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ADP010336

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Miniature Remote Eye/Ear Land Vehicle

(April 1999)

B. Hall
B Hall Industries Inc.
146 McAllister Rd.
Toronto, ON, M3H 2N7
Canada
and
J.J. Grodski
Defence and Civil Institute of Environmental Medicine
P.O. Box 2000
Toronto, ON, M3M 3B9
Canada

Abstract

A miniature remote surveillance land vehicle was developed for experimental real-time video/audio data acquisition in air defence live-fire training. A mobile sensing platform was needed to acquire the video/audio data at a close proximity to the gunners, without breaching safety requirements. The platform was designed to be small, conforming to the need to transport it as a passenger luggage on a commercial airline. A commercially available ready-made largest 1/10 scale Radio Control (R/C) hobby vehicle with 4 wheel drive system was chosen as the platform. It incorporated pre-built drive, suspension and steering systems. The chassis was fitted with 4 kg payload for a total weight of 8 kg. It was very stable after adding damping shocks and extending the chassis. It was capable of climbing 15 cm sidewalk curbs, driving down off 20 cm ledges, climbing 10 to 20° slopes and through about 10 cm of light to medium snow with its original rubber tires. Its total travel range was shown to be over 800 m. The control function for the vehicle and its sensing system was achieved using an R/C unit whereby a channel-select plus channel signal multiplexing system was developed to operate one selected channel of 7 possible at a time using only two radio channels. The sensing capability of the vehicle involved a digital video/audio recorder positioned at the front of the platform and a miniature camera and microphone assembly placed on the top of a telescoping mast with an ultralight pan-tilt unit based on a micro R/C servos. The video and audio signals from the mast-mounted package were transmitted to the control station using a repackaged commercial transmitter. Testing and use of the vehicle determined operational limits of its performance and led to its modifications and enhancements.

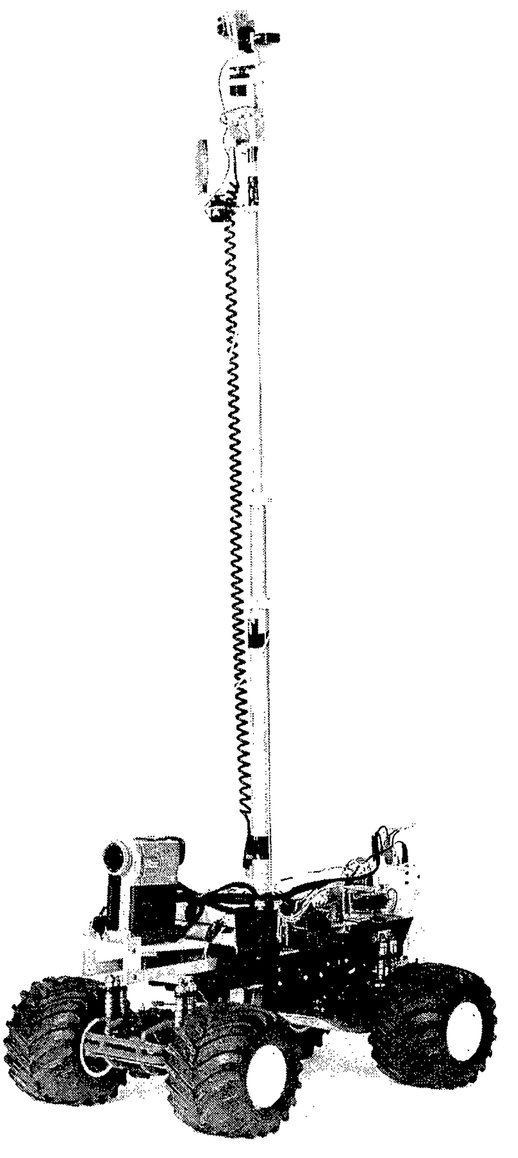

Figure 1. The miniature surveillance vehicle with fully extended mast.

Paper presented at the RTO SCI Symposium on "Warfare Automation: Procedures and Techniques for Unmanned Vehicles", held in Ankara, Turkey, 26-28 April 1999 and published in RTO MP-44.

Introduction

Data acquisition work has been carried out during air-defence field firing trials of the Canadian Forces over a number of years for a variety of reasons. The practical experience from this work and interaction with the operators brought up the need to document performance of the gunners as well as the missile launchers during the exercises. However, tactical scenario of the exercises and safety considerations, combined with the variability in the activities and the scene, made it practically impossible to acquire useful video and audio data reliably from remote, fixed video/audio systems. This led to the desire to have a remotely controlled camera/audio system that could be positioned at will without requiring any hands-on adjustments and which would not be subject to the range-safety restrictions imposed on personnel. It was also desired that this system have a real time video link to the control area so that remote camera alignments and fields of view could be seen and adjusted as required, as events evolved. It was particularly important to adjust the location of the camera so as to avoid blocked-view situations which occurred with a fixed-view camera. This could be naturally accomplished with a mobile platform. A mobile platform would allow for placement of a camera even in the down-range area which is not accessible to personnel on account of the safety issues.

The ideal objective was also to have the system small enough to go as a normal luggage on a commercial airline. This objective imposed significant weight and size limitations. It also precluded gasoline as the source of power since the fuel vapours create a hazard in transportation. Moreover, noise and controllability issues of gasoline engines create unnecessary problems when compared with the inherent quietness and ease of controllability of electric drive. Battery power, therefore, became the main alternative.

Upon deciding to develop a miniature remote eye/ear land vehicle that would conform to these objectives, a time and effort conservation approach was taken in conceiving its design. It was also desired to keep the costs down. With this in mind it was noted that the vehicle could consist of a set of subsystems all 'glued' together. The aim was to minimize the effort. This lead to a market survey of hobby R/C vehicles already equipped for remote radio control operation as a source of a pre-built chassis with power, suspension and steering.

Initial Considerations

Method of Project Development: The aim of the project was to design the smallest, lightest and yet economically practical and operationally functional remotely controlled vehicle with camera and microphone functions. The approach in the design of the vehicle was driven by the need to maximize its range of travel. It is well known that heavier vehicles have greater power consumption and with a fixed power source, their range decreases correspondingly. The weight of a battery-powered vehicle consists of vehicle chassis, including its payload and batteries. The low energy consumption aim was therefore turned into the goal of minimizing the weight of the vehicle. An iterative process was applied to optimize the match between the payload requirements and the chassis/payload capability. The market was searched for subsystems to maximize the system capabilities, minimize its cost, minimize its weight and satisfy the compatibility requirements. The following sections address issues related to the planning of the capabilities and design approach for the vehicle. Functional aspects, chassis and payload capabilities were considered. The payload had to be determined first before the chassis could be addressed. The payload was to include: video/audio sensing, video transmitter, the channel mutiplexer/optoisolator, battery and battery switching circuit for the main drive motors, telescoping mast for bird's eye view camera, radio receiver with antenna, and radio battery and electronic speed controller for the wheel drive motors.

Video System: A video unit, either a camcorder or a discrete camera with a separate VCR was the central item in the payload of the vehicle. The video capabilities were to include a camera head with lenses, preferably mounted on a pan-tilt and/or leveling mechanism and transmission or recording equipment to allow monitoring and logging of the video scene. It was anticipated that either option would represent a substantial load. Hence, the camera was to be mounted centrally on the chassis. In operation, low quality video could be used for navigation purposes and then the system could be switched over to high quality for actual data acquisition and recording. Data acquisition had options of recording at a base station after transmission and recording on the vehicle. The on-board recording option was limited by tape length while base station recording could be affected by transmission quality. Video transmission was also required for camera alignment and sighting.

Once the very light and very small tape digital camcorders became available, all heavier and larger analog units were eliminated from considerations. Sony, digital DCR-PC7 with 60 min quality recording tapes (or 90 min in the extended play mode) was chosen as the camcorder for the vehicle. It weighed 621 g with a new Lithium Ion battery with 90 min. capacity. It used proprietary image compression technique before laying it to tape. The overall quality of the compressed image was slightly lower than Hi-8. However, this was a reasonable trade off for the smaller weight and size.

The digital camcorders functioned as auto-focus, auto-exposure camera system without any external control, unlike discrete camera systems (e.g. Sony XC- 777). With the use of an additional control signal, the camcorder approach offered a fully motorized zoom lens function, again at a large weight, volume and cost advantage over discrete camera with a motorized lens, although with a lesser zooming power. The digital camcorders had NTSC composite video output which could be transmitted and monitored back at the base station.

A mast-mounted camera was also added. It would be particularly useful for navigation. The plan was to have a short mast for general travel. It could telescope on command to greater height. The telescoping capability would serve two useful purposes. It could allow to "see" overtop of obstacles, such as toll grass or bushes. It could also help video transmission quality by raising the mast-mounted transmission antenna to facilitate better signal propagation. The camera was meant to be very small and lightweight and was also to be mounted on a similarly extremely small and lightweight pan-tilt mechanism that would be at the top of the mast. MicroVideo PC37XSA B&W camera was chosen. It came with a relatively wide-angle lens at 78° field of view and an onboard microphone, both weighing only 31 g.

Video Transmission: The video transmission can be accomplished in many different ways and means, each with its technical and regulatory pros and cons. An unlicenced alternative, explicitly noted as being FCC Part 15 approved, was chosen for the project. Two frequency bands, 900 MHz and 2.4 GHz, are generally used in FCC Part 15 equipment for video transmission. Each system typically consists of a transmitter and a matched receiver. Wavecom 2.4 GHz units offered by Microvideo were chosen as they operate in the less crowded band. The units could be operated in one of 4 channels within the 2.4 GHz band. Therefore, one could operate 4 different send-receive pairs in the same area. The basic turn-key NTSC color video plus stereo audio transmit-receive pair was also advantageous. A higher gain receiver was also acquired to facilitate a longer range transmission. Enclosure of the sending unit was substituted with a lighter, smaller one. Only one audio channel was connected as the camera had mono sound. A 10-cell 12V battery pack used sub-C Sanyo NiCd cells. The cells were arranged in a compact enclosure which was mounted crosswise on top of the chassis, near its center.

Chassis: A basic task was to source a chassis that would be as small and light as possible while being able to carry a nominal payload. It was to have the ability to drive reliably over and through different environments without getting stuck. It was also to have a stable, low center of gravity so that the chassis could be oriented in different directions on a slope without danger of tipping over. A contradictory desire was to have lots of ground clearance under the chassis so that relatively large obstacles such as rocks and stumps could be driven over without getting hung up. It was also desirable that the chassis should have a suspension system such that a smooth ride was delivered to the camera and VCR payload. A contradictory objective was that the suspension should not be soft and compliant because the chassis would then be subject to movement induced by any gusts of wind. Deployable stabilizers could be added but their weight and complexity would be detrimental. With considerations for the chassis features, the video and radio equipment, a general size for the payload was anticipated to be less than 4.5 kg.

Use of tracks was considered to achieve very good all-terrain mobility. However, detrimental derailing tendency of tracks with increased traction and lack of tracked options, compatible with the anticipated size of the vehicle, led to the consideration of wheeled alternatives. Wheeled chassis were developed by the R/C hobby industry. They addressed the issues of miniaturisation, adequate strength, durability and low cost. One of the overall benefits of using a ready made large scale R/C chassis was that it had drive, suspension and steering systems all pre-built and ready for use. The practical issue was to find a model with suitable overall size and strength. The common R/C size is 1/10 scale (about 30.5 cm long vehicle chassis) with electric 4-wheel drive. This was too small to fit the basic VCR and the other equipment. The largest chassis were gasoline-powered 1/6, 1/5 or 1/4 scale with about 61 cm long wheel-bases and rear axle 2-wheel drive with a full differential. For this application, the gasoline engine would have to be replaced with an electric motor. Lack of compatible assemblies precluded use of more robust replacement differentials and creation of a 4-wheel drive which would be more suitable for off-road driving with a larger payload. The Clod-Buster "Monster Truck", the largest 1/10 scale commercially available 4-wheel drive chassis was discovered. It had all-wheel steering, 15 cm diameter heavily treaded tires, a 27 cm wheel base and an overall width of 37 cm across the outsides of the tires. The vehicle weighed about 3.6 kg without the cosmetic truck body. Each wheel plus tire weighed 380 g which meant that the four wheels plus tires weighed 1.5 kg total. The drive was done with two separate motors plus differential axles. It offered an excellent initial suitability for off-road use.

Development of Clod-Buster Based Vehicle

Drive Train Tests: Various bench tests were carried out with the Clod-Buster 7.2 volt 540 motor differential assemblies with plastic gears. Data were taken about energy usage and motor current draw that is directly related to generated forces and torques. Since both ends of the chassis had an identical motor and differential assembly, only one was tested. Two different modes were used; one where both wheels spun simultaneously, involving one set of gear meshing and another where only one wheel spun and the differential action was invoked. 2.6 A current was needed to break the static friction and start the gear train with no external loading. Only 1 A was required to maintain spinning. The spinning freewheel rpm increased as a function of the applied motor terminal voltage: rpm = -11.28 + 73.88 x V. The actual speed would be lower on account of the load from rolling resistance and losses in the electronic speed control for the motor.

The single motor/differential combo was then tested under load. The current requirements would correspond to initiating forward motion of the vehicle against rolling resistance or a slope: Motor current (A) = 1.63 + 0.19 x Torque (N-m). If the vehicle weighed 4.5 kg and rolling resistance was neglected, with the 15 cm diameter wheels, an incline of 10° would require a forward thrust of 7.7 N which should require current draw of 11.3 A. The motor's terminal resistance was measured to be about 0.17 ohms. The motor near-stall at 7.2 V supply would draw very high current, mitigated by the systems resistance and onset of motion. At slow armature rotation, the motor currents near 6 A were taking only 1 V on the motor. The rough analysis shows that the chassis would have a fair amount of thrust capability, despite the seemingly small battery voltage of 7.2 V.

Another test with one wheel locked indicated that differential did not incur significant losses when their action was invoked. The back driving of the differential was also tested in analogy to the vehicle starting motion down a slope. At 0.34 N*m torque, the motor/differential would back drive without any power applied. That would imply that in the 10° slope example, its 7.7 N thrust would be held by the pair of differentials, meaning that the vehicle would not roll down when parked down hill with the power off.

It is estimated that the drive train is about 90% efficient as it uses spur gears and it is likely a non-issue when compared to the real world rolling resistance as a function of terrain and vehicle weight.

Telescoping Camera Mast: A telescoping camera mast was needed for the vehicle to facilitate the diverging needs associated with the (low center of gravity) mobility on one hand and the highest possible camera position in a static state on the other.

There was a need for a telescoping mast that would be very light, operated with low power, achieve chest-height on deployment and that would stay at the height it was moved to after power was removed from its motor. It was to have a minimum height when retracted. Mast designs with 2, 3 and 4 stages were pursued. In the final version, a 450 g, 3-stage mast was developed, placing the camera at the level of 140 cm above ground. Figure 1 and Figure 2 show the extreme positions of the mast on the vehicle. The motor for the mast was a servo, modified to be a gearhead motor with unlimited turning of its output shaft. The drive used a pulley and a slip clutch. Custom made teflon slip bushings were used for the telescoping assembly. A positive drive string system was used to lift the stages with a string in a closed loop passed over pulleys at the top edges of each mast piece and then down under pulleys at the bottom edge of the next inner mast piece. The string had to pass through the gap between each pair of sliding members. The system worked on the principle that the string could lift from the top edge of the outer member upon the bottom edge of the next inner member. When a member rose to its most upper position as defined by hitting a travel stop, the string would simply roll through the ball bearing pulleys. The friction of the string over the pulleys was almost zero and it was this that allowed the use of a stock servo as bottom drum pulley motor.

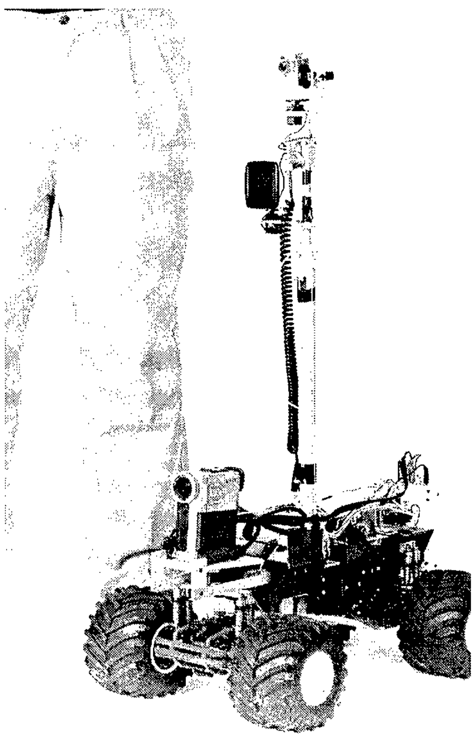

Figure 2. The vehicle with its mast collapsed.

Initially, a separate fixed-length mast was made for the video transmitter. It was substituted with a special mount made to hold the antenna near the top of the telescopic mast, at a sufficient radial offset so that the mast would not be in the transmission path. The antenna transmitted in an approximately 180° arc pattern from its face but the strongest transmission was on its axis. The range of the antenna positions on the mast was decided based on two factors. One was to have the main range of motion pointing away from the mast. A second was to consider what situations it would operate in so that transmission could go unimpeded. Typically, it would be pointed rearwards or sideways from the vehicle.

Mast Camera Pan-Tilt: A very light, low precision pan-tilt unit was made for the mast-top camera. Microsize R/C position servo was used as the entire drive, electronics and axis mechanism for each axis of motion. This was possible because the extremely light weight camera was not likely to overload the plastic gears, shafts and bushings of the servos. The Supercircuits PC37XSA black and white camera with microphone/preamplifier and the pan-tilt assembly weighed about 140 g. It is shown in Figure 3. The clear plastic box around the camera was only 3.8 cm square on its front.

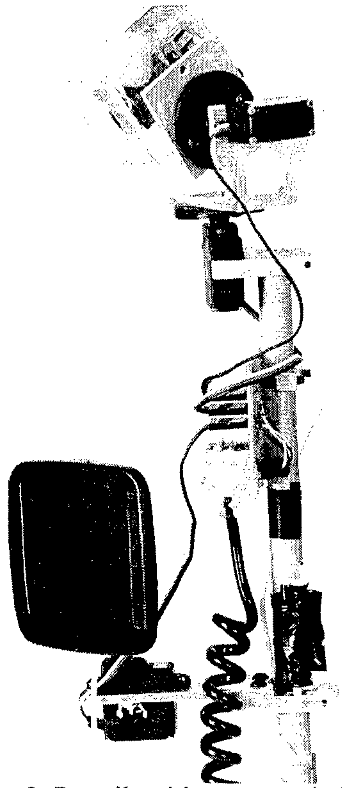

Figure 3. Pan-tilt with a camera/microphone assembly and video transmitter antenna at top of the mast.

Multi-Channel R/C Radio Operation: There was a need to use a number of R/C radio channels to control various functions on the vehicle, such as the pan, tilt, antenna orientation and steering. Two 8 channel radios were acquired with the expectation that they operate on different frequencies. However, their specialised channel mixing functions were not advantageous to this application. A channel select plus channel-signal multiplexing system was developed which used 3 output channels that were relatively directly coupled to outputs in the radios. A multipole wiper switch was modified and coupled with a servo, providing the means to switch signal and power connections. The signals were multiplexed using one signal as a chooser channel and another channel as the command to be sent. Thus, the radio's two joysticks could be used in a predictable and relatively simple way to operate seven channels. The third channel was connected directly to the electronic speed controller for the drive motors on the wheels. An opto-isolator was used to provide a barrier between the long servo lead wires that went up the masts and to various locations on the chassis and the radio receiver. The isolator also allowed separation of the receiver power from the device loads to extend its run time. The left-right action of the right joystick was used for an intuitive steering control. The front-back action of the left joystick was connected as the control for the channel selection because it did not have a spring return action. The selector serviced steering, mast height, mast camera pan, mast camera tilt and video camera orientation. It also had the capability to serve tilt for the camcorder and select video output to the transmitter.

Initial Testing and System Modifications

In the initial tests, extreme *fore-aft rocking* of the chassis during acceleration, deceleration or when on bumps indicated that the chassis was too tall or too top-heavy for its length. Moreover, the masts and video battery pack occupied nearly all of the central chassis region and there was no space for a camera which was yet to be mounted. The chassis wheelbase was therefore extended nearly 50% to 39 cm. The completed vehicle weighed about 7.3 kg, effectively doubling its original weight. The extended chassis was very stable. It was capable of climbing up 15 cm sidewalk curbs and driving down off of 20 cm or 23 cm ledges. It was capable of climbing 10° to 20° slopes. Some amount of maintaining momentum in driving style helped significantly in overcoming small surface irregularities on the slopes.

Side-to-side rocking motions induced from even the smallest bumps in the grass were corrected with the use of replacement coil-over shocks which could be filled with oil of desirable viscosity and thus provided more effective damping. The shocks also allowed preloading adjustment thereby to take care of inequality in load balancing.

Differential action was found to halt progress if one wheel of a differential set lost traction and started spinning. An electronic differential action occurred when the two motors were wired in series in economy mode in that, if one motor broke free, the total current dropped and with it the drive force dropped. In parallel wiring power mode each mechanically differentialled wheel pair could develop its own thrust regardless of the slippage of the other wheel set. A traction problem occurred when the stiffly suspended chassis became supported on a pair of diagonally opposite wheels in that both drive wheel pairs would lose drive as the suspended wheels spun freely with little or no contact force with the ground. Softening of the preload in the shocks to increase the suspension compliance allowed larger obstacles to be accommodated on the diagonal wheels before loss of contact pressure on the other two diagonal wheels occurred. However, softening of the suspension increased side swaying. A smooth nylon sheet skid plate was attached to protect undercarriage from gouging during contact with protruding obstacles.

The steering was not strong or rigid enough despite the increased servo strength to 0.812 N*m, resulting in uncontrolled course changes when an obstacle would hit only one wheel, jarring the steering. This occurred because of the anti-breakage spring-torque link in the steering linkage. Excessive tightening of this link was discouraged by the increased risk of breakage in the steering system.

The pan-tilt with the top segment of the *mast* was panning in random motion whenever chassis hit a bump. The pan-tilt off-axis center-of-mass created the problem. An anti-rotation feature was implemented on the mast to prevent the problem. It was a piece of piano wire glued to the side of the tube to form a straight, uniform sized ridge.

The *range of travel* of the vehicle was shortened significantly when carrying its extra payload and rolling in the grass. The stock battery was replaced with three 1500 mAhr packs to extend the range. A three battery switching circuit was set up to protect the NiCd batteries from discharge below 1.1V.

Performance Tests of the Vehicle

Preliminary testing of the vehicle mobility and communications was carried out during a summer air-defence firing camp and later, during a snow storm.

The vehicle was driven for an *endurance* test from a control position at a range, over a raised road about 150 m away and out to the firing point, another 70 m further. Direct external viewing was used in the control process. The ground was relatively hard, flat, sometimes grass-covered terrain with bumps and protrusions significant for a miniature vehicle. The first run was via direct view from the control position. At the road, the vehicle became hard to control because it was hardly visible at the distance. Some traction problems occurred there when the vehicle encountered a gravel ridge. The vehicle was initially run in the slower economy mode to lower the chances for a driving accident. Once the motor was switched to parallel wired power mode, the vehicle climbed up the incline and over the road ridge. Controlled by an operator at the road, the vehicle proceeded to the firing point, maneuvered around the firing point, climbing up the mound a few times. Then, it was driven back to the road, crossed the road and was driven all the way back to the base for a total of 400+ m travel. This completed the basic endurance test. The opportunity to drive it till it ran out of battery power was then exercised. At this point in time the range observation tower was used and found to offer a good view all the way from the base out to the firing point. The vehicle was driven back out to the road at which point it seemed to stall. A thermal shutoff had occurred but once it cooled off the vehicle was driven out to the firing point again and driven all the way back to the base for a new total of 800+ m travel. Battery power was still available at that time but the test was terminated.

The vehicle was also tested for *terrain traversal* capability. A small hill was used for the test. In addition to the incline there were irregularities on the surface which tended to form small segments of higher incline. The mast was the only way the vehicle could be seen in tall grass when climbing the mound. Inconsequential tipping was seen when the vehicle was driven with one side's wheels over a stone. More significantly, on account of the insufficient steering strength, the stone turned the wheels, altering the direction of the ascent. Then, the vehicle would hit the bump or depression, possibly at speed. There was no way of predicting the hazards before driving into them, particularly in the tall grass or when operating at a distance. There was a potential hazard of flipping the vehicle when encountering substantial obstacles such as stones, falling into small holes or depressions created e.g. by truck wheels in mud. However, the vehicle was stable even when encountering unplanned obstacles at speed, showing quite a resistance to flipping over. The chassis proved quite robust despite its overloading as compared to its intended commercial purpose. Considering the size of the vehicle, its terrain traversal capability was judged to be excellent. Perhaps the best example of its successful performance was a crossing of a plot where brush and small trees were cut at about 8 cm above the ground. The tires and suspension absorbed the 8 cm tree stumps without excessive perturbation.

The colour digital *camcorder* mounted at the front of the vehicle was tested in a navigation task. A styrofoam wedge was used to trim it to an angle that balanced some land vs. sky such that waypoint navigation was possible. The camera was not equipped with its pan-tilt unit. Rough panning was accomplished with vehicle turning but tilting was not easily achievable. Navigation was difficult with the approximately 30 cm height of the camera lens above the ground. The viewing attitude did not allow for good scoping of the ground layout for any significant distance ahead. Trying to see through the tall grass was distracting. Moreover, the autofocus on the blades of grass, made the desired background blurry. Outdoor lighting conditions posed a difficult task for the good automatic iris capabilities of the camera. The brightness of sky and darkness of land could not be seen simultaneously, particularly on an overcast day; the sky was too bright and/or the land was too dark. A moderately wide field of view was required for onboard camera navigation so that waypoints could be retained in view despite vehicle motions. A narrow field of view was required to see any useful detail at the activity site of interest if a moderate and unobtrusive stand off distance was to be maintained. Color provided much better depth and feature perception than the black and white mast-top camera. There was some degree of picture rocking and shaking due to chassis motions, the amount of which varied with how rough the terrain was.

The *mast camera* imagery was also used for remote navigation of the vehicle. The very local, semi-bird's eye view from the mast camera was particularly useful for way-point navigation, for perceiving ground features and general ground layout ahead of the vehicle and for driving over and around obstacles. One could nearly intuitively pan and tilt it as if it was one's own head and eyes to attain situational awareness. The camera could view the vehicle wheels, as shown in Figure 4, and it could also pan-tilt to survey the surroundings to get a bearing. The camera could be tilted front-wards to see more range in front. The bird's eye view mast camera was more useful than a lower camera in seeing obstacles and in getting a better down-angle view from which to better see land features ahead. For navigation, the black and white image provided less object depth, differentiation and perception usefulness than a color image would. Once near the area of interest, the wide field of view of the mast camera was less useful for observation of activities of personnel within the field of view.

The *video transmission* equipment worked very well but required a clear line of sight between the antennas. The video was found to break up when natural land obstacles or tall grass impeded the line of sight. This occurred quite easily with the vehicle mast set to its lowest position. When the base receiver antenna was elevated, the video transmission was successfully tested to 700 meters and was expected to be able to go much further, provided the line-of-sight criterion was satisfied. The directionality of the antenna setting was not critical but obstacles such as tree or brush in the way of the signal degraded it significantly. When operated in a courtyard, the 2.4 GHz video transmission suffered reflections from the building walls resulting in image breakup.

Some power or *current consumption* tests were done with the vehicle fully loaded. Current measurements were done for both power and economy modes of motor operation, few speed ranges and on various surfaces: flat pavement, level mowed grass and 10° slope mowed grass. In the last case, in series-wired motor mode, the motors used 12 to 13 amps and the vehicle could barely climb the hill. The equation from the earlier bench tests was converted to a form with forward thrust. Knowing that 15 cm dia. wheels were used: motor current in amps = 1.63 + 22.0 x wheel pair thrust in N, yielding 10.2 N thrust per axle. This implies that the total of 20.4 N thrust was used to barely climb the hill in the series mode. The calculated thrust for 10° slope is 11.6 N. The difference between 20.4 N and 11.6 N would be the extra rolling resistance caused by deformation of the tires and softness effects of the grass and soil. This is a significant increase over an idealised calculation. It confirms an expectation that ground conditions are very significant in drive train loading.

The vehicle was also tested for *snow and cold weather performance* (traction and driveability). It was capable of ascending gentle slope mounds in 2.5 cm to 5 cm snow. With this snow coverage, it was also mobile on a road with small ridges of snow created by cars. However, it got stuck in hard-packed snow drifts 10 cm to 12.5 cm deep. Backing out with some wheel spinning was successful in some conditions. Rocking motion did not always dislodge it either when stuck via diagonal support which allowed differentials to act, spinning the unsupported wheels freely. To reduce the diagonal supporting action, the preload was reduced on the front wheels shocks. The vehicle was then going more effectively over discrete obstacles such as the tire ridges in the snow. The more compliant suspension was still subject to limitations when substantial obstacles were encountered. Aggressive driving created significant snow spray which eventually affected the drive circuits of the unprotected payload.

Figure 4. View of wheels in snow, seen through the mast-top camera.

Conclusions

A miniature surveillance vehicle has been successfully developed and demonstrated to satisfy the basic intended objectives. The fully loaded 8 kg vehicle was shown to have a functional capability of traversing a typical range terrain with the power capacity to travel over 800 m. Its image acquisition and transmission capability was satisfactory but some enhancements need to be implemented to make its use easier and more flexible; zoom control on the camcorder and change the mast camera to a colour unit would be particularly advantageous. A video switching selector circuit for alternating between the camcorder and the mast camera, and tilt for the camcorder have been already implemented.

It was observed that travelling around obstacles was the most prudent approach to reliability and energy use conservation.