Ultra-rugged Soldier-Robot for Urban Conflict Missions

Hagen Schempf [a] hagen+@cmu.edu
William Crowley[a] crowley@rec.ri.cmu.edu
Chris Gasior [a] cgasior@rec.ri.cmu.edu
Capt. David Moreau[b] moreaudw@mcwl.quantico.usmc.mil

a: Carnegie Mellon University
Robotics Institute
5000 Forbes Ave.
Pittsburgh, PA 15213

b: US Marine Corps
Marine Corps Warfighting Lab
RSTA Technology Division
Quantico, VA 22134-5069

I. ABSTRACT

The Marine Corps Warfighting Laboratory (MCWL) is currently funding the development of a mobile ground sensor for use at the small unit level that is operating in the urban environment, dubbed *Dragon Runner*. A pre-prototype evaluation unit was developed for MCWL and tested under simulated conditions in the former George AFB, Victorville, CA as part of Millennium Challenge '02. The complete system consists of a backpack-carried vehicle and hand-operated Operator Control Unit - see Figure 1. The vehicle, being the focus of this paper, is based on low-cost materials and commercial components, integrated into an ultra-rugged, small and light-weight unit capable of being handled and thrown by an individual Marine in a fast and rapidly-changing urban mission. The system can operate in either a mobile reconnaissance- or sentry-mode, using its on-board pitcheable low-light video-camera (with IR illuminator) and wide-angle motion detection sensors and microphone. Its initial testing results indicated the validity of the concept and the value to the individual warfighter and small unit operation, but also highlighting the need for technology improvements in areas of locomotion, video-imagery, battery endurance and wireless control authority - all to be explored in a follow-on program in 2003.

Figure 1 : Dragon Runner System: Vehicle & OCU

II. BACKGROUND

The urban environment will undoubtedly become a center stage for future U.S. combat operations. Potential adversaries have studied past and present U.S. military operations and know that it is prohibitive to fight toe to toe, in open terrain, where air supremacy, fluid command and control, and joint interoperability are dominant. The realization is that to achieve success against such a force, one will have to pull it into areas where it is off balance: the urban environment being one such possibility. Confronting forces that use the asymmetric nature of urban areas to their advantage poses a real challenge to any military planners. This confined space battlefield limits the advantages of maneuver warfare, degrades the effective ranges of direct fire weapons, and limits the use of indirect fire weapons. In addition, the mixing of combatants and non-combatants remains a constant problem.

Figure 2 : Military infantry in MOUT training mission

To build upon USMC urban doctrine, the Marine Corps Warfighting Lab (MCWL) has conducted numerous urban experiments, trying to identify the deficiencies as well as the strengths these unit leaders may face when confronted with urban operations. It is through this experimentation that the Warfighting Lab has developed urban specific Tactics, Techniques, and Procedures (TTP) that are then available as an addition to the very limited tactical urban ground combat doctrine existing today. Unfortunately, it has been assessed that further TTP development will not solve nor will it alleviate some of the inherent deficiencies levied upon Marine units operating in a MOUT environment.

III. INTRODUCTION

As recent history has shown U.S. and allied forces are being deployed to enter urban and increasingly unfamiliar complex environments. Threat assessments indicate that troops will face forces utilizing asymmetric tactics. Future battlefields will be forced into populated areas. This is where one of the most important facets of urban operations becomes paramount: the ability to conduct timely reconnaissance, surveillance, and target acquisition (RSTA). This ability to conduct RSTA missions has been a primary focus area for the Warfighting Lab for over two years. A majority of urban missions will fall to the small unit level: Company and below. It is here that the need for tactical RSTA is most beneficial. Small unit leaders rely on the eyes and ears of the men to the right and left in providing information on enemy activity. Windows, walls, sewers, and other confined spaces restrict their ability to see and listen when conducting operations in urban areas. Combatants are unable to look through walls or around corners, nor can they see down multiple avenues of approach that may be hidden by buildings. The Warfighting Lab realized that a technological fix was the best approach at trying to reduce the deficiencies resulting from the inherent nature of urban areas. Further TTP development and supplementary additions to current urban warfare doctrine would not solve all of the problems facing Marines conducting MOUT (Military Operations on Urbanized Terrain). Hence the concept of a *Mobile Ground Sensor* (MGS) was born.

IV. REQUIREMENTS & SPECIFICATIONS

The Marine rifle company and below need an organic capability to conduct RSTA in their assigned areas of influence. For this mobile ground sensor to have a chance at success, it must be a low-cost, reusable but expendable system, using a majority of commercial-off-the-shelf technology.

The ***Dragon Runner*** system was developed with the guidance of a Concept of Employment (COE) document developed by the USMC. The COE describes a mixture of performance and systems requirements, which led the development team to the prototype design by way of several testing and design revision steps.

Focusing specifically on the urban environment, the Warfighting Lab laid the groundwork for Dragon Runner, that would be employed at the small unit level within the Ground Combat Element. Its primary mission was to increase the unit's situational awareness, by aiding in the observation of tactical objectives and danger areas beyond the unit's line of sight. The Warfighting Lab expects the Dragon Runner to provide the following:

- *Elevate situational awareness*
- *Provide limited early warning capability*
- *Increase the speed in providing adequate RSTA coverage*
- *Provide "around the corner" observation*
- *Provide a man-portable, configurable system, for use in confined areas where access by humans is impractical or unsustainable*
- *Increase real-time feedback*
- *Increase stealth*

After conducting a technology search that looked at numerous robotics platforms, it was determined that the MCWL would need Dragon Runner to be built from the ground up. All other systems that were designed for the 'so-called' urban mission were too heavy (in excess of 30 to 40 lbs), moved too slowly (2 to 4 feet per second), and could not be considered expendable due to their relatively high cost. Marines fighting in an urban area need something light, fast, and deployable within seconds. One particularly difficult part of conducting a MOUT mission is moving your force up stairwells. There are systems that can climb stairs, but they all move slowly, keeping the operator in one place entirely too long. Since Dragon Runner needed to be deployable within seconds, the decision was made to make it tossable. Second floors could be searched by simply throwing Dragon Runner to the top of the stairs and remotely controlling its operation from a safe position. The remainder of this paper describes the design and experimental efforts of the pre-prototype development effort.

V. SYSTEM OVERVIEW

The ***Dragon Runner*** (DR) pre-prototype unit is an 11 pound, invertible, tele-operable robot vehicle that transmits video, survives three-story falls, and is equipped with motion sensors to provide for sentry-functionality. DR is powered by on-board BB-standard military batteries and is outfitted with a variety of communication and computing systems. The baseline model, intended to be the low-cost model, utilizes an ISM-band wireless modem and a UHF video transmitter to provide the necessary data-feedback and command-and-control link. An image of the prototype vehicle and its backpack-carrier, are shown in Figure 3.

Figure 3 : DR vehicle and backpack carrier

All on-board electronics are packaged in rugged modules with connectors for easy field replacement. A rear-mounted handle allows for easy handling and pull-pin power on/off operation. Motion and IR distance sensors are mounted in the front and on the sides of the frame and provide for sentry-functionality at low power drain levels. The front-mounted tilting CCD camera provides for daytime video feedback; IR illuminators provide the necessary lighting for nighttime operations. At 11 pounds and measuring 15.5" x 11.25" x 5", DR fits inside the standard Modular, Light-weight, Load Carrying Equipment (MOLLE) Patrol Pack. The shell is custom molded of materials suited to the application, ranging from urethanes to thermoplastics with additives for varying applications. A CAD-image with rough overall dimensions (Length: L=17.5”, Width: W=11”, Height: H=4.9”) is shown in Figure 4:

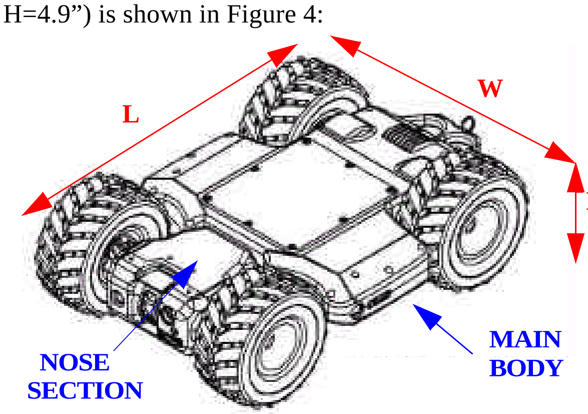

Figure 4 : CAD rendering of overall assembly

The frontal body-element (nose-section) houses a pitcheable camera, as well as motion-, range-sensors and an IR illuminator. In addition, it houses the ackerman steering actuator and push-pull linkage; a set of custom-molded rubber boots ensures the nose-section remains sealed. The connection to the rear body-element (main body-section) occurs through the custom-designed impact-absorbing rocker-bogie pivot. The main body-section houses a central bay for easy battery exchanges (without requiring opening of the sealed shell-halves). In addition, the side-pod sections of the shell house the computing and DC/DC power stage electronics, as well as the wireless command-and-control (C&C) and video/audio transmitters and transceivers. The rear section of the main body-section supports the rear wheels, which are driven off a brushless DC motor running through a single 3:1 gear-up train driving a fixed shaft; a co-axial slip-clutch protects both motor and drivetrain against overloads. The remainder of the space is primarily taken up by the wiring harness to distribute power, signal and video to and from the actuation, sensing, computing and communication systems. The internal see-through view of the DR-vehicle shown in Figure 5, depicts the main elements internal to the vehicle:

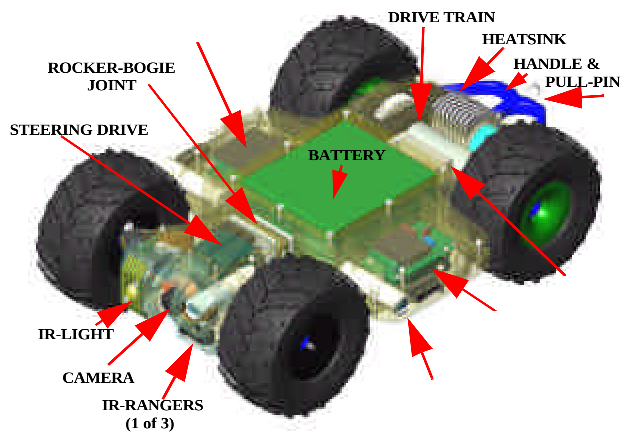

Figure 5 : See-thru packaging design for DR vehicle

The electronics system for the DR vehicle are based on a straightforward centralized architecture. An on-board CPU is interfaced to the OCU through a wireless modem transceiver unit, allowing it to exchange C&C information with the operator. All relevant actuation (drive, steering, camera-pitch) is performed through PWM control over digital I/O ports; motion-sensors are monitored on thresholded TTL input-lines. Video and audio are directly fed into a separate analog wireless transmitter. Power is provided through the on-board military battery, whose output is in turn power-conditioned to provide for all the different power supply sources required by all electronic systems on-board - the notable exception is the drive-motor, as its Electronic Speed Controller (ESC) is directly fed from the battery itself. A simple standby power-mode was implemented through a NO current loop to the DC/DC power-conversion board, by way of the pull-pin interface in the backhandle of the vehicle (this allows for miniscule standby power-drain during missions, and immediate power-up upon pulling the pin and thereby establishing a power-up condition). An image of the simplified (signal-bus) electronics architecture is shown in Figure 6.

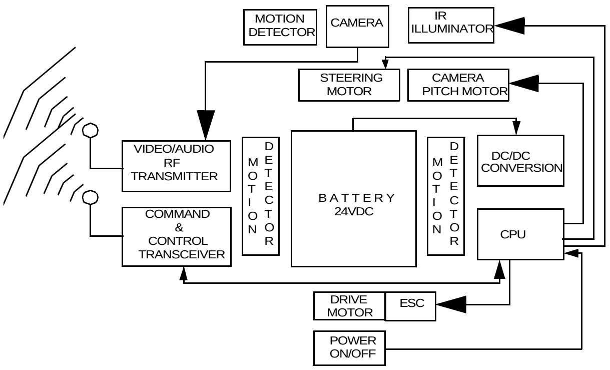

Figure 6 : Overall electronic systems architecture (signal-bus only)

In order to easily handle the vehicle, from inside the backpack, throwing and picking it up, despite its low weight, there was a need to easily manage these tasks with a single hand. Towards that end, a handle was molded to allow for 2- to 4-fingered grip (including the use of cold-weather gloves) so as to hold the system inverted and then swing it and fling it to any desired place while letting go at the appropriate moment. In addition, the central core of the handle is used as a retainer for a pull-pin, which closes/ opens a circuit to power-up or shut-down the system. A picture of the handle and pull-pin assembly, is shown in Figure 7.

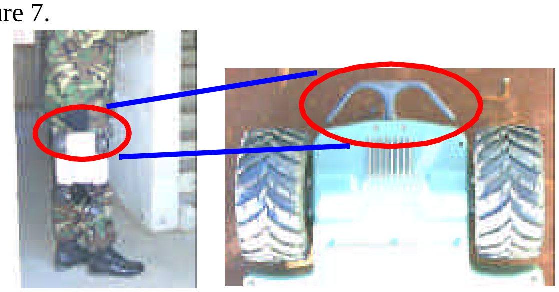

Figure 7 : Throwing/Handling finger-handle with coaxial pull-pin (pulled for power-on)

VI. PRE-PROTOTYPE TESTING RESULTS

The Dragon Runner pre-prototype underwent field trials in the southern California Desert in the late summer of 2002. This testing included durability, terrain-ability, and methods of employment. With the incorporation of thermoplastic injection molded shells, Dragon Runner was able to withstand numerous tosses through plate glass windows and falls from as high as 30 feet. Terrain-ability showed that (not surprisingly), while Dragon Runner operates near flawlessly on well groomed/finished surfaces, it has difficulty in approaching its target from a peripheral area that has many obstacles such as soft sand, large rocks, and roots. Its low ground clearance caused the vehicle to become stranded on large rocks or very loose sand (also caused by wheel spin-out due to over-torqued accelerations). An image of one of the fielded systems during trials in the desert, is shown in Figure 8:

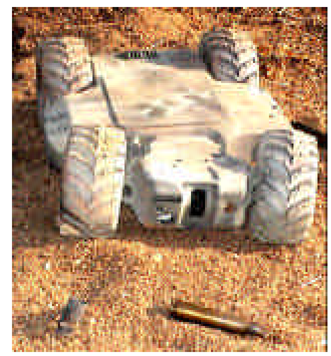

Figure 8 : DR vehicle prototype undergoing testing

From an employment standpoint though, the system showed real promise. It is estimated that when a small unit wishes to deploy a Dragon Runner system, it will take no longer than 10 seconds to do so. From a small backpack to being thrown over a wall or into a window, Dragon Runner proved remarkably simple and quick to employ. It will provide instant feedback to the operator of what is around the next corner, or down the next street, in a fairly fast manner. The vehicle's top speed of 25 mph enabled it to conduct route reconnaissance while it was being operated from within a moving vehicle. One could envision the application of having a small mobile ground sensor ahead of a convoy or mounted patrol that can be operated remotely from within the confines of a moving HUMMWV, sending back real-time imagery of possible roadblocks or opposing-force positions. From an overhead position, an operator may move Dragon Runner to the apex of a roof and scan the other side of an area, without exposing the operator or his unit to possible enemy fire.

In separate payload feasibility tests, a miniature thermal camera was attached to the top of Dragon Runner via a 1913 rail interface (Picatinny-Rail) and provided thermal imagery to the operator. In addition, a simple panning/ tilting searchlight was mounted and used in nighttime operations. Most recently, Dragon Runner also participated in a non-lethal demonstration where it carried a point taser on a similar rail interface as the thermal camera, but incorporated a tilt mechanism. For purposes of the demo, Dragon Runner remotely entered a room, identified a target, and accurately engaged with the taser from approximately 10 feet away. In yet another implementation, a simple smoke/stun grenade launcher was mounted to demonstrate the utility of simple remote obscuration of a target/activity area. All of these implementations are depicted in Figure 9.

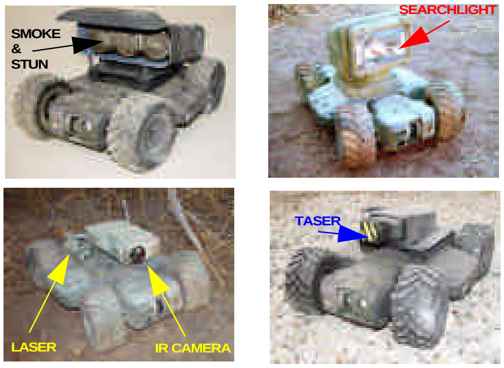

Figure 9 : Dragon Runner Payload Deployment Example

VII. CONCLUSIONS

Dragon Runner may someday provide the needed RSTA capability for Marine small units operating in a MOUT environment. The Dragon Runner is being developed to provide increased situational awareness by allowing Marines to rapidly see around corners inside as well as outside of buildings, day or night. It is also intended to act as a listening/observation post, providing a tactical force protection capability while in sentry mode, alerting Marines to a possible enemy presence. Plans to equip Dragon Runner with varied payloads, as well as lethal, IR marking, and nuclear, biological, and chemical/explosive sensor payloads are being considered as well. Based on experimental findings to date, MCWL has decided to fund a substantial upgrade to the Dragon Runner prototype system in 2003, learning from the early pre-prototype design and experimental results.

VIII. FUTURE PLANS

CMU and MCWL are currently engaged in an upgrading effort for both the vehicle and OCU systems. The vehicle is being envisioned as an all-wheel drive system with zoom-camera and integral payload interfaces. Custom antenna and RF gear will ensure proper range, while proper battery selection will ensure an appropriate mission duration. The OCU will be based on a re-design in terms of control interface, ergonomics and an improved daylight-readable display unit with easy storage and flex-cord interface.

Half a dozen 2nd generation prototypes will be developed for a limited objective experiment (LOE) slated to run in late fall of 2004. The LOE will focus on the utility of experimental TTP development of a Marine small unit utilizing a Dragon Runner mobile ground sensor system in a MOUT environment. MCWL hopes to have an Industry Day sometime in late 2003 and a Technology Transition Agreement drafted between the Science and Technology activity and the acquisition agency for Dragon Runner as well. Transition to Marine Corps Systems Command is expected to begin in 2004.

IX. ACKNOWLEDGEMENTS

CMU wishes hereby to acknowledge funding from ONR under Contract # N00014-01-1-0901 and N00014-02-1-0361. Additionally we wish to acknowledge the support of the Project Officer and the Commanding General at MCWL for their vision in supporting this project.

X. REFERENCES

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