# 1 Computing & Electronics

## 1.1 Computing Requirements

| Function | Requirement Estimate | Definition |
|---|---|---|
| Stereo | 100 MIPS | Whats needed to compute 80 dofx2mx2cm-res/second |
| Light Striping | 10 MIPS | Whats needed to light stripe & integrate 30 frames/second |
| Navigation | 15 MIPS | Whats needed to robustly safeguard at 1 m/s |
| Global Nav | 10 MIPS | Whats needed by D* at 5 m resolution |
| Star tracking | 1MIPS | Whats needed to know global position within 500 m |
| Pos Est: Inertial + Proprio | 10 MIPS | Whats needed to know relative position within 1%/6m<br>Whats needed to know antenna pose w.r.t earth to 1 mrad |
| Compression | X MIPS | Compress live video of AxBxC resolution to X Mb/s |
| Power | 1 MIPS | Servoing to the sun, power conditioning and management |
| Comm Pointing | 5 MIPS | Antenna pointing to earth |
| Low level safeguarding & maintenance | 5 MIPS | Whats needed to provide last line of defence & motor control + safety |

Total = 50 or 140 MIPS + 50% margin = 75 or 220 MIPS

## 1.2 Electronics Requirements

| Function | Requirement Estimate | Definition |
|---|---|---|
| Perception | 4 cameras + frame buffer + 4 I+O lines | |
| Actuators | 10 motor controllers + power amps + 20 I + 10 O | |
| IMU | 6 I lines, 1 O | |
| Star trackers | 2 cameras + 2 I+O | |
| Temp Sense | 5 I lines | |
| Science | 10 I/O lines | |
| Proximity | 10 I/O lines | |
| Power monitors | 15 I lines | |
| Misc | 10 I/O | |
| | | |

Total = 90 I + 50 O + 50% margin = 150 I + 75 O lines

## 1.3 Architecture

The combination of VME cage and VXWorks is well understood systemically, robotically, and CMU has considerable inhouse expertise & software. In addition the Mesur pathfinder is setting a precedent by using this system. Hence this is the recommended path for the real time system. It is also encouraging to note that one of the candidate CPU boards developed by the RAPTOR program (ref Nick Collela) is VxWorks compatible.

## 1.4 Components & Qualification

The nature of commercial components is such that many sub-micron fabrication devices are inherently rad-hard or rad-survivable. In addition, these very chips offer the state of the art high computing and low power specs. Additionally since these components are widely used in embedded applications, they are designed for reasonable temperature ranges (-50 to +70 C).

Hence the task of designing a computing/electronic element is reduced to finding components that do not upset or latchup. And if they do, ensure acceptability of the rates of upsets/latchups, and design software & hardware to effect recovery from such incidents. The first step is to understand the mission environment:

1. Launch environemnt
    - Electrical
    - Shock & vibration/ acceleration
    - Thermal
2. Landing environment
    - Jerk(landing impulse)/ acceleration
    - Vibration
3. Lunar Environment
    - Galactic cosmic rays
        - Gamma rays
        - Heavy nuclei
        - Protons
    - Solar ionizing radiation
        - Light nuclei
        - Protons (local ionization [charge accum, point defects], high density defects)
            - Total dose
            - Single Event P
            - Upset (non-destructive, destructive [non-preventable, preventable])
            - Punch through
        - Electrons
        - E-M spectrum (UV, soft X-rays)
    - Thermal
    - Vacuum
    - Power balance

| Induced Defect | Test | $$/part | Cure |
|---|---|---|---|
| UV breakdown | Sun Gun | ~20 | Surface coating or shadow |
| Total Dose | Gamma Ray<br>Low E protons<br>(< 20 MeV) | ~50<br>600/hr<br>x 3 | Pick parts with adequate margin, MRC Colorado springs |
| SEP | Hi energy protons<br>(10 -100 Mev) | 600/hr<br>x 3 | Data, memory and algorithm integrity checks |
| Latch up | med-Hi protons,UCD<br>Cf source/fission src.<br>Heavy ions-LBL/<br>Brookhaven | 600x10<br>Cheap<br>1000 x<br>10 | Avoid parts with non-recoverable latchups<br>Use power watchdog to reboot upon recoverable latchup OR power cycle each processor x minutes if acceptable to mission & chip |

Total mission qualification cost estimate = 15-20 k/ part + 1 man month; if successful = $30-35 k/part (may reduce/incre dep on expertise and no. of parts)

Note that the cost is about the same if a whole board is tested, so several screened parts can stuffed to a prototype board and tested simultaneously, cost ? = 100 k?