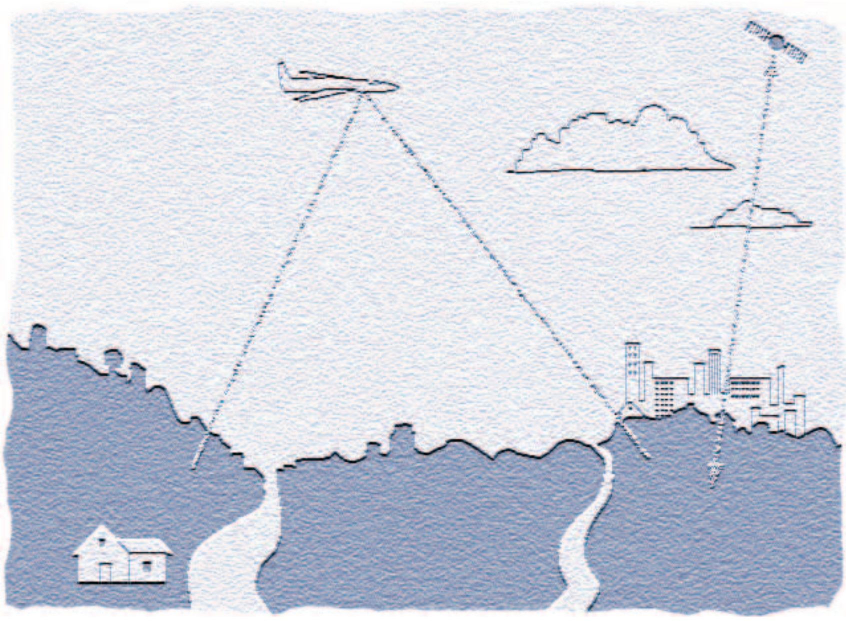


Fig 2: visual representation of remote sensing

The intensity or amount of reflected energy measured by the receiver provides the needed information about the target. With lidars, the light source is not a radio wave, but rather it is in the visible and adjacent (ultraviolet and infrared) regions of the electro-magnetic spectrum. The light source is generally a laser.

Most of the remote sensors in use today are passive sensors: they are easier, and therefore, cheaper to build. Unfortunately, passive remote sensors deployed on satellites only work when the sun is shining on the area to be viewed.

Remote Sensing: NASA's Next Mars Rover to Zap Rocks With Laser

The Chemistry and Camera (ChemCam) instrument on the rover Curiosity can hit rocks with a laser powerful enough to excite a pinhead-sized spot into a glowing gas. ChemCam then observes the flash through a telescope and analyses the spectrum of light to identify the chemical elements in the targeted rock. That information about rocks or patches of soil up to 7 metres away will help the rover team survey the rover's surroundings and choose which targets to drill into, scoop up, for additional analysis by other instruments on Curiosity. With the 10 science instruments on the rover, the team will assess the primary objective: whether any environments in the landing area have been favourable for microbial life and for preserving evidence about whether life existed. In late 2011, NASA will launch Curiosity, delivering the rover to the surface of Mars in August 2012.

An instrument on NASA's Mars Odyssey orbiter, which reached Mars in 2001, assessed radiation levels above the Martian atmosphere. The RAD instrument on Curiosity will monitor the radiation environment on the surface. The experimental design to monitor surface radiation levels involves taking data for a full Martian year, nearly two

Earth years. One time set of measurements by RAD will not be enough as the steady radiation level timeframe can vary from greater than a year and less than an hour. Therefore samples will be recorded for 15 minutes of every hour throughout the mission.

This data will be important for future human habitation missions to Mars as humans and life on earth are shielded by a magnetic field and atmosphere from the possible deadly effects of galactic cosmic rays and solar particle events. Mars, however, lacks a global magnetic field and has only about one percent as much atmosphere as Earth.

Teacher Preparation

In addition to the introductory information, the following study materials will assist students in bringing together the concept of the design challenge in the context of Remote Sensing, encompassing parameters required to design Martian-based equipment for a purpose. These creative activities leadinto the following subsection: Satellites in Space that investigates the construction, components and purpose of OzeSat (Satellite in a Can) and examines effective monitoring techniques for collecting useful data.

- *Download and distribute the factsheet: Mars Science Laboratory*

  http:// www.nasa.gov/pdf/482645main_MSL%20Fact%20Sheet.pdf
- *Distribute STUDENT WORKSHEET: Journal*
- *Distribute FACT SHEET: Investigating a Robot*
- *Download and show video of Building Curiosity - Rover Rocks Rocker-Boogie http://*

  www.nasa.gov/multimedia/ideogallery/index.html?media_id=18416173

STUDENT WORKSHEET: Journal

Introduction

A creative way of designing new technologies to be used to live and work on places like Mars is to examine the human senses that are capable of remotely sensing.

HUMAN Remote Sensing Robot

Many of the human senses gather their awareness of the external world almost entirely by perceiving a variety of signals, either emitted or reflected, actively or passively, from objects that transmit this information in waves or pulses. People hear disturbances in the atmosphere carried as sound waves, experience sensations such as heat (either through direct contact or as radiant energy), react to chemical signals from food through taste and smell, are aware of certain material properties such as roughness through touch (not remote), and recognises shapes, colours, and relative positions of exterior objects and classes of materials by means of seeing visible light issuing from them. All of the sensations that are not received through direct contact are remotely sensed.

Questions to be recorded in your Journal:

Examine worksheet: Investigating a robot and list all the features that fall into either the passive or active remote sensing tools? Using your human senses one at a time, expand your awareness to tune into each sense and record what you notice.

Touch Sight Taste Smell

If you were to design a robot, what would you like it to do?

Explain using your sensory observations and creative imagination.

FACT SHEET:
Investigating a Robot

When asked what a robot is, people often come up with images of fictional devices like C3PO, which walks with a human gait and talks with a British accent in the Star Wars movies. Another robot candidate is the one in the movie Artificial Intelligence. Such Hollywood-generated robots are shaped more or less like humans and they communicate like humans. Students tend not to think of washing machines or spacecraft like Voyager or LRO as robots; but these are classic examples of what is meant by a robot.

Definition of a robot:

A programmable and/or remotely controlled machine, capable of performing or extending humanly performed tasks, often in environments that are too hazardous for humans or in situations that are too repetitious or tedious for humans.

Robots like Voyager, Pathfinder and Lunar Reconnaissance(LRO) are extensions of human senses, not only in terms of operating in a remote, hostile environment like outer space, but also in terms of sensing in ways that humans cannot (e.g., detecting magnetic fields or seeing in the IR or UV portions of the electromagnetic spectrum).

Lunar Reconnaissance Orbiter Component Functions

Spacecraft (body/torso/skeleton)

The bus is the core structure (or framework) to which bus spacecraft components are attached. This is made out of aluminum, the same metal used in soft-drink cans.

Computers (brain)

Computers manage a variety of intelligent functions such as navigation and propulsion, storing information from scientific instruments and sending information to Earth.

Spacecraft cameras (eyes)

Lunar Reconnaissance Orbiter Camera (LROC) will collect very detailed pictures of possible future landing sites and places for habitats. The camera's pictures will help scientists learn about different lunar soils.

High-gain/low-gain antennas (ears and mouth)

Receivers and transmitters are used for communication between the spacecraft and Earth-based controllers. The antennae hear and speak for the spacecraft.

Thermal Control (sweat glands)

Mechanism that dissipates heat generated from the spacecraft out into space.

Solar Arrays (food and drink)

These are the source of energy for instruments and transmitters. The solar power is then stored in the onboard battery.

Orientation thrusters (dancing feet or legs)

These are small rocket thrusters that are used for delicate maneuvers that rotate the spacecraft. This is useful for aiming instruments and pointing the antennae toward Instruments (e.g., hands, tongue, nose, etc.)

Cosmic Ray Telescope for the Effects of Radiation:

Cosmic Ray Telescope for the Effects of Radiation (CRaTER) measures radiation. It will test special shielding that could be used to protect bases and space¬craft from radiation. Radiation can be very harmful to people; we have to know the amount of radiation in different places on the Moon so that we can live and work there safely and for a long time.

Lyman Alpha Mapping Project:

Lyman Alpha Mapping Project (LAMP) will use UV light that is reflected off the Moon's surface from starlight. Using this tiny bit of light, scientists can look into places that regular cameras cannot see into — places like very deep craters that are always in the shadows. These places are protected from the Sun's heat and radiation — which means they are very cold — and they may have hidden ice.

Magnetometer Boom (Extended Arm):

This is an 11-meter-long arm extending from the spacecraft. There are instruments in the middle and on the end of it that are used to detect and measure magnetic fields.

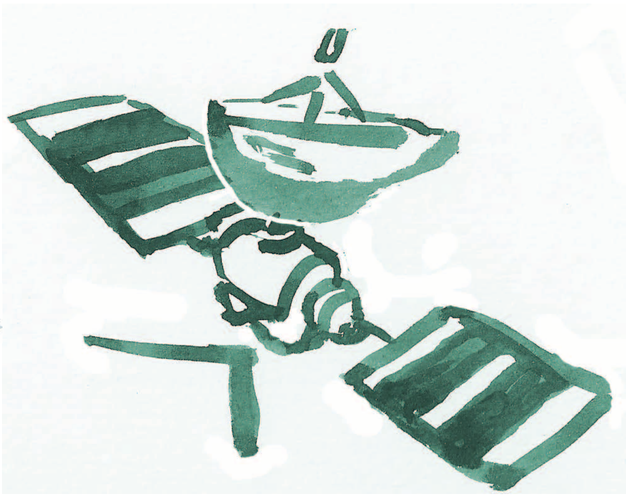
Lunar Orbiter Laser Altimeter:

Lunar Orbiter Laser Altimeter (LOLA) will send harmless laser beams to the Moon's surface. The beams will bounce back to LOLA and can be used to make a map of the entire surface — a map that shows scientists features as small as 0.48 m across. LOLA will help scientists figure out how smooth or rough the surface is and if ice is there — because different surfaces cause laser beams to scatter in different ways.

Fig 2: Artists concept of an LRO.

Source: based on NASA's Saturn Educators Guide

MARS Exploration Design Challenge



Satellites in Space

SATELLITES IN SPACE

Remote sensing is the backbone of the space program.

Introduction

Tele-operated rovers, both aerial and land based, will be used extensively by Martian crew members to explore terrain that is too dangerous for the human crew, and to study proposed traverse routes. These craft may be operated by the crew from the safety of the habitats, vehicles and virtual reality displays to provide real time data input and acquisition. Mini-rovers can also gather material samples to support the scientific experiments being studied throughout the mission from both the base camp and manned vehicles.

A communication system will be implemented to support ground and remote communications for the crew. This system will contain high-gain directional antennas, areostationary relay satellites, and local transmitter/ receivers for line-of-sight communications.

Communication systems to deal with scientific data received from hand-held instrumentation in both the habitat and field environment including monitoring life support systems for crew members will be critical for a human-based mission on Mars.

Objectives

a. *Compare the differences between Mars and Earth in the context that planetary characteristics that can be remotely sensed*

b. *Understand field work conducted and monitored in earth-based anolog site to Mars*

c. *Construct an OzeSat kit (Satellite in Drink Can) and investigate how satellites monitor variables such as temperature, relative humidity and air-pressure*

d. *Design an experiment to test the 3 variables and learn how to visually interpret data*

e. *Apply the principles collected by satellites to monitor the scientific or engineering variables (functions) of the Mission Team product*

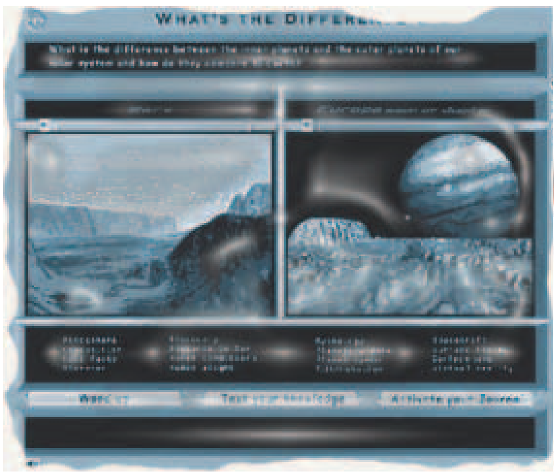
Depending on the course that this C2C in Space program is utilised in may determine the emphasis placed on the use of this module. Teachers integrating this MARS Challenge into a science subject for instance, may prefer to have the OzeSat pre-assembled prior to students engaging in this module to focus on remote sensing techniques and data analysis.

Teacher Preparation

Background INVESTIGATION A

It is suggested that students are first directed to use the online programs below "What's the Difference?" and "The Virtual Field Trip" to research the differences between Earth and Mars and examine real field work conducted by scientists in the Pilbara outback region of Western Australia.

There are several environments studied around the world that are considered analog sites to Mars having similar planetary extreme environmental attributes. Like the Pilbara region in WA, some of the other desert regions studied by planetary scientists are Arkaroola in South Australia; Namibia, Chile and Arizona in the USA. Antarctica is also studied due to the extreme permafrost conditions found on Mars that may contain for instance, ancient forms of life like cyanobacteria (blue-green algae) where ancient rivers are once flowed.



http://quest.nasa.gov/vft/

*****It is recommended that you download these programs onto the classroom computers well in advance, since the files are large and may take some time to upload.*

Teacher Preparation

Background INVESTIGATION B

A follow up student worksheet: Exploring the Martian Environment will introduce students to the concept of planning and executing a field- based mission requiring visual imagery interpretation skills on basic land formations and the associated importance of environmental data collection.

From conducting these exercises, students will be better prepared to design a field experiment outside of the classroom or in the laboratory to test OzeSat parameters; pressure, relative humidity and temperature for Investigation C

Materials and Equipment

- *Download programs "Whats the Difference" and Virtual Fieldtrip http://www.quest.nasa.gov/vft/*

  It is recommended that you download these programs onto the classroom computers well in advance, since the files are large and may take some time to upload.
- *Download "Solar System Math" http://www.quest.nasa.gov/vft/ if students require further numeracy skills prior to main design challenge*
- *Distribute Student Worksheet: Exploring the Martian Environment*

Additional Information:

- *NASA Spaceward bound: Planning and Executing Planetary Analog Field Research Expeditions http://quest.nasa.gov/projects/spacewardbound/index.html*
- *C2C in Space Resource CD*

STUDENT WORKSHEET

Exploring the Martian Environment: Investigation B

An orbiting satellite has taken remotely sensed images of the topography of Mars using a technique called Infrared spectroscopy (using light wavelength technology to determine altitude). Understanding the geophysical features (terrain) of Mars is a good starting point when looking for places to live and work that may provide valuable information for exploration purposes and selecting a nearby safe location for the crew habitat.

Astronauts will need a base-station in an open temperate area on Mars where the climatic conditions are least extreme (temperate), to provide where possible un-interrupted telecommunications and data transfer between the habitat and earth and habitat to manned and unmanned vehicles exploring the Mars surface . This can be achieved by the use of orbiting satellites and ground-based antennas with receivers.

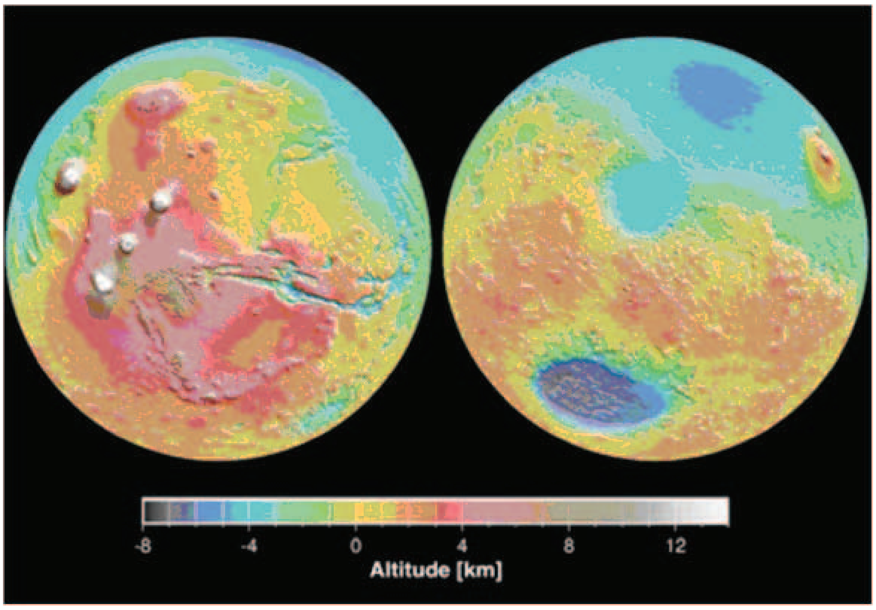


Figure 1: Global dataset: Topography of Mars

Questions

1. From the image above, use a pencil to circle the following geophysical features of Mars.
   - *Impact craters from meteorites*
   - *Ancient volcanoes*
   - *Polar-capped mountains*
   - *Ancient river systems forming valleys*

2. Indicate where you might locate the Mars habitat where astronauts live and work?

3. List reasons why it is important for vehicles exploring the Mars surface to collect remotely sensed temperature and altitude data that at the same time can be monitored by astronauts in the Mars habitat?

OzeSat: INVESTIGATION C

Overview

The purpose of is OzeSat is to enable students to develop practical skills in the fields of remote sensing and data analysis techniques that will need to be applied during the MARS Exploration Design Challenge. Students may also develop practical experience in building a small satellite (OzeSat) comprising of various electronic components and understanding the relationship between all parts of a satellite. The final section of the OzeSat manual guides students step by step, how to program the OzeSat and acquire data on a laptop, however this is an extension option to the design challenge designed for grade levels 9 and above.

Teacher Preparation

The OzeSat is a kit containing:

- *Three circuit board modules*
- *Transmitter Module (TM)*
- *Controller Module (TM)*
- *Sensor Module (SM)*
- *Serial Cable for connection to your PC*
- *All required software*
- *2 Aluminium Panels*

- *Assorted nuts and bolts*
- *OzeSat Manual for teachers and students located on the C2C in Space Resource CD*

The OzeSat with operations manual can be purchased from the Victorian Space and Science Education Centre (VSSEC) and costs $195.00 inc p/h. Visit their website: http://www.vssec.vic.edu.au/ to place an order

The pre-programmed parameters in the OzeSat are:

Air Pressure

Relative Humidity

Temperature.

Other items:

Antenna and receiver unit

C2C will supply each school with one unit, for return at the end of the C2C in Space program, however, should more be required, the units can be purchased from Pratt Hobbies in the US for $250. Note that it may take several weeks to order a shipment from the US, so planning allowance for this is required.

Additional supplies:

Laptops for data acquisition in the field (optional)

Aluminium drink can for OzeSat

12V battery for OzeSat operation

Graph and Blank Paper for illustrating findings

Workshop Investigation

Since it may be only possible to have one OzeSat per class, careful planning is required to ensure that each Mission Team has the opportunity at a minimum to:

1. Identify the components of a satellite
2. Design an experiment that tests the capabilities of the OzeSat parameters.

Activities with the OzeSat

There are many ways in which the OzeSat can be used to collect data. The following are suggestions to generate ideas and have an idea about preparation materials required:

- Water or sounding rockets are a fun way to launch an OzeSat to collect atmospheric information. The OzeSat can be deployed from the rocket if you connect a release tethering system with a parachute to ensure a safe landing. Refer to the additional resources section of this manual for more information on water rocket activities.
- Students may also build a kite or use a helium balloon large enough to keep the OzeSat in the air to collect data. The drawback with using a kite is that it is reliant on windy conditions and may not be suitable on the day that the activity is scheduled. Balloons need to be filled with helium no later than 1 day prior to use. It may be best to hire a helium canister for ongoing use during the project testing phases.

- A remote controlled vehicle or robot carrying the OzeSat can be used to simulate field work on the surface of Mars. A spy camera attached to the front of the vehicle and a visual interface screen viewed by the operator for less than $150 would be great for simulating a remote sensing rover traversing a path of exploration from a Martian habitat.

Non-remote sensing equipment to measure variables

- *Mercury or aneroid barometer* can be used to measure air pressure. Particularly useful when students wish to undertake repeatable laboratory experiments using pressurised chamber equipment since the OzeSat will not be able to detect much variation in air pressure using a water rocket, kite or balloon. The aviation authority will need approve height measurements above school buildings.
- *Hygrometer* is a device used to measure the relative humidity in the air. There are several different types of hygrometers available, including ones marketed specifically for use in terrariums, simulating cabin environments. Hygrometers are quite delicate and need to be calibrated for accurate measuring. They are also not instant devices - it can take up to two hours to get an accurate reading or to record changes in the relative humidity. This instrument may be useful where students wish to test when humidity turns to condensation.
- *Thermometer (preferably an **alcohol bulb**)* may be used to measure temperature variations of various liquid or solid states, where the OzeSat may only be used for measuring altitude air temperatures. For instance, a frozen soil experiment simulating the Martian environment, recording temperature at various depths over time.

Satellites in Space
Resource Fact Sheet

The following background information forms a basic understanding of the variables air pressure, temperature and relative humidity that will help guide students in designing experiments, making relationships between variables and visually representing findings.

Atmospheric pressure on Mars is less than 1% of Earth's, and no human could survive there without a pressurized spacesuit. Atmospheric pressure is the amount of force exerted over a surface area, caused by the weight of air above it. Since fewer air molecules are present at higher elevations, atmospheric pressure decreases as altitude increases. The most common unit of measure for atmospheric pressure is the millibar (mb). On Earth, the average atmospheric pressure at sea level is 1,050 mb, while on Mars it is only 7.5 mb.

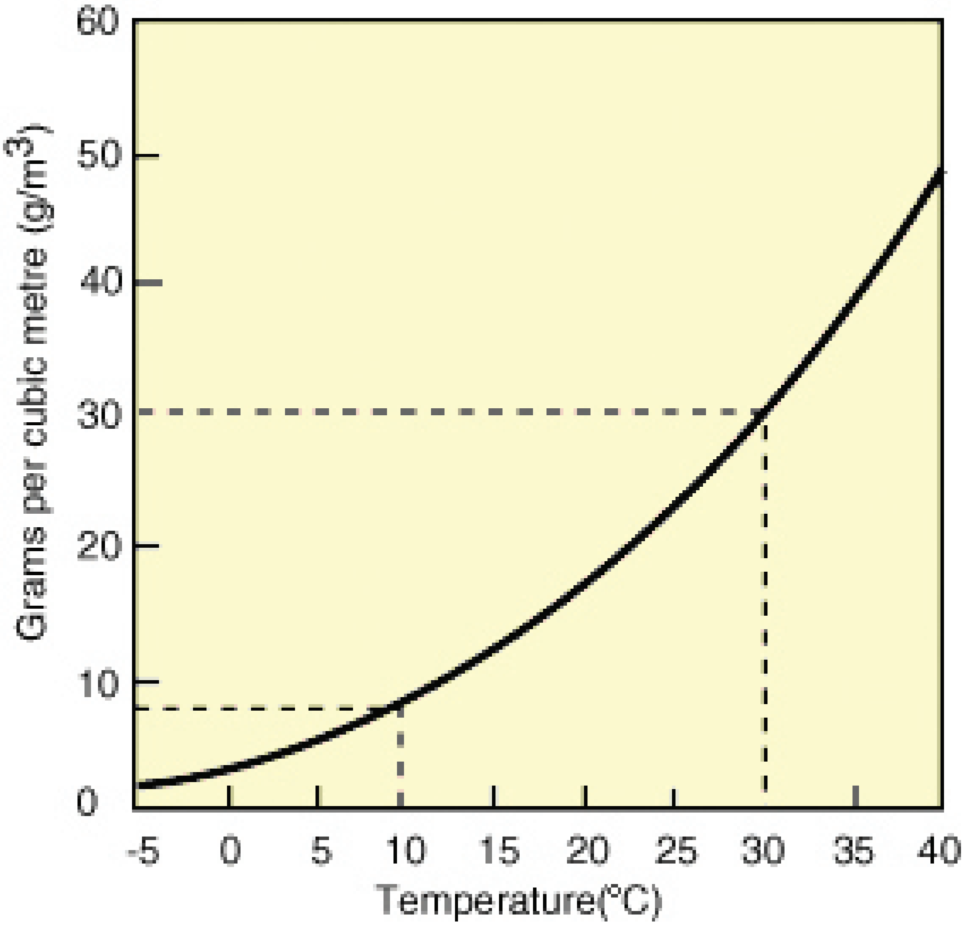
Air pressure is not uniform across the Earth. The normal range of the Earth's air pressure is from 980 millibars (mb) to 1050 mb. These differences are the result of low and high air pressure systems which are caused by unequal heating across the Earth's surface and the pressure gradient force.

A low *pressure system* is usually associated with high winds, warm air, and atmospheric lifting. Because of this, lows normally produce clouds, precipitation, and other bad weather such as tropical storms and cyclones. High pressure areas are usually associated with clear skies and calm weather.

Temperature - Global variations of average surface-air temperatures are largely due to latitude, continentality, ocean currents, and prevailing winds. Mars lacks oceans and dense clouds of liquid vapour and has a thinner atmosphere that is unable to hold in the heat. The temperature on Mars is typically about -63 oC (-81 oF). However, the equatorial regions of Mars may occasionally reach temperatures of up to 30-40 oC (50-68 oF), while during the long polar nights, the temperature can fall to around -120 oC (-184 oF

Relative Humidity is the ratio of the actual amount of water vapour present in a volume of air at a given temperature to the maximum amount that the air could hold at that temperature, expressed as a percentage. Warm air can hold more water vapour than cool air, so a particular amount of water vapour will yield a lower relative humidity in warm air than it does in cool air. Martian air contains only about 1/1,000 as much water as our air, but even this small amount can condense out, forming clouds that ride high in the atmosphere or swirl around the slopes of towering volcanoes. Local patches of early morning fog can form in valleys, just like in the foggy deserts of the Namib Desert in Africa that is considered an analog site to Mars.

Below is an example of a relationship between Relative Humidity and Temperature.



- - Fig 1. Change in amount of water vapour in saturated air with temperature.

The air's capacity for water vapour increases as air temperature increases. Air with a temperature of 30°C can hold more than three times as much water vapour as air at 10°C.

Things to consider before operation of OzeSat

- *Detail the design features that will allow the experiment to survive the flight and to be usable for another flight*
- *Teams must provide their own payload containment, insulation, power*
- *Will the OzeSat be tethered to the kite, balloon or rocket for deployment*

If a parachute is required to ensure a safe landing of the OzeSat, test the deployment using the payload containment without satellite.

- *Be sure the experimental design meets the safety requirements*
- *Calculate the payload capacity (mass of the OzeSat, insulation and fuel load for instance batteries, helium). Make a simple estimation of the size and mass of vehicle/rocket/containment. Make sure the weight ratios are proportionate*
- *OzeSat is not to contact water if used in conjunction with a water rocket or laboratory vacuum flask under high humidity conditions*
- *Outside areas will need to be surveyed to ensure that the flight area is clear of water sources, roof tops and any objects that may obstruct the flight and deployment of the OzeSat*
- *Make sure that the OzeSat is not launched higher than the highest school building without official aviation clearance*
- *If using a remote controlled rover or similar to collect data from OzeSat, ensure that it is secured properly and is well insulated*
- *Use excel to graph, temp, humidity, air pressure. How does this compare to minimum and maximum conditions on Mars.*

Note that students can use I Buttons for data collection if required. AusSat cannot be used with projects involving water or steam due to the non-water resistant nature of the product and electrical components.

STUDENT WORKSHEET

Satellite in a Drink Can: OzeSat Investigation C

Within your Mission Teams, using a small satellite OzeSat, design your own experiments to test the variables temperature, relative humidity and air pressure.

Purpose

The 3 variables to be tested under experimental conditions are monitored extensively by remote sensing equipment for various applications both on earth and in space. Aerospace Engineers who design aircraft such as helicopters and rockets, rely on this information particularly for aviation purposes. Natural hazards such as wind storms, tornados and associated air pressure systems have an influence on flight path navigation ability. On Mars, outside temperature extremes and inside humidity caused by astronaut respiration may also have an influence on the function of electronic components. These are just a few but very important variables that need to be remotely sensed to enable a successful human mission to Mars.

Equipment and Materials

The OzeSat kit contains:

- Three circuit board modules
- Transmitter Module (TM)
- Controller Module (TM)
- Sensor Module (SM)
- All required software to record data
- Aluminium drink can
- Materials to fit circuit board in a can
- OzeSat Operations Manual
- 9V battery
- Antenna and receiver unit

Additional items

You will need access to a computer for obtaining data
Graph and Blank Paper for illustrating findings

Procedures

In your Mission Teams:

1. Identify the components of the satellite - OzeSat using the Operations Manual provided
2. Use the Satellites in Space - Resource Fact Sheet to generate experimental design ideas. For instance, what is the purpose of your study of each of the variables and how might this information be useful for operations on Mars?

3. Once your team has decided on an experimental design of choice, consider comparing temperature, relative humidity and air pressure with only one or two other variables, for example, recording temperature data at different altitudes over time. The key is to Keep it Simple
4. Refer to list of "Things to consider before operation of OzeSat" and address the answers in your Reflection Journal. Include any considerations that are specific to your experiment
5. Check with the teacher to see if what your group proposes to do is possible given the time frame and equipment available
6. Follow the instructions in the Operations Manual to set up the OzeSat and Receiver Unit to receive data.
7. Set up your experiment and repeat procedures 3 times. Keep your experimental technique the same each time and record any observations during data collection in your Reflective Journal.
8. Retrieve data from the OzeSat or other equipment used and interpret the information. Keep it Simple. There is no right or wrong interpretations or answers here.
9. Chose the best method to represent your results by drawing a simple graph with x and y axis, bar graph or pie chart to visually illustrate your findings. Depending on your experiment, you may need to represent the 3 variables separately.

Questions

1. *Give a brief description of your findings referring to your graphs and or charts to answer this?*
2. *Did you discover any relationships between variables temperature, relative humidity and air pressure?*
3. *How would you design your experiment differently if your investigation was carried out during an actual Mission on Mars?*
4. *Write down 3 ways that collecting data on each of the variables investigated could assist mission operations when living and working on Mars?*

Temperature:

Relative Humidity:

Air Pressure:

5. What other information could satellites collect on Mars that would be useful for supporting astronauts living and working in a habitat and or for exploring the Martian environment?