MARS EXPLORATION - GROUP ASSIGNMENT

Mars is the fourth planet from the Sun and the second-smallest planet in the Solar System, after Mercury. In English, it carries a name of the Roman god of war, and is often referred to as the "Red Planet because the reddish iron oxide prevalent on its surface gives it a reddish appearance that is distinctive among the astronomical bodies visible to the naked eye. Mars is a terrestrial planet with a thin atmosphere, having surface features reminiscent both of the impact craters of the Moon and the valleys, deserts, and polar ice caps of Earth.

Several rovers have been dispatched to Mars:

- *Mars 2, Prop-M* rover, 1971, *Mars 2* landing failed taking Prop-M with it. The *Mars 2* and *3* spacecraft from the USSR had identical 4.5 kg *Prop-M* rovers. They were to move on skis while connected to the landers with cables.
- *Mars 3, Prop-M* rover, 1971, lost when *Mars 3* lander stopped communicating about 20 seconds after landing.
- *Sojourner* rover, Mars Pathfinder, landed successfully on July 4, 1997. Communications were lost on September 27, 1997.
- *Beagle 2, Planetary Under-surface Tool*, lost with Beagle 2 on deployment from Mars Express in 2003. A compressed spring mechanism was designed to allow movement across the surface at a rate of 1 cm per 5 seconds and to burrow into the ground and collect a subsurface sample in a cavity in its tip.
- *Spirit* (MER-A), Mars Exploration Rover, launched on June 10, 2003 at 13:58:47 EDT and landed successfully on January 4, 2004. Nearly 6 years after the original mission limit, Spirit had covered a total distance of 7.73 km (4.80 mi) but its wheels became trapped in sand. Around January 26, 2010, NASA conceded defeat in its efforts to free the rover and stated that it would now function as a stationary science platform. The last communication received from the rover was on March 22, 2010, and NASA ceased attempts to re-establish communication on May 25, 2011.
- *Opportunity* (MER-B), Mars Exploration Rover, launched on July 7, 2003 at 23:18:15 EDT and landed successfully on January 25, 2004. *Opportunity* surpassed the previous record for longevity of a surface mission to Mars as of May 20, 2010 and surpassed the previous record for distance travelled off-Earth as of July 28, 2014 by covering a total distance of 40.25 km (25.01 mi). *Opportunity* is still operational and mobile as of September 10, 2017.
- *Curiosity*, Mars Science Laboratory (MSL), by NASA, was launched November 26, 2011 at 10:02 EST and landed in the Aeolis Palus plain near Aeolis Mons (informally "Mount Sharp") in Gale Crater on August 6, 2012, 05:31 UTC. Curiosity Rover is still operational as of September 10, 2017.

CURIOSITY

Curiosity is a car-sized rover designed to explore Gale Crater on Mars as part of NASA's Mars Science Laboratory mission (MSL). *Curiosity* was launched from Cape Canaveral on November 26, 2011, at 15:02 UTC aboard the MSL spacecraft and landed in Gale Crater on Mars on August 6, 2012, 05:17 UTC. The Bradbury Landing site was less than 2.4 km (1.5 mi) from the centre of the rover's touchdown target after a 560 million km (350 million mi) journey.

The objectives of the mission of Curiosity are the following:

Biological

1. Determine the nature and inventory of organic carbon compounds
2. Investigate the chemical building blocks of life (carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur)
3. Identify features that may represent the effects of biological processes (bio-signatures and biomolecules)

Geological and geochemical

4. Investigate the chemical, isotopic, and mineralogical composition of the Martian surface and near-surface geological materials
5. Interpret the processes that have formed and modified rocks and soils

Planetary process

6. Assess long-timescale (i.e., 4-billion-year) Martian atmospheric evolution processes
7. Determine present state, distribution, and cycling of water and carbon dioxide

Surface radiation

8. Characterize the broad spectrum of surface radiation, including galactic and cosmic radiation, solar proton events and secondary neutrons. As part of its exploration, it also measured the radiation exposure in the interior of the spacecraft as it travelled to Mars, and it is continuing radiation measurements as it explores the surface of Mars. This data would be important for a future manned mission.

Curiosity has a mass of 899 kg (1,982 lb) including 80 kg (180 lb) of scientific instruments. The rover is 2.9 m (9.5 ft) long by 2.7 m (8.9 ft) wide by 2.2 m (7.2 ft) in height. *Curiosity* is powered by a radioisotope thermoelectric generator (RTG). Radioisotope power systems (RPSs) are generators that produce electricity from the decay of radioactive isotopes, such as plutonium-238, which is a non-fissile isotope of plutonium.

The temperatures at the landing site can vary from −127 to 40 °C; therefore, the thermal system of Curiosity will warm the rover for most of the Martian year. The thermal system will do so in several ways: passively, through the dissipation to internal components; by electrical heaters strategically placed on key components; and by using the rover heat rejection system (HRS). It uses fluid pumped through 60 m (200 ft) of tubing in the rover body so that sensitive components are kept at optimal temperatures.

Curiosity uses two identical on-board rover computers, called Rover Computer Element (RCE), that contain radiation-hardened memory to tolerate the extreme radiation from space and to safeguard against power-off cycles. The computers run the VxWorks real-time operating system (RTOS). Each computer's memory includes 256 kB of EEPROM, 256 MB of DRAM, and 2 GB of flash memory.

In order to communicate with Earth, *Curiosity* is equipped with several telecommunication means – an X-band Transmitter/Receiver that can communicate directly with Earth, and a UHF Electra-Lite software-defined radio for communicating with Mars orbiters.

Communication with the orbiters is expected to be the main path for data return to Earth, since the orbiters have both more power and larger antennas than *Curiosity*, thus allowing for faster transmission speeds. The rover has two UHF radios, the signals of which the 2001 Mars Odyssey orbiter is capable of relaying back to Earth. An average of 14 minutes, 6 seconds will be required for signals to travel between Earth and Mars. *Curiosity* can communicate with Earth directly at speeds up-to 32 kbit/s, but the bulk of the data transfer should be relayed through the Mars Reconnaissance Orbiter and Odyssey orbiter. Communication from and to *Curiosity* relies on internationally agreed space data communications protocols as defined by the Consultative Committee for Space Data Systems.

Curiosity is equipped with six 50 cm (20 in) diameter wheels in a rocker-bogie suspension. The suspension system also serves as landing gear for the vehicle, unlike its smaller predecessors. Each wheel has cleats and is independently actuated and geared, providing for climbing in soft sand and scrambling over rocks. Each front and rear wheel can be independently steered, allowing the vehicle to turn in place as well as execute arcing turns. Each wheel has a pattern that helps it maintain traction but also leaves patterned tracks in the sandy surface of Mars.

Curiosity has 17 cameras: HazCams (8), NavCams (4), MastCams (2), MAHLI (1), MARDI (1), and ChemCam (1). Each MastCam includes the Medium Angle Camera (MAC) which has a 34 mm (1.3 in) focal length, a 15° field of view, and can yield 22 cm/pixel (8.7 in/pixel) scale at 1 km (0.62 mi). The other camera in the MastCam is the Narrow Angle Camera (NAC), which has a 100 mm (3.9 in) focal length, a 5.1° field of view, and can yield 7.4 cm/pixel (2.9 in/pixel) scale at 1 km (0.62 mi). A pair of MastCams were developed which include zoom lenses, but these were not included in the rover because of the time required to test the new hardware and the looming November 2011 launch date. Each MastCam has eight gigabytes of flash memory, which is capable of storing over 5,500 raw images, and can apply real time lossless data compression.

ChemCam is actually two different instruments combined as one: a laser-induced breakdown spectroscopy (LIBS) and a Remote Micro Imager (RMI) telescope. The purpose of the LIBS instrument is to provide elemental compositions of rock and soil, while the RMI will give ChemCam scientists high-resolution images of the sampling areas of the rocks and soil that LIBS targets. ChemCam has the ability to record up to 6,144 different wavelengths of ultraviolet, visible, and infrared light.

MAHLI is a camera on the rover's robotic arm, and acquires microscopic images of rock and soil. MAHLI can take true-colour images at 1600×1200 pixels with a resolution as high as 14.5 micro-meters per pixel. MAHLI has an 18.3 to 21.3 mm (0.72 to 0.84 in) focal length and a 33.8–38.5° field of view. MAHLI has both white and ultraviolet LED illumination for imaging in darkness or fluorescence imaging. MAHLI also has mechanical focusing in a range from infinite to millimetre distances.

Curiosity stores the images generated by MastCams, the ChemCam and MAHLI in three different databases. Field-Programmable Gate Arrays (FPGAs) are used by *Cusiosity* in order to categorize these images based on their significance and store them in the respective database. The significance of an image is defined by image processing algorithms that identify specific features of each image (eg. density, contrast) and produce a decision about them. For example, if the image processing algorithms identify the significance of an image to be above 70%, then they store the image in Database A. If the significance of the image is between 45% to 69%, it is stored in Database B while for significance below 45%, then the image is stored in Database C. It is possible that an image is elevated to Database A from Database B or even from Database C depending on the conditions of the mission of *Curiosity* on the surface of Mars or inversely, an image can be downgraded to Database C from Database A. These elevations and/or downgrades can be done randomly depending on the change of each mission's conditions.

The most significant pictures are emitted by FPGAs through the UHF Electra-Lite software-defined radio to the Mars orbiters and then back to earth. All the images though are used for obstacle track identification on the Mars surface and coordinates definition for the rover. Specifically, a data clustering algorithm is used to extract the coordinates identified in each image and place them to a 3D coordinate system. Every day, the 3D coordinate system is updated and a copy of the updates is stored on the memory of RCE. These copies are then sent directly to Earth through Curiosity's X-band transmitter so that NASA knows exactly the route followed by the rover.

<u>OPPORTUNITY</u>

Opportunity, also known as **MER-B** (**Mars Exploration Rover – B**) or **MER-1**, is a robotic rover active on Mars since 2004. Launched on July 7, 2003 as part of NASA's Mars Exploration Rover program, it landed on Mars on January 25, 2004.

Fixed science/engineering instruments of *Opportunity* include:

- **<u>Two Panoramic Cameras (Pancam)</u>** – examine the texture, colour, mineralogy, and structure of the local terrain. The Pancams can generate panoramic image mosaics as large as 4,000 pixels high and 24,000 pixels around.
- **<u>Navigation Camera (Navcam)</u>** –These black-and-white cameras use visible light to gather panoramic, three-dimensional (3D) imagery. The Navcam is a stereo pair of cameras, each with a 45-degree field of view to support ground navigation planning by scientists and engineers. They receive the data from the Pancam and process them so that a prototype 3D imagery is developed.
- **<u>Miniature Thermal Emission Spectrometer (Mini-TES)</u>** – Mini-TES is an infrared spectrometer that can determine the mineralogy of rocks and soils from a distance by detecting their patterns of thermal radiation. All warm objects emit heat, but different objects emit heat differently. This variation in thermal radiation can help scientists identify the minerals on Mars. Mini-TES records the spectra of various rocks and soils. These spectra are studied to determine the type of minerals and their abundances at selected locations. The data collected by Mini-TES are fed back to the Navcam for reasons of obstacle tracking and finding the optimal route on the Mars surface. In this case, the prototype 3D imagery is enhanced.
- **<u>Mössbauer spectrometer (MB)</u>** – used for close-up investigations of the mineralogy of iron-bearing rocks and soils. This spectrometer is used in both *Opportunity* and *Curiosity*. The instrument has two major components: (1) a rover-based electronics board which contains power supplies, a dedicated central processing unit, memory, and associated support electronics and (2) a sensor head for placement of the instrument in physical contact with soil and rock.
- **<u>Alpha Particle X-ray Spectrometer (APXS)</u>** – close-up analysis of the abundances of chemical elements that make up rocks and soils. The APXS takes measurements both day and night. Most APXS measurements take two to three hours to reveal all elements, including small amounts of trace elements. The measurements acquired by APXS are compared to the measurements of the Mössbauer spectrometer through an electronic board of sensors. These sensors include chemical, temperature, and optical sensors. Each of these sensors analyses its respective measurements and if it finds any data related to the operation of the other sensors of the board, it extracts these data and sends them to the other sensors.
- **<u>Hazcams</u>** - two black-and-white cameras with 120-degree field of view that provide additional data about the rover's surroundings.

During each trip to the Mars surface, *Opportunity* assigns a specific camera from the above list to be its main camera while the rest of the cameras play an auxiliary role. Specific Artificial Intelligence algorithms (eg. Artificial Neural Networks) evaluate the different conditions and/or the purpose of each trip and define which camera will act as the main camera. There is rotation though among cameras for maintenance purposes. Specifically, each camera that becomes a main camera can operate as one for the period of 3 days. After that period, the camera will become auxiliary and it will be checked for any malfunctioning by the Mars Reconnaissance Orbiter. The orbiter sends the results back to the NASA Staff for further evaluation if there is any trace of malfunctioning or it can send them to the Mars orbiter for final verification if there are not any traces.

ASSIGNMENT TASKS

Your task is to create a relational database and a number of prototype system functions utilising certain database features.

Specifically, you need to:

1. **Refine your work from the Individual Assignment. You need to work as a group and bring together the good elements of your work on the Individual Assignment and produce a refined ER Model. For the refined ER Model, you will also need to consider the new information related to the *Opportunity* rover.**
   [Weight: 20% of the Group Assignment Grade]

2. **Based on the refined ER model, develop a database in Oracle SQL Developer 11g (the version we use in the labs). Pay particular attention to adding as much of the semantics (meaning of the data - constraints) as possible at this stage. [15%]**

3. **Provide prototype user front ends using web forms in PHP or in any other programming language of your choice. These front ends should connect to the database you developed in Question 2. The aim of these interfaces is to process data from the database and depict the data flow of the system. [20%]**

4. **Create examples of appropriate data processing with procedures, functions and triggers. [20%]**

5. **Provide a documented explanation of your Testing Plan & Results. [25%]**

For each section you will gain only a basic mark for a technically good solution. It is important that you think about what you have produced, consider various alternatives and justify your solution. This is reflected in the mark scheme. The numbers in [ ] represent the weighting of each component.

This is a Group Assignment and you are expected to work as a group. However, the grade of each of you in the specific assignment may be different from the other members of your group and this will be based on each member's contribution in the realisation of the assignment. If you feel that one member does less work than the other members in a group, then this should be mentioned by email to me. It is also good to keep a log of your group meetings where the contribution of each member will be recorded and in addition, all the members of the group will sign it.

I will release a form close to the submission deadline which each of you will use after the submission of the assignment and in which, you will provide a rating from 0 to 10 to rate your contribution and the other members' (of your group) contribution. After you complete the form, you will send it to me by email. If there are significant differences in your ratings, then I will organise a meeting with your group to clarify the contribution of each member.