# The Redback: A Low-Cost Advanced Mobility Robot

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**Abstract**

Many of the more interesting applications of mobile robotics involve robots that are able to traverse unstructured environments. Unfortunately, currently available robots for such a purpose tend to be limited in their mobility (very few can climb stairs for instance), are excessively heavy, must be custom built or are very expensive. This article describes preliminary work on construction of an advanced mobility robot based on a Tarantula radio controlled toy, sold by MGA Entertainment. Despite being very low in cost (sub-\$200AUD), this toy can easily climb stairs and overcome obstacles that challenge much larger robots. It can easily carry an onboard computer which can directly interface with the existing motor controllers as well as additional cameras, small laser rangefinders and other sensors. The full cost of parts for the basic robot, including computer and simple sensors, is expected to be around the \$1,000AUD mark with basic computer-less versions starting below \$300AUD. The modified robot has been dubbed Redback, after the Australian spider of the same name.

# 1 Introduction

Robotics researchers who wish to investigate advanced mobility in unstructured terrain have generally had a difficult time finding suitable robotic platforms. Example criteria for advanced mobility research robots include:

**Low cost** To encourage use in more "dangerous" situations where damage may be possible. This also opens up the possibility for swarm robots and the use of advanced mobility robots in classroom environments.

**Durability** The ability to sustain a fall or tumble, or to be driven in "unwise" ways without sustaining severe damage.

**Light weight** The ability to be carried in and out of environments without the need for trolleys or slings and to be "spotted" and caught by hand should it become unstable or fall off a platform.

**Strong drivetrain** To force its way through, over or around obstacles without sustaining damage.

**High mobility** At the very least, the ability to climb human-sized stairs; the ability to handle other "interesting" terrain is also useful.

**Stability** A low center of gravity to prevent tipping on inclines, stairs and other obstacles.

**Reasonable payload** To carry an onboard computer, cameras and sufficiently capable sensors to enable advanced mobility.

Robots that satisfy these criteria are almost impossible to come by. Standard robots such as the Pioneer P3AT [1] have some rough terrain handling capabilities but their low ground clearance and high center of gravity mean they are unable to overcome all but the lowest of steps. They also tend to be quite heavy.

Robots with large wheels such as CMU's lightweight Corky robot [5] have met with some success in overcoming rough terrain although stairclimbing is still an issue.

The Yujin Robotics Robhaz DT-3 [7] is capable of climbing stairs, traversing very rough terrain and has an extremely powerful drivetrain. It is also incredibly robust and can carry an impressive 45Kg payload. However it is very heavy, expensive and can sometimes get stuck on seemingly trivial obstacles due to its low ground clearance.

The BlueBotics Shrimp [2] is considerably cheaper and lighter while still having a reasonable payload. However, it has quite a high center of gravity and a complex mechanism which causes problems with stability and manoeuvrability, especially on open stairs or terrain with concave vertical surfaces.

Toin University of Yokohama have had considerable success with their custom built Toin Pelican series of robots, which have won the RoboCup Rescue Robot League competition two years in a row (2004/2005) [4]. Their robot has come closest to answering the criteria above, however few institutes have the luxury of facilities and expertise to fabricate such pieces of hardware.

Our approach is not the first to be based on the MGA Tarantula. Most noteably, RescueRobots Freiburg have had some success with a fleet of three

Figure 1: An unmodified MGA Tarantula RC toy

"Lurker" robots, based on Tarantulas. These robots were able to overcome all obstacles in the 2005 RoboCup Rescue Robot League arena and helped them achieve 4th place in the main competition. Whilst our "Redback" robots share similarities with the "Lurker" robots, our approach calls for a somewhat lighter weight robot and with an emphasis on an easy-to-follow build procedure that makes use of commonly available parts.

In the following sections, we describe the structure and design of the unmodified Tarantula and our modifications to form the prototype Redback robot. We then discuss intended future modifications in order to make this a viable advanced mobility platform.

# 2 The Tarantula

The Tarantula RC vehicle, sold by MGA Entertainment through such stores as *Wal-Mart* and *Amazon.com*, is shown in figure 1. It is a unique toy vehicle in that, out of the box, it easily handles stairs, obstacles up to 40cm in height and other very challenging terrain.

Some of the highlights of this platform, with no mechanical modifications, include:

**Low cost** The cost of the robot base is less than $200AUD and basic computer controlled versions can be built for around $1,000AUD including the cost of the computer.

**Relatively durable** Torque limiters, extensive internal bracing and electronic protection help the robot resist damage. The prototype has had its flippers jammed, been rolled down stairs and generally mistreated with no signs of stress on the chassis or drivetrain. [1]

[1] There have been several revisions of the MGA Tarantula. Some, especially early models, suffered from weak gears, defects in the torque limiters and substandard tracks which resulted in an excessive number of mechanical failures. Based on reviews and discussions with other groups that have used MGA Tarantulas as robots, most of these issues seem confined to Tarantulas purchased during early 2005 and before mid-2004. Techniques are being developed to further reinforce points of failure.

**Light weight** The prototype weighs less than 7kg (with batteries and 1.5kg payload) and can be carried and, if necessary, caught with one hand. Indeed, it is possible for one person to easily carry three of the prototypes without additional equipment. This also opens up the possibility of using this robot, in conjunction with a larger robot, as a marsupial pair.

**Easy interfacing** The existing motor control board can be easily driven by custom circuitry.

**Strong motors** The existing motors have more than enough torque to lift the robot and drive it up very steep slopes.

**High mobility** As figure 4 shows, this platform has amongst the best mobility of any robot up to twice its size. Stairclimbing is almost trivial for this robot.

**Stability** Having flippers at both ends means that, with appropriate control, it is almost impossible to flip this robot backwards when attempting stairs and other such obstacles, unlike many other stairclimbing robots.

**Independent control of flippers** Front and rear flippers move independently. They are also offset so both sets can rotate continuously, allowing for actions such as “swimming” over rubble where the front flippers rotate forward continuously and the rear pair stay set to the rear.

**High ground clearance** The robot may be driven on the tips of its flippers, providing a ground clearance of 25cm as shown in figure 2, an impressive feat considering the robot itself is normally only 25cm high.

This platform does have certain disadvantages that disqualify it from some applications. The base robot is a toy and does suffer from some fragility issues, particularly due to plastic-on-plastic bearings. Still, the extent to which this toy has been engineered to resist damage is impressive and its low cost opens the possibility of purchasing several for use as spare parts – interchanging parts is, for a toy, surprisingly easy. Control issues for a robot with four degrees of freedom can be quite profound. Indeed, semi-autonomous or autonomous control of such a robot would be an open research area. The payload carrying capacity is relatively small, no more than 2Kg and ideally no more than 1.5Kg. However, this is enough for a small computer, communications equipment, cameras and a small laser rangefinder plus around one hour of battery runtime. For example, a viable sub-1.5Kg payload might be:

- 3 cell 2.2AH LiPoly battery pack: 2x120g
- Sharp Zaurus SL-C3000 computer with wireless LAN card: 400g
- Camera with omnidirectional mirror: 200g
- Hokuyo URG laser range scanner: 160g
- Microcontroller board: 50g
- Flipper feedback components: 100g
- USB hub: 50g

Figure 2: An unmodified Tarantula sitting on the tips of its flippers, demonstrating its high ground clearance. The robot may be easily driven and turned in this configuration.

- Cabling, sensor armour, mounting hardware: 300g
- **TOTAL: 1.380Kg**

## 2.1 Physical Description

The stock Tarantula is shown in figure 1 and opened in figure 3. The body is 50cm long and has four flippers, each 30cm long. The frame and flippers are constructed from plastic, with considerable internal bracing structure. The gears are of tough plastic with metal drive chains and shafts. The frame, flippers and drivetrains have survived tumbling down several flights of paved stairs while carrying a 1.5Kg payload without any signs of cracking or stressing.

## 2.2 Flippers, tracks and drive

The main feature of the robot is its two pairs of rotating flippers. The flippers are arranged in a forward and backward pair – the forward pair move together, independently of the rear pair. Each flipper is covered with a rubber crawler track. The crawler tracks running around each flipper operate in a standard "tank style" skid steering arrangement – the tracks on the left two flippers may be driven forward or backward independently of the pair of tracks on the right two flippers.

The flippers are capable of lifting the robot as shown in figure 2, flipping and self-righting the robot, all while carrying a 1.5Kg payload. Figure 4 demonstrates the fully loaded prototype climbing over a 40cm high Sun workstation. To prevent damage to the drive train from the flippers overloading or jamming, each flipper has torque limiters, shown in figure 6. The crawler tracks are also driven by relatively powerful motors; during testing a lack of torque was rarely an issue.

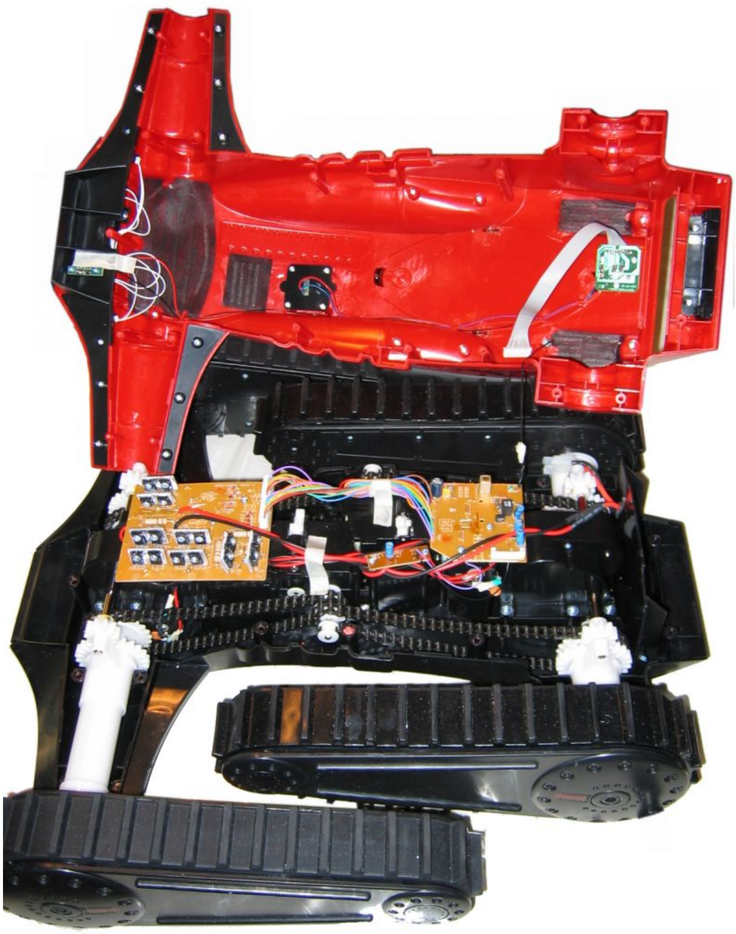

Figure 3: The unmodified Tarantula with the shell opened

Figure 4: The prototype Redback climbing over a 40cm high Sun workstation while carrying a 1.5Kg payload (including onboard computer – the black box to the rear of the robot). White arrows indicate the directions that the flippers were rotated in to advance to the next frame.

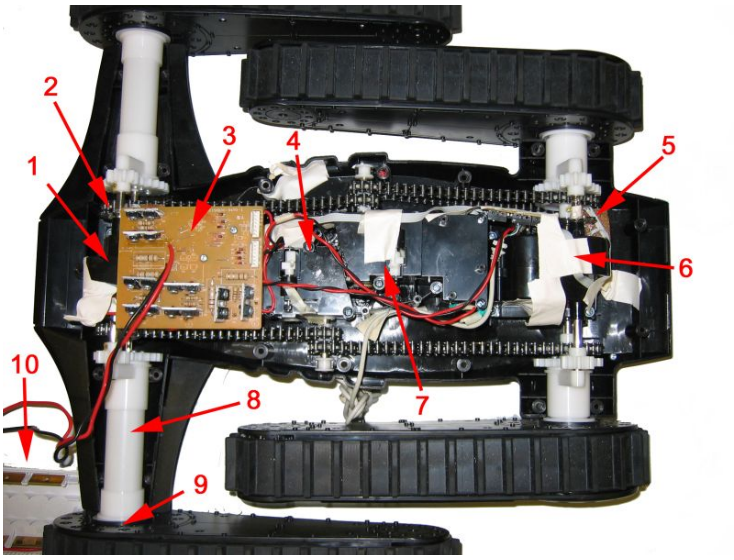


Figure 5: The inside of the Redback (modified Tarantula), front is to the left. Components shown are: 1: Front flipper drive motor, 2: Front flipper encoder (hidden), 3: H-bridge board, 4: Left track drive motor, 5: Rear flipper encoder, 6: Rear flipper drive motor, 7: Right track drive motor, 8: Left front torque tube, 9: Position of torque limiter (see figure 6), 10: Extended battery (normally on top of (6) and (7)) – additional power components not shown.

Figure 6: Closeup of the disassembled torque limiter. The disk to the left is driven by the torque tube shown in figure 5. The inside of the flipper is shown on the right. The two pieces are normally linked by the two spring loaded nodules which allow the two to turn relative to each other should excessive torque be applied. The location of this assembly is also shown in figure 5.

## 2.3 Electronics

Power to the Tarantula comes from a standard 9.6 volt 660mAh NiMH battery pack (8x AAA cells), which is good for about 20 minutes of runtime. However there is ample room within the body of the Tarantula for a significantly larger battery pack. Four H-bridges control the four motors. Each H-bridge has two inputs which can be directly driven (and pulse-width modulated) from TTL level signals, each controlling one path through the H-bridge with positive logic. Shoot through protection is already in place and “double-on” signals to the H-bridge default to driving the motor in one direction. There is also rudimentary current sensing available through an op-amp circuit. Unfortunately without modification, it is not possible for the H-bridge to be placed in motor-short (brake) mode. In practice, the H-bridge board appears to be running well within current limits and the transistors never became excessively hot during initial testing.

The Tarantula’s stock remote receiver is able to receive four three-state channels (driving each of the motors in either direction or stopped) and one two-state channel (operating the headlights). Alternatively, the signals within the remote transmitter may also be driven via TTL level signals with inverted logic. With stock antennas, the range of the remote is approximately 10 meters. The remote control runs at the standard toy frequencies of 27MHz and 49MHz for the red and yellow versions respectively.

# 3 The Redback

We will now describe the fitout to turn the Tarantula RC toy into a Redback robot which is a lightweight, high mobility platform capable of carrying approximately 1.5Kg worth of sensors, computing equipment and associated batteries, with a runtime of around one hour. The first proof-of-concept prototype carried an embedded Wafer-5820 PC with a Cyrix MediaGX processor and notebook hard drive, webcams and wireless LAN equipment. The prototype is shown in figure 7.

An example of a typical payload might be a small omnidirectional camera, a lightweight webcam on a servo-based pan-tilt unit and a small Hokuyo URG

Figure 7: The prototype Redback climbing stairs. The black box contains the computer while the round object on the rear (left of centre) is the cooling fan for the onboard power supply. Extended batteries are inside the shell.

series [3] laser rangefinder, all connecting to a small embedded computer such as a Sharp Zaurus (with USB host) [6]. Alternatively, an "ultralight" version may only have an onboard microcontroller for basic control, with sensor data sent offboard via radio transmitters.

The following modifications were made, and are described in detail below.

- Adding rotation encoders on the flippers
- Implementing external control of the motor board
- Implementing motor brakes on the flippers
- Mounting and interfacing to onboard computer

Unfortunately, due to technical issues stemming from improper vibration isolation of the onboard hard disk drive, full evaluation under computer control was not possible. However, the performance of the mechanical system, when fully loaded, was extensively tested. Future improvements to this platform are described in section 4.

## 3.1 Rotation encoders on the flippers

The flippers allow the Redback to reconfigure itself and overcome obstacles that cannot be overcome by a standard tracked vehicle. With eyes-on control (or, to an extent, eyes-off control with suitable camera arrangements), flipper encoders are unnecessary as the operator can directly observe the flipper configuration.

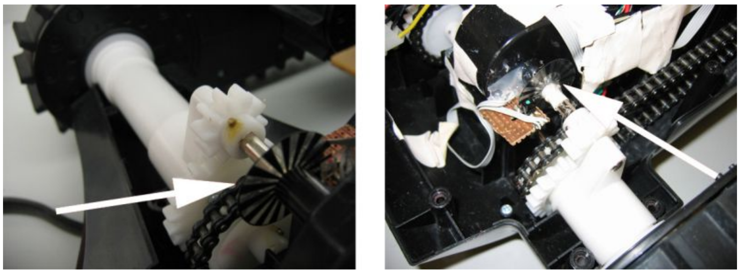

Figure 8: Encoders installed in the front (left) and rear (right) flipper drivetrains. Their positions are also shown in figure 5.

However, direct feedback of flipper position can be helpful for operator awareness, allows configuration presets to be implemented and will be essential for autonomous control. For simplicity and cost effectiveness, optical quadrature encoders were chosen. Potentiometers may also be used however finding a suitable mounting location on the rear flippers may be problematic. Figure 8 show the quadrature encoders used. While commercial units may also be used, they are hard to fit in the confined spaces of this robot – indeed due to the tight spaces, the existing encoders could not be fitted to the torque tubes themselves, instead they were fitted one level back, on the gearbox output shafts. Since the quadrature encoders only provide relative position, the prototype required that the flippers be manually homed; a future extension is to install homing switches to allow for homing on bootup.

## 3.2 External control of the motor board

There are 8 H-bridge control lines, which can be driven by TTL signals. Each line drives one diagonal path through one H-bridge. The logic required is as follows. Note that raising both lines ("double-on") is an error condition but protection circuitry is in place so that the bridge defaults to a safe state.

- 00: Open circuit (stopped but not braked)
- 01: Drive forward
- 10: Drive backward
- 11: Error condition (but defaults to driving in one direction)

The initial prototype was controlled via the parallel port of an onboard PC – the 8 output lines (pins 2 to 9) were wired directly into the controller board and the signal ground (pins 18 onward) linked to the motor controller's ground. A more elegant solution would be to use a microcontroller for this purpose.

An overcurrent output is also provided but was not used in the prototype. The voltage on this pin is directly proportional to the average current drawn by all the H-bridges and may be used to detect a motor stalled condition using a comparator or an analogue input on a microcontroller.

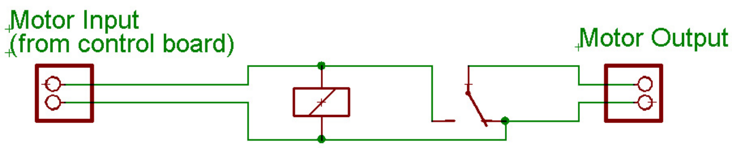


Figure 9: Simple motor brake circuit. Motor is braked whenever there is no motor input.

## 3.3 Motor brakes for the flippers

The existing H-bridge controller leaves the motors in open circuit when not powered. This leaves the gearbox in "freewheel" state, an undesirable state for the two motors that drive the flippers as these often need to support the weight of the robot. In order to lock the flippers, it is necessary to put the motors in brake mode by shorting them. For simplicity and cost effectiveness, relays were chosen for braking the motors.

Figure 9 shows the circuit used in the prototype. Whenever the H-bridge was not driving the motors, the relay shorted out the motor (but not the H-bridge). When the H-bridge drove the motor in each direction, the relay would energise, simultaneously releasing the brake (by not shorting the motor) and connecting the motor to the H-bridge. Note that at no point is it possible to short the motor control board with this circuit. As the relay coil is unpolarised and the H-bridge already protected from inductive loads, no additional circuitry was required. This arrangement also has the advantage that the relay coil acts as a low-pass filter so the brake ignores PWM signals.

An unfortunate side effect of placing the relay coil across the motor is that the motor's back-EMF can keep the relay coil energised. This situation arises when the external torque applied to the flippers is in the same direction as the motor's drive direction at the instant of switch-off, such as if the robot was attempting to lower itself at the instant of switch-off. Torque applied in the opposite direction, as would be the case if the robot was raising itself at the instant of switch-off, would not cause this problem as the back-EMF from the motors would cause the relay current to reverse, dropping the relay's magnetic field for long enough to cause the relay's contacts to short the motor.

This problem will be solved in the next prototype by driving the relays directly from the microcontroller, using another two digital outputs. Setting up the relays to activate on a double-on signal, and making use of the control board's shoot-through protection, is also possible although the relay's activation delay may cause problems, as may a small amount of current leakage through the H-bridge when in this state.

## 3.4 Mounting and interfacing of onboard computer

The prototype made use of a Wafer-5820 3.5" ("Biscuit PC") motherboard with a 233MHz National Semiconductor Geode x86 processor. As this board was too large to fit inside the shell of the robot, it was housed in a padded enclosure bolted to the rear of the robot as shown in figure 11. Unfortunately the padding used was insufficient during some of the robot's more challenging manoeuver.

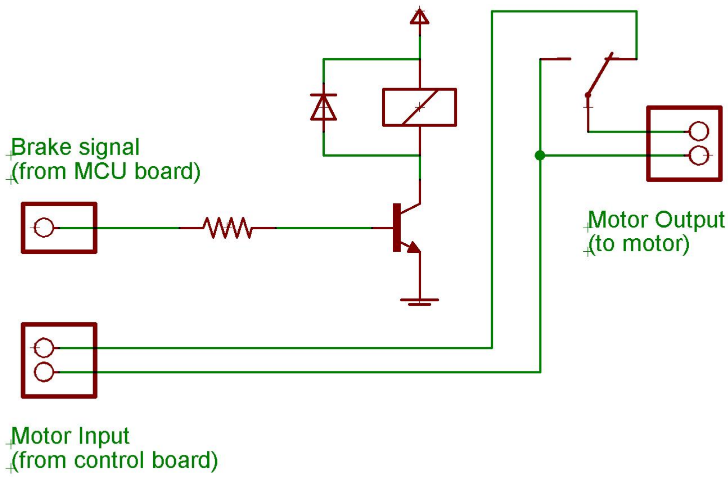


Figure 10: Motor brake operated by a separate digital line from the microcontroller.

The onboard hard drive failed after a tumble down a flight of stairs. A more suitable onboard computer and mounting arrangement is shown in figure 12.

The onboard PC controls the H-bridge board through its parallel port – each of the 8 parallel port output lines connected to a H-bridge input. It was found that simple software control was fast enough to perform effective PWM control. The quadrature encoders for the flippers were connected through a ball mouse control board, which performs the necessary thresholding and quadrature decoding and is connected to the serial port on the onboard computer. Although not implemented, provisions were in place for using the mouse button inputs as "click" encoders for track movement, providing basic odometry.

Eight 2.5AH NiMH cells power the prototype, mounted above the rear two motors. Without the onboard PC, these batteries provide enough power for over one hour of runtime; power management issues with the onboard PC shortened this to 20 minutes. Communications offboard were handled via a IEEE 802.11b wireless LAN adapter plugged into the USB port whilst vision came from a simple USB webcam.

# 4 Planned Enhancements

The Redback prototype has proven that it is possible to modify a Tarantula RC vehicle to form a viable robot, with onboard computer control. Future modifications intend to take the Redback in two different directions. The first is a very low cost robot, suitable as a backup robot in the RoboCup Rescue Robot League. Constructed for less than $300AUD, this robot is intended for teleoperation although some degree of automatic control using off-board processing may be possible. The second is a more refined version of the computerised Redback, which may form the basis of a self-contained, semiautonomous robot with enough computing power to perform mapping and enough battery power to run for around one hour.

Figure 11: A Wafer-5820 PC on the rear of the prototype Redback. The black plastic tubing forms a bumper to protect the PC since this section hits the ground first if the robot flips onto its back.

## 4.1 Redback "Lite"

Redback "Lite" is intended to be a very low cost, high mobility platform. Whilst it will almost certainly not be used alone in a RoboCup Rescue environment, it may be used as a secondary robot to approach areas that a more advanced sensor carrier might be able to see but not approach, or for use as a backup in case the main robot becomes stuck. The only sensor on Redback "Lite" will be a single wide-angle camera. This camera, mounted on a boom, normally points down at the robot, allowing the operator to view the position of the flippers and the immediate area around the robot. This eliminates the need for position encoders on the flippers – they may be directly observed from the camera. A rotary solenoid is able to rotate the camera forward, providing additional vision from the front of the robot. Control will be via the original remote control, keeping the cost and complexity low. Control range may be extended by using the original remote as a base-station and running the controls themselves through data lines. The control signal for the camera is derived from the original remote controller's headlight signal. Video feedback is obtained via a standard wireless video receiver of the type used on model helicopters.

### 4.1.1 Parts and Estimated Prices (AUD)

**MGA Tarantula** $120.00

**Lightweight, wide-angle camera** $75.00 (with built-in transmitter)

**Motor brake relays** $15.00

**Rotary solenoid** $15.00

**Camera boom and other hardware** $15.00

**Battery pack (8x AA 2.5AH NiMH cells)** $30.00

**TOTAL:** $270.00

### 4.1.2 Anticipated Procedure

To allow for precise control over the flippers, it is necessary to implement the motor brake as in 3.3. For ease of control, configuring the relays to brake on a separate signal from the control board (as opposed to the motor control board's output) is recommended.

The video camera boom's length depends on the angle of the camera lens but should be no higher than approximately 30cm from the top of the robot. The boom should be constructed from a material that will allow the robot to roll over sideways completely as the robot is able to self-right if it rolls over completely but will get stuck if propped up on its side. Experiments with other robots have shown that two flexible hacksaw blades (sometimes sold as a "non-shatter" or safety blades) stuck together with a layer of foam-backed double-sided tape works well as a vibration-damped boom and is of approximately the correct length.

If a lightweight camera with inbuilt transmitter is used only a small rotary solenoid is required to rotate it from pointing downwards to pointing forwards. If a rotary solenoid cannot be sourced, a small hobby motor may be used, a series resistor may be required to prevent burnout as the motor will be stalled in both positions. If the solenoid is a return-to-default type, it can be directly coupled to the headlight control of the Tarantula's original receiver. Alternatively, if a motor or bidirectional solenoid is used, it can be driven via a simple relay or transistor circuit.

The battery pack may be mounted in a variety of locations. The easiest location is on the rear of the robot, above where the false turbojets would sit – this is where the computer was placed in the prototype shown in figure 7. Alternatively, for balance the pack may be split into two groups of four and placed towards the middle of the robot or just inboard of the front flippers.

## 4.2 Redback 1.0

Redback 1.0 may be used as a primary robot although due to its lightweight sensor package, it may be more suited as a secondary robot or as one of a small swarm of semi-autonomous robots. A sensor package including a laser range scanner (potentially on a tilting mechanism), omnidirectional camera and optionally one or more webcams, plus flipper encoders, accelerometers and other sensors make Redback 1.0 a potentially very rich platform on which semi-autonomous advanced mobility operation can be developed. A mocked up image of the completed Redback 1.0 appears in figure 13.

A possible primary computer for Redback 1.0 is the Sharp Zaurus SL-C3000. This is a very capable computer with a 400MHz PXA processor, 64MB system RAM, 4GB hard drive (which can be replaced with a solid state compact-flash card for durability) and, by default, a Debian-based operating system. Unlike most other PDAs, in stock form it also has a free SD card slot (for which an SDIO stack exists), a free compactflash type 2 slot and the ability to operate as a USB1.1 host via an onboard USB host controller. This allows it to control microcontrollers, USB webcams and potentially small laser range scanners such as a Hokuyo URG [3] simultaneously through a powered USB hub, while communicating to a base station via a wireless LAN compactflash card. Its 400MHz processor also allows it to perform rudimentary image processing and

Figure 12: The prototype Redback with a Sharp Zaurus SL-C3000 fitted to the rear (in place of the power control circuitry visible in figure 7). Removal of excess plastic from this region will allow more of the screen to be visible.

mapping and provides the option of semi-autonomous operation. Its internal battery provides over one hour of runtime and can be externally powered from a 5 volt supply. The small size of this PDA allows it to be placed inside the existing robot's shell, where it can be well protected as in figure 12.

An alternative computer is the Sony Vaio U71, which weighs only 600g with wireless LAN equipment and has a considerably more powerful 1.1GHz Pentium M processor, 60GB HDD and 512MB RAM. However for size reasons, it will need to be mounted outside the shell and suitably armored against rolls and falls. In addition to the significantly faster processor, the Vaio also has firewire and USB 2.0 for improved connectivity.

#### 4.2.1 Parts

The following parts are in addition to those listed in sections 3.1 and 4.1.1.

**Computer** Sharp Zaurus SL-C3000, SL-C1000 or SL-C3100

**Wireless LAN** Planex GW-CF11X (or any compactflash wireless LAN card with a PRISM2 or PRISM3 chipset)

**Standard camera** Logitech QuickCam 4000 (or any camera with OS support)

**Accelerometer** ADXL311 (or any accelerometer with a serial or USB interface)

**Microcontroller board** UNSW/CSE USB-AVR323 board (or any AtMEGA323 development board with USB interface)

**USB hub** Generic 4-port USB hub with external power input

**Battery pack** 2x Lithium Polymer model aircraft pack, total of 4.6AH, 11.1V

**Power supply** MAX1626 based power supply (or any DC-DC 11.1V to 5V 2A switchmode power supply)

**Range scanner (optional)** Hokuyo URG-X002 or similar

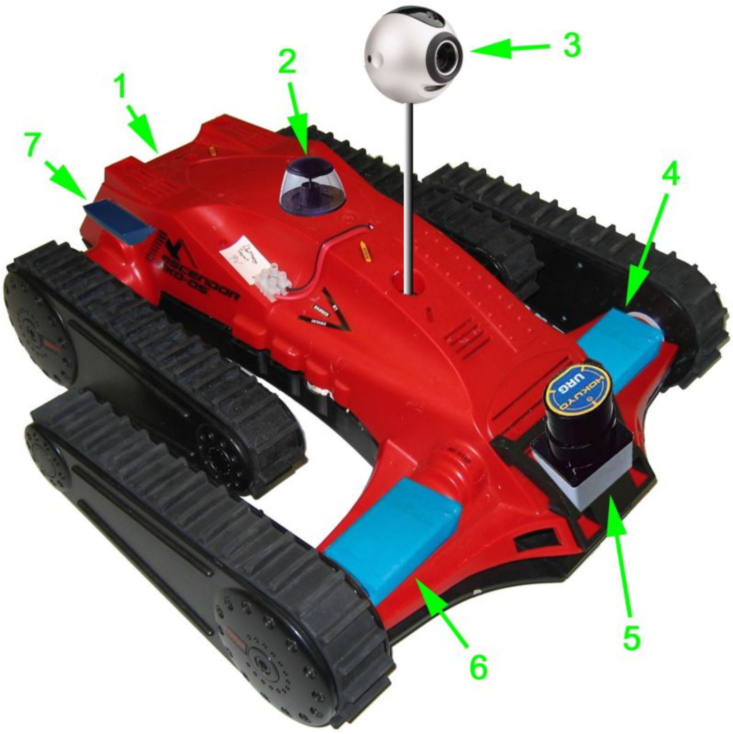


Figure 13: A mockup of what a Redback 1.0 might look like. Significant components are: 1: Onboard computer (hidden), 2: Omnidirectional camera, 3: Driving camera, 4: LiPoly battery pack, 5: Laser range scanner, 6: LiPoly battery pack, 7: Wireless LAN antenna

**Omnidirectional camera (optional)** VStone VS-C15MR or similar with USB webcam

**Pan-tilt and laser tilt servos (optional)** Generic miniature hobby servos

#### 4.2.2 Fitout Notes

A mockup of what a completed Redback 1.0 might look like appears in figure 13.

The computer will be placed in the rear of the robot as shown in figure 12. This position allows access to the user interface, external power and USB without removing the shell, while keeping it protected in the case of rollover. The power switch may be accessed through another slot cut in the shell. The compactflash wireless LAN card is inserted through a slot cut in the left of the shell – this area is not structural so this slot will not weaken the shell. Alternatively, if other devices are to be used in the compactflash slot, a USB wireless LAN adapter may be used.

The driving camera may be placed either on top of the robot as in figure 13(3), on a pan-tilt mount or, if that location is to be used for an omnidirectional camera, in the very front of the robot. Alternatively, this camera may be omitted altogether if an omnidirectional camera is used. The omnidirectional camera may be mounted through a hole in the top of the robot such that only the mirror is exposed as shown in figure 13(2). There is ample space under the shell at this point for a small webcam mounted under the mirror. An acrylic tube may be used to protect the camera in the event of rollover should it not be strong enough to take a fall.

Several options exist for the Hokuyo laser. Due to the size of the flippers relative to the robot, there will not be a location on the robot where the flippers will never obstruct the laser. However, this may be reduced if the laser were mounted in front of the front gearbox, where there is also ample plasticwork to protect it as in figure 13(5). Additional protection may be afforded by an acrylic tube of suitable size. Alternatively, the laser may be mounted on a tilting servo in the same position to enable the generation of 3D maps, although protection from rollover may be more difficult. The USB Hokuyo laser may be connected through the USB hub to the computer, alternatively a serial version may be connected to the microcontroller. The serial accelerometer may likewise be connected to the microcontroller or, through a USB to serial adapter, to the computer.

The microcontroller provides the appropriate signals directly to the H-bridge. Two lines are also used to control the motor brakes. The microcontroller can also provide servo signals for the optional pan-tilt unit and/or tilting Hokuyo laser scanner. The quadrature encoders may be directly interfaced to the microcontroller. Alternatively, the original mouse control board may be retained and the serial output connected to the microcontroller, thus saving three GPIO pins and eliminating the need for a thresholding circuit.

An AVR AtMEGA323 based board was chosen for simplicity – it is easy to come by, is relatively cheap, has a large user base and has enough GPIO lines for basic control. Alternative microcontrollers from Microchip, Philips and others may be used. Control of the basic Redback requires the following inputs and outputs. Additional I/O for pan-tilt units, accelerometers and the like will also be required depending on the fitout desired.

**Actuation** 8x digital outputs driving the existing H-bridge, 0-5V signal (tested with TTL level, should also work with CMOS level)

**Flipper feedback option 1** 1x UART or software UART for mouse board input

**Flipper feedback option 2** 4x digital inputs for quadrature decoding

**Flipper feedback option 3** 2x ADC inputs for potentiometer inputs

**Odometry option 1** 2x digital inputs for "click counting" odometry (rely on motor drive for direction)

**Odometry option 2** 4x digital inputs for quadrature "click counting" odometry

**Offboard communication** 1x UART or software UART for offboard communication

Due to the added power consumption of the sensors and computer, a suitably upgraded power supply is necessary. It is anticipated that an 8xAA 2.5AH NiMH cell pack will not be sufficient for a fully fitted out robot, instead two 2.4AH 3 cell lithium polymer battery packs should easily provide sufficient power for over one hour of operation and, being sufficiently small, may be mounted on the front of the robot as in figure 13(4,6). Running at 11.1 volts and with a significantly lower internal resistance than NiMH, they should also enable the motors to provide much greater torque although additional heatsinking on the H-bridge transistors might be required. PWM control may be used to reduce the chance of overheating especially when the additional torque is unnecessary. As all of the additional equipment operates on 5V, a suitable DC-DC buck converter is necessary. A switchmode buck converter is recommended for efficiency and heat dissipation reasons.

With the removal of the original remote control, there is ample space inside the shell for the microcontroller, USB hub and power control circuitry, as well as the computer. The only devices that need be on the outside of the robot are the omnidirectional camera mirror, driving camera, batteries and laser range scanner. A basic rollcage may be fashioned to protect these sensors although care must be taken that the roll cage does not prop up the robot if it were to roll over sideways – the robot is able to self-right if it ends up flat on its back but not if it is propped up sideways.

# 5 Conclusion

This paper has described how an MGA Tarantula RC toy can be converted into a very capable, low cost robot, dubbed Redback. Despite being a toy, the Tarantula is reasonably well built and parts may be replaced reasonably easily. Being relatively small and lightweight, the logistics of building and using the Redback are simpler compared to many other solutions. Its low cost also lends it to use for a wider variety of projects and parallel projects – purchasing several robots is a practical option. The mobility of this robot is without question – the platform is physically able to climb human sized stairs, overcome “pillar” obstacles twice its height and has enough torque to lift itself vertically should it somehow find enough grip.

The prototype Redback has an onboard computer and is equipped with a webcam, wireless LAN, control over the robot’s motors and feedback on the robot’s configuration. Unfortunately, evaluation was cut short by power difficulties and a hard disk crash. We have planned the construction of two new versions of the Redback. The first is a highly mobile camera base which can be built for less than $300.00AUD including the platform. The second is a potentially autonomous, highly mobile version with a predicted cost of around $1,000AUD – most of that cost involves the onboard PC. Additional equipment to provide omnidirectional sensing and 3D sensing and mapping capabilities can push this cost up beyond the $4,000AUD mark.

The Redback fills a substantial niche in mobile robotics, as a very low cost, highly mobile, easily constructed robot, suitable for a wide variety of research projects from the RoboCup Rescue Robot League to experiments in reconfigurable robots, user interface design for highly mobile robots and autonomous control of robots in unstructured environments.

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