VEHICLE FOR ICY TERRAIN LOCOMOTION: A ROVER PROTOTYPE FOR EUROPA BY A UNIVERSITY OF COLORADO AEROSPACE ENGINEERING SENIOR PROJECTS TEAM. V. Vertucci[1], K. Rash[2], R. Hickman, C. Homolac, J. Krupp, H. Love, K. Ligon, A. Paulson, [1]University of Colorado Aerospace Engineering Sciences Veronica.Vertucci@colorado.edu, [2]University of Colorado Aerospace Engineering Sciences Kathryn.Rash@colorado.edu.

Introduction: The Senior Design Praticum is a year long senior level class in the Aerospace Engineering Department at the University of Colorado in which students design, fabricate, test, and verify projects in the Aerospace Engineering field.

The primary objective of the Vehicle for Icy Terrain Locomotion (VITL) team is to design and build a prototype for the locomotion system of a vehicle exploring a Europa-like surface capable of traversing 1 km of icy terrain in 7 days with characteristic obstacles. This objective was built off of past work done by JPL scientists on a future Europa mission [2].

Objectives for a Theoretical Europa Mission (TEM) include environmental temperatures around 100K, ice with a Brinell hardness of about 170 as well as a very harsh radiation environment with a dose of about 1 MRad in seven days making shielding absolutely necessary. The materials and moving parts used in the rover need to account for these effects of the harsh environmental elements. Similarly, the mass of the vehicle needs to be minimized in order to make its launch with landing gear feasible.

Power issues are also a major constraint for a Europa mission as solar power is not feasible and the use of an RTG could contaminate the pristine Europa environment.

Europa, in addition to the aforementioned environmental complications, has a gravity of near that to the Moon, about 1/6 Earth's gravity. This lowers the normal force that can be achieved with ice-traction methods and makes the wheel system much more difficult to design. Europa is also without a substantial atmosphere so surface conditions are near vacuum ambient pressures (10^{-6} Pa). Standard low-pressure design procedures must be included in engineering the vehicle in a TEM.

Science payloads will absolutely be included in a TEM. These science packages would be designed to go on board and must be allowed to operate unhindered by the normal operations of the TEM vehicle.

The specialized materials and power sources needed for this mission were not available to the VITL team due to budget and schedule constraints; thus considerations were made in the design to incorporate these necessary changes. The overall objective of building a vehicle that can maneuver on Europa's ice is not affected and the current design accomplished this. Europa's ice, as previously mentioned, has a Brinell hardness of about 170, similar to that of mild steel or concrete. Europa's ice also has a coefficient of friction of about 0.55, ice to ice. There are also theoretical characteristic ruts and bumps that cover the ice which have been estimated by high resolution photos from spacecraft, shown below in Figure 1.. These are roughly one inch high by three feet long bumps and ruts as well as slopes up to 20°. Other obstacles include walls and cliffs that the rover must avoid upon encountering.

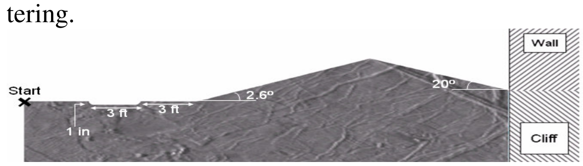

Figure 1: Europa terrain characteristics [1].

The objectives of the simplified Senior Projects Engineering Design and Manufactured Unit (EDMU) are similar in many ways to a TEM. The ice and surface characteristics will be the same but there are many environmental simplifications. For example, the temperature that the vehicle will be designed for is increased from 100K to 0ºC. This simplification allows for a cold temperature design requirement and testing, but is feasible for the team to accomplish compared to the 100K requirement.

The power issues and science payloads involved in creating a TEM are accounted for in the design by accommodating the mass and volume of a required power supply and a theoretical payload, but the development of such a supply or instrument lies outside the scope of this project. The pressure and radiation effects were likewise not implemented as these lie outside the scope.

Design Requirements: The major requirements of the prototype are outlined below. These requirements drove the design of the overall system and subsystems for the vehicle.

Geometry: The vehicle shall fit within a 1 cubic meter volume. This size restriction exists in order to satisfy the payload faring constraints of a typical long-range launch vehicle which would house the spacecraft caring the vehicle in addition to any landing gear.

Payload: A 10 kg dummy payload was used to simulate the mass and volume of a potential TEM science package.

Obstacle Detection: Sense impassable obstacles specified in the Introduction (above) and stop.

Mission Life: All systems shall be capable of operation at least 7 days (3.5 days of commanded operation), to simulate the radiation limiting factor.

Terrain Crossing and Inclination: Cross terrain specified in the Introduction including up to 20º slopes on Europa which translates to 2.62º on Earth by equating toques.

Direction Change: The vehicle shall be able to change the direction of motion on a slope to avoid impassable obstacles.

Temperature: Although the 100K environment of Europa cannot be simulated the system shall be capable of operation at 0ºC.

Range: During the 7 day mission, the vehicle and its components shall be capable of traveling up to 1 km in total distance.

Efficiency/Accuracy: After traveling 100 m on a flat surface in a straight line, the vehicle shall be within one body length of its expected position.

Final Design Architecture: The final system architecture can be seen in the following figure. The vehicle system consists of six wheels: four "slip" wheels and two powered spike wheels. Each of the spiked wheels consists of four rows of spikes. The vehicle will use the two powered spiked wheels to gain enough traction to pull itself up 20° slopes (2.62º slope for gravity equivalence on Earth), and over several obstacles outlined in the Introduction. The increase in slope is so that all geometry requirements of the suspension can be met while testing the vehicle up a slope.

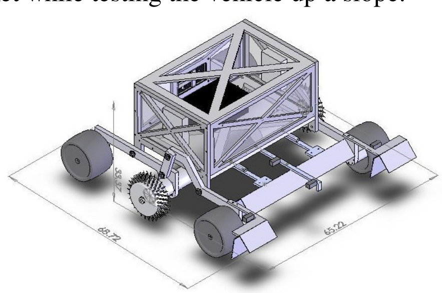

Figure 2: Final system architecture

The iso-grid structure of the rover is made from solid aluminum plates although for a future mission other materials with more desirable performance at cryogenic temperature can be utilized. The structure supports the rest of the subsystems and is the attachment point to the Rocker-Bogey suspension system. The rover is well under the one cubic meter requirement.

The current design illustrates the obstacle detection system which uses IR sensors to detect deflection of the mechanical bumper when an obstacle is encountered. Similarly the center beam includes an IR sensor which detects an approaching cliff. The only other additional sensor is an accelerometer mounted on the PCB inside the component box which determines when the vehicle encounters a slope of greater than 20 degrees.

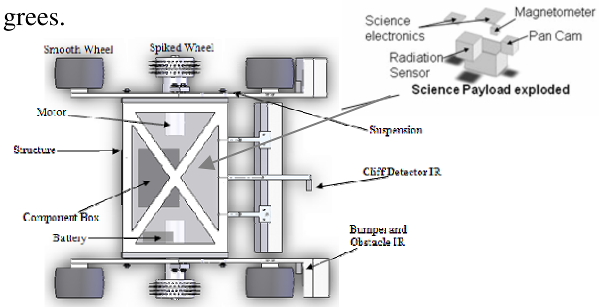

Figure 3: View of obstacle detection sensors, internal layout, and science payload.

Figure 3 shows the internal layout of the vehicle, the potential postion of the science payload, and the arial view of all other components. Although only one battery is illustrated for testing purposes, this number would need to be brought up to 36 batteries to power a 7 day TEM, which adds an additional 22.5 kg to the rover mass. Currently, the motors and structure are designed to accommodate this additional mass as well as up to 10 kg of payload mass. VITL used two interchangeable, rechargeable batteries to demonstrate successful completion of the requirements. The vehicle turns by skid steering, rotating the two powered, spiked wheels in opposite directions that create a moment about the center of the rover. The accuracy of the vehicle can be measured through the motor encoders, but this was not completed due to time constraints.

Conclusions: In short, the completed VITL rover, shown below, satisfied all of the project's requirements that were within scope. It also provides a preliminary design for a future terrestrial exploration vehicle on Europa.

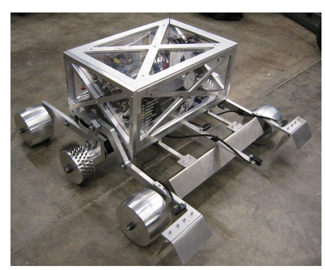

Figure 4: Completed VITL rover.

References:

[1] Murray, Norman. Universiy of Toronto. http://www.cita.utoronto.ca/~murray/GLG130/Pictures/Jupiter/Europa_flow.jpg [2] Balint, Tibor S. "Europa Surface Science Package Feasibility Assessment" JPL, Pasadena, CA 2004.