Electronics Group - Atacama Desert Trek

Pre-review (Draft)

The following document is intended to describe the electrical/electronics systems for the Atacama desert trek robot (Nomad).

1.0 System Description

The electronic/electrical system consists of the following sub-systems:

- Power generation / UPS / distribution system
- Locomotion / Steering systems
- Real time computing system
- Navigation computing system
- Imaging system
- Communication system
- Primary sensor system
- Secondary sensor system
- Environmental / Physical systems - thermal management, cabling, connectors, enclosures, shock absorption

These subsystems will be discussed in detail below.

Additional material can be found in the appendices.

2.0 Sub-system descriptions

2.1 Power generation / UPS / distribution

The power generation / UPS / distribution system provides 120 VAC at 60 Hz to the various subsystems. The power is generated on board the robot by an alternator driven by an internal combustion gasoline engine. An uninterruptible power supply (UPS) provides power to certain subsystem to isolate those systems from fluctuations in power from the generator due to changing load conditions

2.1.1 System requirements (power budget)

See appendix for a spreadsheet of the power budget for several operation modes. These modes are deployment, normal and night modes with additional reduced function and shut-down modes. The deployment mode is entered initially to fully deploy the wheels from the stowed position. Normal and night modes imply operation with full function during the day and operation at reduced speed with on-board illumination for the stereo vision system during the night, respectively. Shut down in the case of generator power failure will occur in several phases. (discussed below)

2.1.2 Engine - Generator set

The engine generator set is provided by Rochester Commercial Industrial. It consists of a single cylinder four cycle OHC carbureted gasoline engine (Lambordini, type ACT280, Italy) integrated with an alternator (Mecc Alte, series A1, Italy). It has been sized to supply 2.7 KW at an altitude of 10,000 feet above sea level. The unit is housed in the lower section of the rover body along with the fuel tank and UPS. It is capable of being started electrically by the real time system or an externally mounted switch. In the absence of the electric start function due to failure of the electric starter or battery, it may be started by a manual recoil starter. Modification to the oil delivery system (oil pump) allows the engine to operate continuously with a tip angle of 45 degrees from normal. Final design of the orientation in the body has not been completed; mounting of the engine generator axis may be up to 23 degrees from horizontal which may reduce time of downward angle travel at angles greater than 22 degrees.

2.1.3 Power buses and load transfer switch

A main power bus that carries the entire load requirements of the robot connects the output of the alternator to the various power sub-systems. (See figure of bus structure.) A load transfer switch allows the entire load of the robot to be connected either to the alternator or to an external source of 120 VAC power supplied through a rear mounted connector. The switch is operated manually and normally is in the on-board source position. The main power bus provides power to the locomotion, steering and environmental systems and the UPS. The voltage of this main bus is maintained within the range of plus and minus 6% of the nominal value during static load conditions and has a maximum transient of equal or less plus or minus 10% of the nominal value for less than or up to than 0.1 seconds in duration under the maximum changing load condition. The frequency is within plus and minus 5% of the nominal value.

A separate protected bus distributes the power from the output of the UPS to the computing, communication and sensor systems. The voltage is within the range of plus and minus 6% of the nominal value for all load conditions.

2.1.4 UPS

A commercial grade UPS (Leibert, possibly Topaz) using lead-acid batteries for backup power provides power to the protected 120 VAC bus. Typically, it conditions the power from the main bus to isolate the systems on the protected bus from variations under changing load conditions. In the event of a total loss of power from the alternator, the UPS supports the real time system, radio frequency modem and, for a limited period of time, the navigation system. Load shedding is performed under control of the real-time system after it has been determined by the real time system that there has been loss of generator power. A time schedule of the load reduction is shown in the following table. The UPS will be mounted in the lower section of the body.

Mode	Normal	Power fail stage 1	Power fail stage 2	Power down stand by
Systems	all	real time, navigation	real time, rf modem	real time, rf modem
Load	750 W	400 W	71 W	71 W
Time	unlimited	1 minute	5 minutes	10 minutes

Table 1. UPS load schedule

2.1.5 Overload protection and distribution control

All loads are connected to their associated buses via circuit breakers of a size appropriate for the load and wiring. All circuit breakers (except that of the UPS line input) for a particular bus are mounted on a separate panel. Each equipment enclosure has either a panel for either main or protected bus or the panel for the protected bus is split into two sub-panels each mounted in one of the two enclosures (depending on the final distribution of heat loads and mechanical considerations). Sub-systems with power under real time system control have either a solid state relay (Crydom Series 1) in the respective primary circuit or the associated AC/DC converter(s) is controlled via an enable input to the converter.

2.1.6 AC/DC conversion

DC power for the individual subsystem is provided by separate AC/DC converters for each subsystem. These are typically be of the switching type (e.g., Vicor FlatPack, Lambda, or Kepco) except for systems, such as the IMU, where less noise can be tolerated on the power input to the device. In these cases, a regulated linear DC supply sized to a particular system (e.g., Acopian) provides the DC power.

2.1.7 Load schedule - start up and shutdown

During start up the real time system as started using the battery power stored from the previous period of operation or, if the charge on the UPS batteries is insufficient, from external AC power. The real time system starts the generator system and, after a stabilization period, apply the loads to the AC bus. During normal system start up, the loads are applied to the power system in a specified sequence. This will assure clean power and prevent the full load being applied at one time. In particular, the individual components of the locomotion and steering systems are to be turned on in sequence to prevent excessive inrush currents. After initial loading of the power system by the real time system normal operation commences.

Shut down of the entire system follows a procedure of orderly shut down of critical systems, such as the navigation system. After all systems except the real time systems are off, the real time system shuts down the UPS.

The first phase occurs when the real time system has determined on board power has failed and shuts down all non-critical systems, such as the panospheric camera and imaging computer. A period of time (approximately 1 minute, as yet undetermined) follows in which the UPS provides power for the real time system, navigation system and portions of the communication system. During this period, the navigation system performs an orderly shut down. After this period, in the second phase, the UPS operates the real time system and radio modem for as long as possible (yet to be determined but at least 5 minutes).

Also see real time document.

2.2 Locomotion / Steering System

2.2.1 System requirement and description

The locomotion system provides power and control for the four wheel actuators. It shares a common power supply with the steering system.

2.2.2 Power supply

The power supply for both the wheel and steering actuators is an unregulated DC supply (Elmo Motion Control). which provides a voltage of 168 VDC with an input of 120 VAC. Resistive shunt regulation clamps the DC bus voltage in the case of back driving of the motors or input overvoltage.

2.2.3 Amplifiers

Amplifiers for both locomotion and steering are miniature PWM three phase servo amplifiers (Elmo Motion Control, type SBA-5/200R). Amplifiers for the wheel motors are set up for velocity mode and command inputs to the amps for the motors are single ended in the range plus to minus 5 V from the real time system or (possibly) directly from an external pendant. Feedback signals from the actuators are obtained from the actuator resolvers. The amplifiers provide pseudo-encoder signals derived from the resolver signals.

2.2.4 Actuators

Actuators are brushless three phase DC servo-motors (Pacific Scientific, type R35MNA-R2-NS-NV-00) with integrated two phase resolvers (Harowe). Actuator temperature sensing is provided via a thermistor integrated within the actuator frame.

2.2.5 Sensors

2.2.6 Control system

2.2.7 Protection - limit sensing/switching

2.2.8 Watchdog / Kill system

The steering and locomotion systems incorporate a circuit to inhibit the amplifiers for these systems if either a watchdog signal is not received for a period of 1 second or if a signal is received from an externally mounted kill switch. (see figure of circuit diagram).

2.2.9 External input (pendant)

The inputs to the steering and locomotion amplifiers are be normally from the real time system. Current real time system presumes all control of locomotion and steering command voltages will originate in the real time system. However, failure of the real time system may preclude control of the drive and steering functions of the robot leading to extrication of the robot from locations by external force. It may be prudent to allow for the control of the command voltages by external input (pendant) In this case, the insertion of a pendant into an externally mounted connector allows both the steering and locomotion amplifiers to be controlled by input signals from a joystick type pendant. In addition, the normal inhibit signals to the amplifiers are then under external control, in the form of a deadman switch on the joystick. The normal function of the kill switch is retained under external pendant control. Two mode of steering are provided: normal steering and skid steering. If the normal steering mode is inoperative or inappropriate skid steering is used. A draw back of this system is the increased complexity of the circuitry.

2.3 Real time system

See real time document.

2.3.1 Requirements

2.3.2 Description

2.3.3 Platform

2.3.4 - Inputs/outputs

See table in real time document.

2.3.5 - Associated devices - sensors, controls

2.3.6 - Watchdog timer / kill / (reset?)

Watch dog timer line under real time system control - actuator amp inputs for loco, steering and pointing.

2.4 Navigation computer system

2.4.1 Description

The navigation computer performs navigation tasks using a suite of applications to acquire and process stereo video data, generate local map, plan path, perform dead reckoning, etc. It uses information in the form of both video data and sensor data acquired and processed by the real time system. Path commands are sent to the real time system sent via the serial port. The navigation system can communicate with the real time, imaging and communication systems (if necessary) via ethernet. See navigation document.

2.4.2 Platform

The navigation computer system consists of a single 166 MHz Pentium motherboard (mfg and type?) with both PCI and EISA slots and 64 MB ram. The additional cards in the system will be two image acquisition cards (Matrox Meteor) and one ethernet card (3Com type). Operating system is be a version of Linux.

2.4.3 - Inputs/outputs

The inputs to the system are four NTSC video lines for the stereo vision system. Additionally, thinnet Ethernet (10Base2) provides communication to the real time, imaging and communication systems. In addition, a serial line connects the navigation system to the real time system over which commands received by the real time system via the radio modem are passed to the navigation system and path commands from the navigation system are sent to the real time system.

2.4.4 - Associated devices

The navigation system obtains IMU, dGPS, compass and laser scanner data acquired and processed by the real-time system via the ethernet port.

2.5 Imaging system

-system description (see communication document) Consists of the panospheric camera - a high resolution video camera (Dalsa) with custom optical components, several body/wheel/forward looking cameras and a pentium type computer.

- input/outputs - frame grabber, multiplexer and ethernet.

- compression hardware - board in imaging computer

2.6 Communication system

See communications document for the following: requirements and description - BW, frequency, distances, directionality & pointing, power

2.6.1 Components

A radio frequency modem provides a low bandwidth duplex communication link between the robot and the control vehicle. The bandwidth is between 9600 and 115K baud and, ideally, the link allows for limited non-LOS operation. Operation commands will be sent to the robot via this link and operating data and status returned from the robot to the control vehicle. Currently the project has a FreeWave DGR-115H RF data transceiver system capable of supporting 115K baud for a distance of up to 9 miles using omni-directional antennas. It is, however, limited to LOS operation. Additional repeater stations may be added but this limits packet error checking from the master to slave portion of the link. Other modems being considered are Pacific Crest which allows repeater modems to be used without error checking penalty.

A radio frequency ethernet bridge (Arlan BR2040-EE) provides a high bandwidth link (up to 4 Mb/s half duplex) to transmit image data from the robot to the control vehicle and satellite uplink. In addition, it provides a means to maintain ethernet communications with the on board computer systems to allow off line debugging and code maintenance. A planar high gain (16 dBi) circular polarization antenna with a beam width of approximately 7 degrees to 3 dB down (Suhner-Huber) is supported by the pointing system to stabilize the antenna orientation during operation.

For the following - see Communication paper and Real Time paper:

- antennas

- pointing system

- imaging multiplexer
- off board relay station and control vehicle

2.7 Primary sensors

2.7.1 Vision system cameras

The imaging system consists of four CCD cameras (Sony, type XC-77) equipped with auto iris lenses. The cameras are mounted on the mast in dust and weather proof enclosures. The cameras are slaved together so that one camera provides sync for the other cameras. The four video signals and sync signal are delivered to the frame grabbers in the navigation system.

2.7.2 Laser scanner

The laser scanner is a proximity detector that allows measurement of distance from the detector to points along a line parallel to the front of the robot at a distance of approximately two meters. The active device is an Acuity Accurange 3000-LIR laser range finder equipped with a rotating scanning mirror driven by a servomotor. The range finder and mirror scanner are housed in one unit and are connected to a controller card via cable which transfers power, control data and range data. The control card in turn communicates with the real time system via an 8 bit SCSI bus.

The laser scanner housing must be dust and weather proof and also provide an aperture of sufficient dimensions and geometry such that the scanned laser beam is not obstructed and backscatter is minimized. Several methods have been proposed, however none have been explored to the extent that performance of the laser scanner can be guaranteed.

2.7.3 IMU

The IMU is a six axis motion sensor (Systron-Donner MotionPak) consisting of quartz rate sensors and accelerometers. The device produces an analog voltage for each of the six axis in the ratio of 50 mV/degree/second for the angular rate axes and 7.5 V/g for two linear accelerometers and 3.75 V/g for the third linear accelerometer. The bandwidth of the angular rate signals is 70 Hz and that of the linear accelerometer is between 800 and 900 Hz. The analog signals are acquired by a/d channels on the real time system and these channels are filtered using single pole low pass filters on the a/d board before conversion. The real time system currently provides 12 bits per channel at a rate of 100 samples/S. Power is supplied to the IMU in the form of plus and minus 15 volts at 7 W by a linear regulated power supply (Acopian).

2.7.4 DGPS

This system is yet to be determined.

2.7.5 Compass

An integrated KVH digital gyro compass and digital gyro inclinometer system (ADGC) provides data via a RS-422 channel to the real time system at a data rate of either 4800 or 9600 baud and update rate of up to 10 times per second. The real time system may also send commands to the compass unit for purposes of initialization. DC power of 12 to 32 at 330 mA is supplied to the compass.

2.7.6 Wheel encoder / resolver

The amplifiers for the locomotion system provide pseudo-encoder signals derived from the resolver feedback signals. These encoder signals are acquired by the real time system via a encode board (O-R). This encoder data is forwarded to the navigation system via the ethernet channel.

2.7.7 Steering angle

Measured by absolute encoders (BEI Encoder Systems, M25 series) with a resolution of 10 bit. The digital encoder data is read by the real time system. Total swing of the steering element is approximately 120 degrees from fully retracted to fully deployed and at maximum steering angle. One encoder is used on each side of the body.

2.7.8 Bogie angle

Measured at the equalizing member using a linear potentiometer (BEI Duncan, model 106). Two potentiometers are used and the analog voltage signal is acquired by a pair of a/d channels on the real time system.

2.7.9 Temperature

The temperature of the wheel actuators, steering actuators, loco/steering power supply & amps, electronics enclosures, generator are measured.

2.7.10 Current monitor

The current monitor outputs of the six amplifiers associated with the wheel and steering actuators are acquired by a/d channels on the real time system.

2.7.11 Power system monitors

UPS line and load voltage, line and load currents, line and load frequencies, engine rpm, fuel level, engine temperature, UPS inverter temperature, oil pressure and oil level are measured by sensors connected to the real time system.

2.8 Secondary sensors

- additional sensors - star tracker (?)

- science package - TBD

2.9 Environmental / physical

The operating environment is assumed to be dry with an operating temperature range of 0 to 25 degrees Celsius. Daytime operation will be in full sun to overcast. Periods of high wind may occur for short periods. Soil type is loose with small rocks causing potentially very dusty conditions. High mineral (salt) content of soil may cause corrosion of exposed metal surfaces, however, humidity is quite low.

Given a heat load of 400 W per enclosure and no cooling other than through surface to free air transfer, expected temperature rise will be 26.7 degrees Celsius. Using one cabinet cooler per enclosure (Noren CC1200), temperature rise will be 5 degrees Celsius. (Note: this has not taken into account heat load from sunlight transferred to enclosures which is assumed negligible for now.) We hope to be able to mount the amplifiers and power supply for the locomotion and steering systems on the exterior walls to reduce the heat transferred to the internal environment

Connections for power and control are mil-spec solder type. Connectors are potted and sealed where necessary. RF connectors are hardened type where possible, however some devices use proprietary types.

All electronics except for the UPS, cameras, laser scanner and Arlan will be placed in one of two enclosures mounted on the upper deck under the shroud. Enclosure dimensions are approximately 44” W X 22” D X 15” H with a top sloping to 4 “H. The enclosures are placed on either side of a air duct which provides filtered outside air for the heat exchangers.

Equipment enclosures and sensitive equipment are mounted on shock absorbers.

The enclosures are sealed to prevent migration of dust into the interior. Sensitive apparatus, such as cameras, mounted on the exterior are enclosed.

3.0 Operating modes, failure modes

4.0 Power Budget

See attached sheets.