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SENIOR DESIGN

SMART PHONE CONTROLLED MISSION PLATFORM

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Executive Summary

Unmanned ground vehicles have been implemented by the military to replace or assist soldiers in dangerous or unreachable environments. From remotely controlled bomb diffusers to completely autonomous reconnaissance vehicles, these unmanned ground vehicles have certainly played a major role in recent military history. To supplement these ground vehicles, there have also been implementations of naval and air unmanned vehicles for similar applications. These types of vehicles are becoming more popular and more complex every day.

The purpose of this project is to design an RC car that can be controlled by a smart phone or a self-configuring ad-hoc network via a WIFI connection. This would allow ground troops to have direct control over the car from a smart phone or similar device, or would allow for a number of these RC cars to be deployed and controlled by a self-configuring network where human interaction would be minimal.

The RC car shall be able to be controlled in two different manners, either directly controlled by a human, or controlled by commands received through an ad-hoc network. The car will have to different operation modes under direct user control, mode number one would allow for the user to have full control over the car, much like an RC car. The second mode will allow for the user to give the car latitude and longitude coordinates and the car shall navigate by itself to the specified location. The car will also have a mode to receive commands over the network, this will be much like the second user mode, but the commands will be coming from a different source.

The RC car will prioritize the different commands that are issued to it, and will decide what shall be carried out. The car will first respond to direct control from a human operator via the smart phone platform. The car will consider the commands received over the network as the second priority. The car will also have the ability to override any of these sources if it detects a self-destructive order, such as driving off a cliff or running into a wall.

The other part of this project is to implement a control system for the car in a smart phone. Considering that Android phones are more easily obtainable globally and their less proprietary hardware and software, we have chosen to only rely on the Android platform as a control system. Since the project requires that ground troops will be able to control this system, we need to choose a relatively small packaged device, but also allow for a large enough screen to make the system useful. Therefore we will be looking in the 4" to 4.5" screen categories of smart phones.

The control system will allow for the two different user interaction schemes outlined above. The first will allow for the user to directly control the car, with controls for direction, speed, and camera direction. The second mode will allow the user to direct the RC car to a location on a map. All control screens will provide sufficient location and or video feeds to allow for the user to properly and effectively control the car.

The group will be broken into three sub groups to complete the projects. The first group is going to focus on the hardware implementation and. This will range from selecting the proper hardware to writing the code that will be controlling the hardware. The second group will be focusing on the control system and interface for the Android device. And the last group will be assigned to deal with the networking issues.

Problem and Need Statement

Below is the project description submitted by Lockheed Martin:

Description

Utilize a commercially available smart phone (for example a droid) to command and control a vehicle and its sensor. These capabilities are applicable to multiple scenarios including military missions, police surveillance and search and rescue activities. The prototype should be developed and demonstrated using commercially available products.

Project Goals

1. Control a vehicle using a smart phone. (Priority 1)
2. Have vehicle respond to navigation commands triggered through a smart phone (Priority 1)
3. Have vehicle avoid environment obstacles such as buildings. (Priority 1)
4. Maintain continuous wireless connectivity of mobile vehicle (Priority 1)
5. Control a vehicle sensor using a smart phone (Priority 2)
6. Have sensor respond to commands triggered through a smart phone (Priority 2)
7. Integrate with "Re-configurable Ad-hoc Network to Track Points of Interest" 2011 project (Priority 3)

Design Constraints

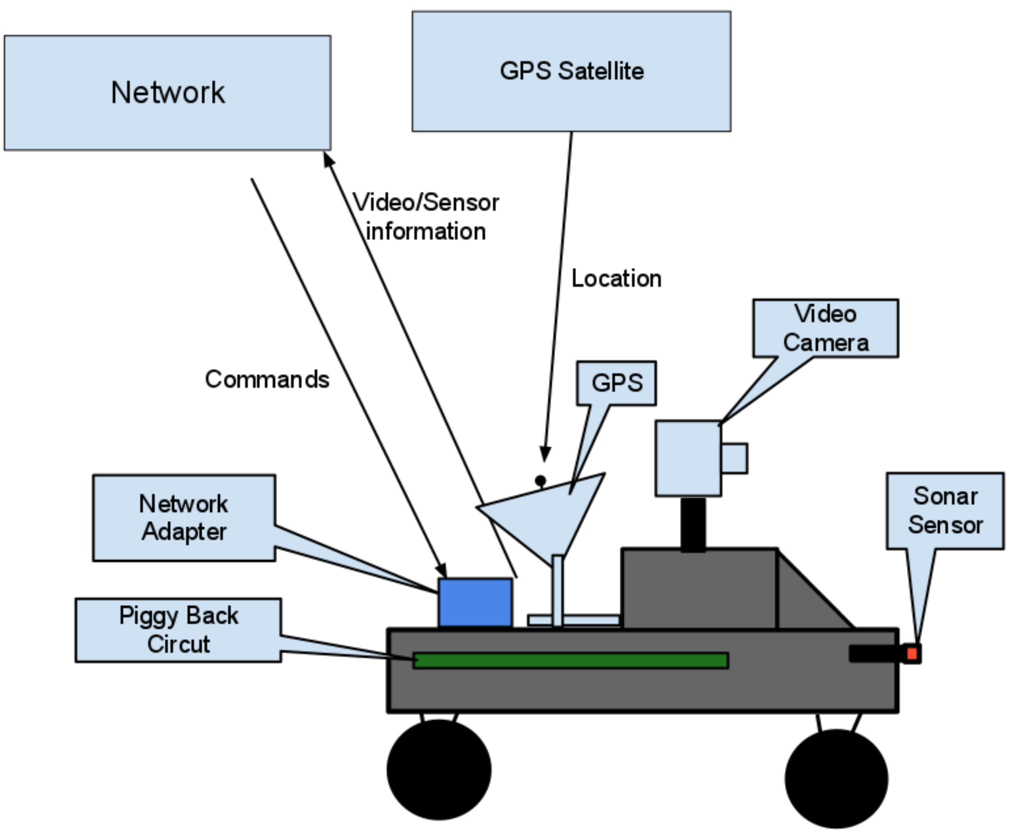
1. Design shall allow for integration with "Re-configurable Ad-hoc Network to Track Mobile Vehicles" 2011 project
2. Use inexpensive off-the-shelf products as much as possible (for example, RC cars for "vehicle")
3. Assume no longer than 1 square mile for demonstration range

Problem Statement

As military environments get increasingly dangerous, having a robotic scout to travel in front of the troops could be a valuable, life-saving asset. The goal for this project is to build a vehicle that can be controlled through a smart phone and can send video from a mounted camera back to the operator. Our team is also responsible for developing the smart phone application, as well as developing hardware that can be mounted on our vehicle to control it and communicate with it through the smart phone application.

Concept Sketch

Figure 1: RC car concept sketch



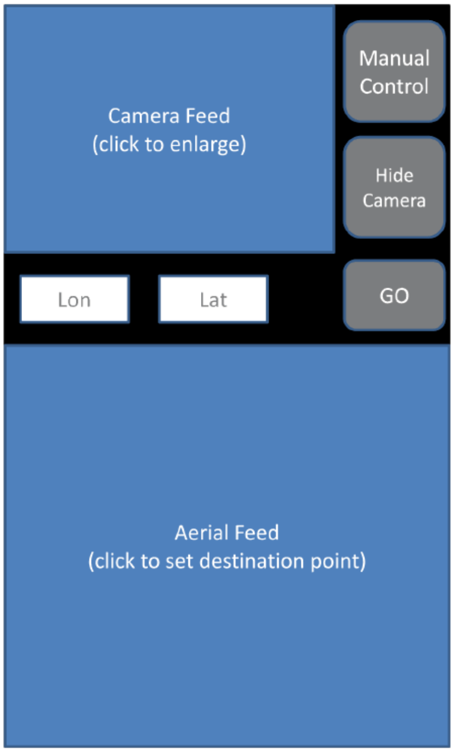


Figure 2 - Autonomous Control Portrait 1

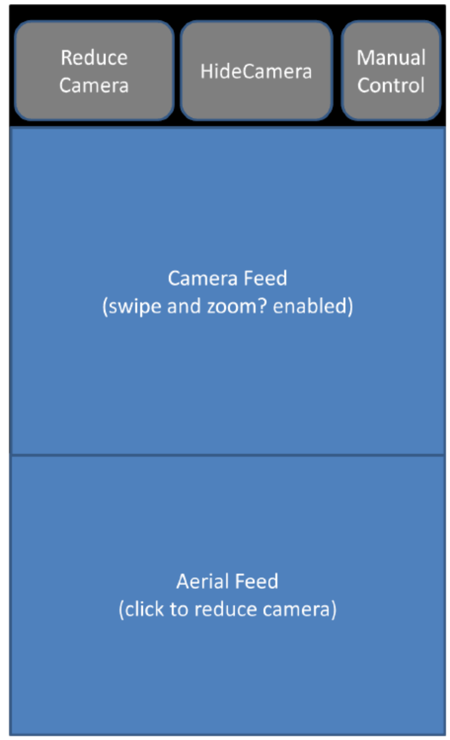


Figure 3 - Autonomous Control Portrait 2

Figure 5 - Autonomous Control Portrait 3

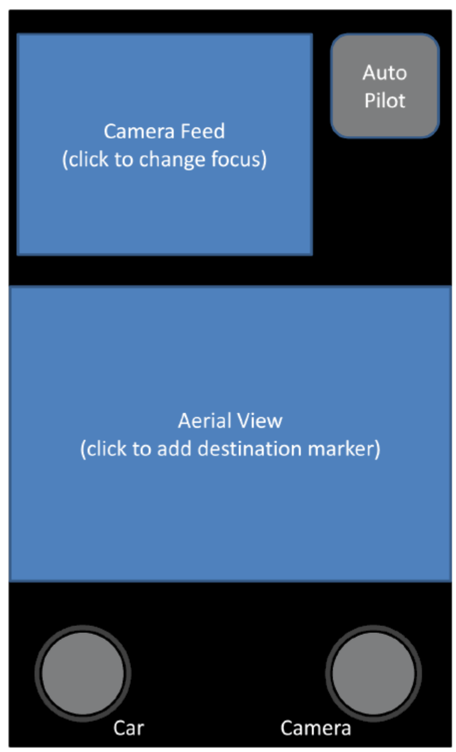


Figure 4 - Manual Control Portrait 1

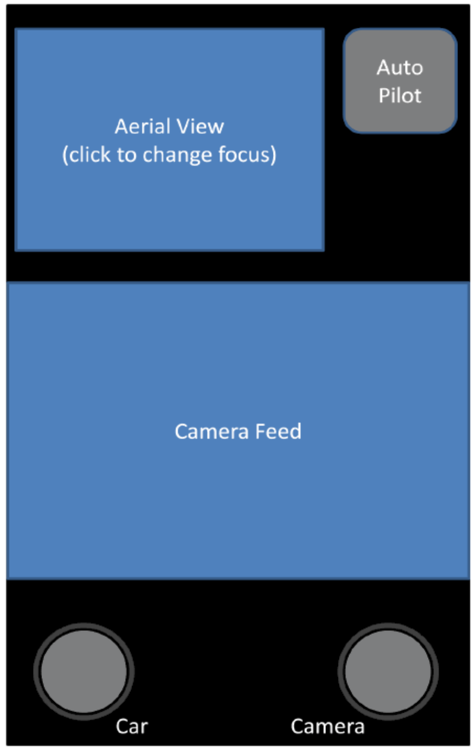


Figure 6 - Manual Control Portrait 2

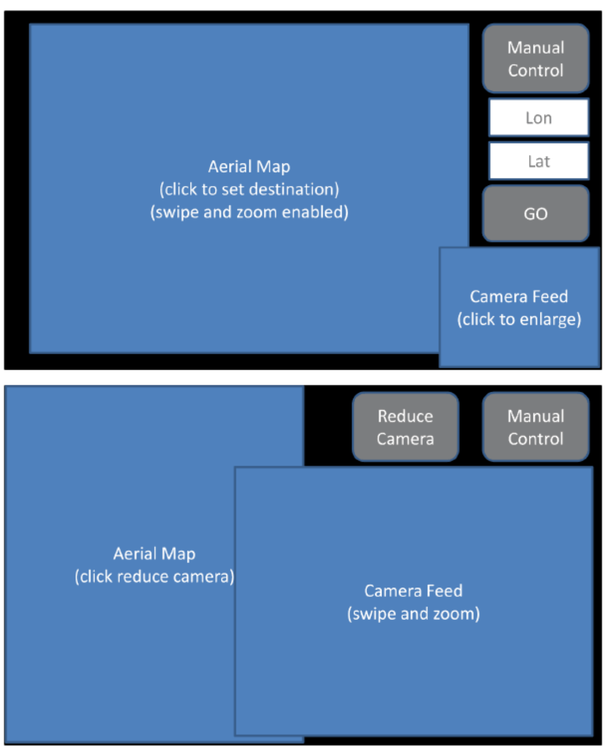


Figure 7 - Autonomous Control Landscape

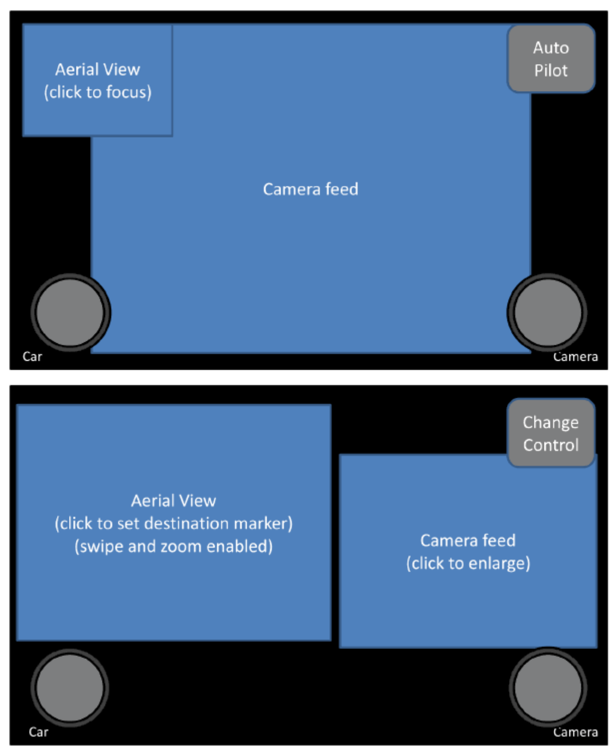


Figure 8 - Manual Control Landscape

System Description

Lockheed Martin has proposed the idea of engineering a remotely controlled vehicle capable navigating and taking video or images. Navigation of the vehicle will either be manual controls or autonomous, via a GPS location. The vehicle will be equipped with WIFI so that it can receive and transmit messages. This system will be able to receive commands from both an ad-hoc network and/or personnel via smart-phone. It must maintain connection to the network and be able to reconnect if the connection is lost. The vehicle will have a camera mounted on the vehicle for gathering video and still images. The camera shall be able to pan and tilt so that it can point at an intended target. Infrared sensors should also be added to the vehicle to aid in autonomous navigation. The vehicle must be able to be deployed for at least 30 minutes of navigation, and be small enough to be easily picked up and transported.

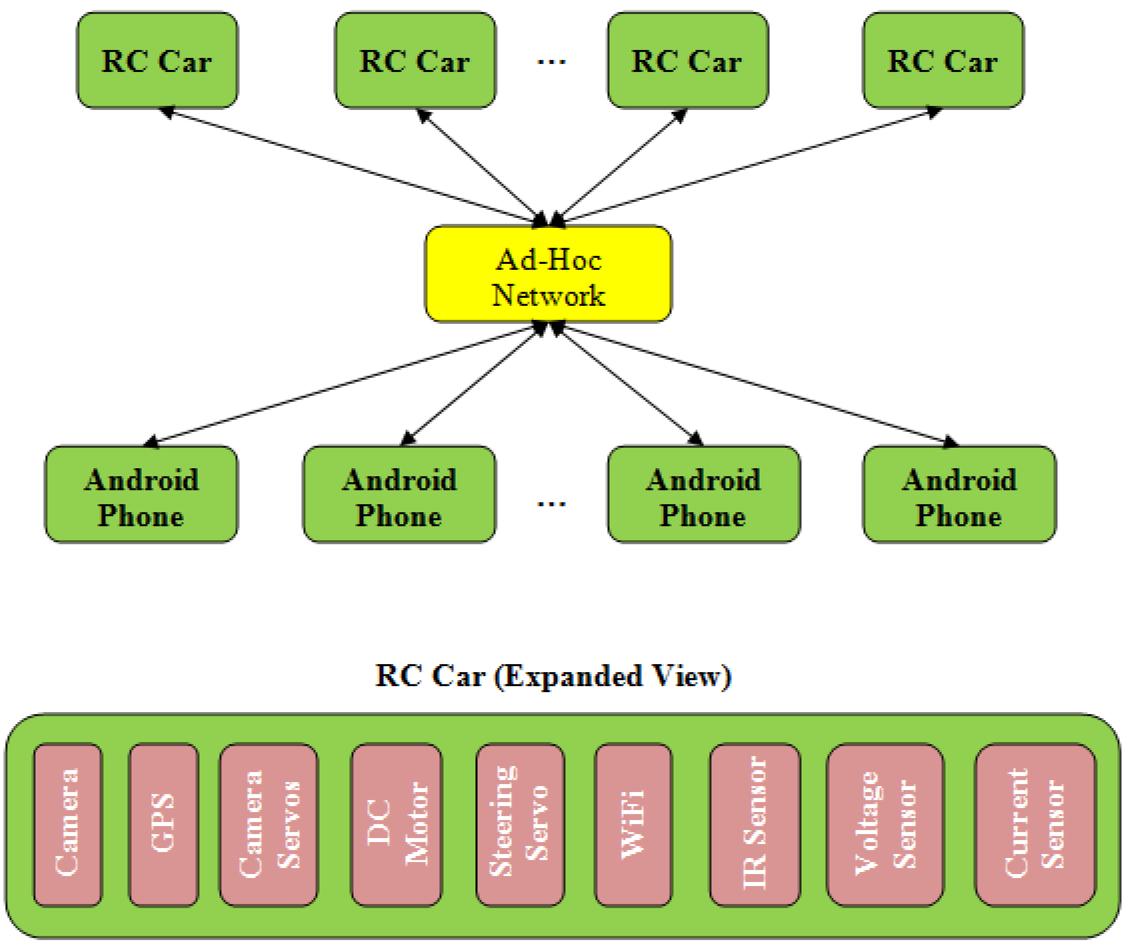


Figure 10 - Project Block Diagram

Operating Enviornment

Software

Our software environment will be Android smart phones and a programmable circuit board.

Hardware

Our hardware operating environment will eventually be that of a military zone. The vehicle will be subject to hazards such as bumpy roads and bad weather. For our testing purposes, however, we are using a clean environment with no real hazards.

Constraints

- Vehicle must be able to run for 30 minutes continuously
- Vehicle must be inside a network to receive instructions and continue operation
- Smart phone and operator must be inside a network to give the vehicle instructions and receive feedback from vehicle

User Interface Requirements

UIR1 - Must have vehicle controls (either setting destination or manual controls)

UIR2 - Must be able to switch between autonomous and manual control.

UIR3 - Must be able to switch between map view and real time camera feed, or show both.

UIR4 - Must be able to control the camera, including pan and tilt, and taking a photo/recording video.

UIR5 - Must be able to navigate through the map.

UIR6 - Must be able to see vehicles location on the map.

UIR7 - Must be able to get to an options menu.

UIR8 - Touch clickables must be at least .75 inches by .75 inches (ISO and ANSI standard) or provide a preview of what is getting clicked while user holds down.

UIR9 - Must be able to use landscape or portrait view.

Functional Requirements

FR1 - Transmit all data between RC car and Android Phone up to a range of 70 unobstructed meters

FR2 - Ability to determine location within 1 meter accuracy while stopped or 2 meters while moving.

FR3 - Ability to process 240p streaming video at 15 fps minimum with 16 bit color (minimum color requirements for an android phone)

FR4 - Use IR sensors to detect obstacles larger than the radius of the wheels within 2 meters from the RC car.

FR5 - Ability to autonomously drive within 1 meter of a given coordinate that is reachable with the current battery life

FR6 - Control point of view of onboard camera with a lateral range of +/- 180 degrees from front of car and vertical range of +/- 45 degrees from a plane parallel to the car

FR7 - Camera controller should be able to rotate 180 degrees in 1 second for both vertical and horizontal rotation

FR8 – Must be able to maintain full operation for 30 minutes

FR9 - The RC car must be able to maintain a minimum speed of 3.4 mph (standard march speed)

FR10 - Climb a 1:6 incline assuming no loss of traction (max for temporary wheelchair ramp)

Non-functional Requirements

NFR1 - RC car can weight no more than 10lbs

NFR2 - The RC car shall run on electric motors

NFR3 - The user control system must use Android

NFR4 - Communication protocol is IEEE 802.11n standard

NFR5 - Location will be determined by GPS coordinates

Work Breakdown Structure

The team will be broken into three sub teams: the hardware team, software team, and the networking team.

Hardware Development Team

- Isaac Kuecker
- Tyler Johnson

The hardware team shall focus on selecting hardware that will meet specification requirements at an affordable cost to keep us under budget. This team will also focus on developing the firmware required to make the RC car operational. The hardware team will also be doing the verification and testing of the hardware platform.

Software Development Team

- Jacob Moellers
- Tayler Todd

The software team will be focusing on the Android side of the project. They will focus on designing an efficient user interface, and implementation of the control system from the user's perspective. This team will also be doing the testing and verification of the software.

Networking Team

- Paul Hovey

The networking team will be focused on creating a protocol based off of TCP/IP standards that will be used to send information to and from the RC car. This team will also be focusing on working with the senior design group that is working on the self-configuring ad-hoc network that will be implemented into our system.

Timeline

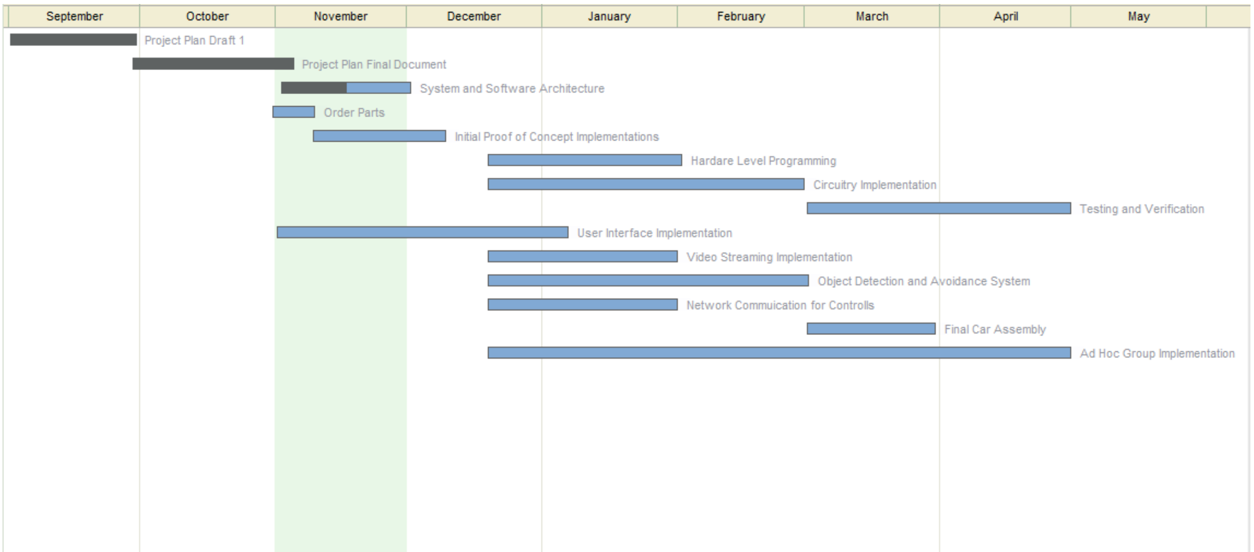


Figure 11: Timeline

Resource Requirements

The exact resource requirements are currently unknown. However we will need to purchase at least 1 Android power phone, 1 RC car, and a single board computer or equivalent system to control the car. All of these need to be purchased for under $2000.

Market Research

Unmanned ground vehicles are becoming very important in today's military. They are in use in many areas, including IED disposal, reconnaissance, and load bearing. Our project will be designed for use in reconnaissance. There are several implementations of UGVs, however, none of them utilize a smart phone for controlling the vehicle. Some of the UGVs that most resemble our project are Dragon Runner Robot from Qinetiq, the DEMO III from Army Research Laboratory, and the Soldier UGV from Future Combat Systems.

Dragon Runner

From www.qinetiq-na.com:

Dragon Runner™ was originally developed for the U.S. Marine Corps. The basic model Dragon Runner weighs 14 lbs and measures just 12.2 x 16.6 x 6 inches. The basic Dragon Runner gave users the ability to "see around corners" in urban environments.

Engineers and roboticists in the QinetiQ North America Technology Solutions Group have developed enhancements that make it possible for personnel in the field to take the basic Dragon Runner SUGV (small unmanned ground vehicle) and add whatever combination of treads, cameras, sensors and/or arms a mission requires.

Sample missions include:

- Reconnaissance inside buildings, sewers, drainpipes, caves and courtyards
- Perimeter security using on-board motion and sound detectors
- Checkpoint security
- Under-vehicle inspection
- Inspection of bus, train or plane interiors
- Hostage barricade reconnaissance and negotiation
- IED clearance
- Explosive ordnance disposal (EOD)

Dragon Runner SUGV can be carried in a standard-issue pack. It can lift from 5 to 10 pounds with its manipulator arm which has rotating shoulder, wrist and grippers for dexterity. Reconnaissance/surveillance options include day/night camera, pan/tilt/zoom cameras, motion detectors and a listening capability. Dragon Runner SUGV has extended RF operating capabilities and can operate in a jammed environment. It can be configured to suit the communications system in use.

DEMO III

From www.gdrs.com:

DEMO III, supported by TARDEC and the U.S. Army Research Lab, is an experimental unmanned vehicle (XUV) testbed developed by General Dynamics Robotic Systems (GDRS) for the integration of advanced autonomous mobility technology. GDRS is proving the feasibility of Autonomous Mobility (AM) as part of a mixed military force containing both manned and unmanned vehicles in demonstrations over varied terrain.

The XUV, equipped with a GDRS-developed sensor package for perception and planning, is commanded by an operator through a Tactical Control Unit (TCU) equipped with a Warfighter-Machine Interface (WMI) that provides map display and analysis tools, mission planning and execution control tools, and Reconnaissance Surveillance Targeting and Acquisition (RSTA) displays and controls.

Live field experiments with the XUVs are an ongoing part of the GDRS robotics program. These tests have given Soldiers hands-on experience with autonomous mobility technology and provided our engineers with invaluable feedback about human factors issues and user needs, as well as developing AM solutions. The technology aboard Demo III has been put through its paces at several stages and has passed rigorous Technology Readiness Level (TRL) 6 tests in rolling, arid environments, vegetated terrains, and urban terrains.

Soldier UGV

From www.gloabalsecurity.org

The Soldier UGV (SUGV) is a man-packable small robot system, weighing less than 30 lbs, used for Urban Operations environments and subterranean features to remotely investigate the threat obstacles, structures and the structural integrity of facilities and utilities. SUGV systems will be highly mobile for dismounted forces and will be capable of being re-configured for other missions by adding or removing sensors, modules, mission payloads, and/or subsystems.

The Small Unmanned Ground Vehicle (SUGV) (Set Aside for Small Business) is a remotely operated, manpackable, robotic vehicle. This is a small man-portable vehicle with modular payloads that will allow the SUGV to perform 1) Reconnaissance, 2) Surveillance, and 3) Assault.

The Soldier UGV (SUGV) is carried by one or more soldiers and typically performs a variety of tasks in support of the dismounted soldier. Example tasks include reconnaissance, surveillance and application of effects, such as door breach, smoke generation, or concussion grenade. The Soldier UGV accepts modular sensor and/or effector payloads to perform these tasks. The Soldier UGV will be part of an organization of vehicles, sensors, C2 hardware and software systems, and communications systems. The Soldier UGV incorporates a lightweight day/night sensor suite on a mast/turret system capable of providing remote surveillance images and sensed information. The Soldier UGV provides mobility sufficient to be tele-operated in an area local to a controlling dismounted soldier, and will be transported to the operational area with dismounted soldiers as stowage. The Soldier UGV will operate in rural and urban terrain, capable of climbing stairs, passing through doorways, operation in subterranean structures, and traversing rubble-type obstacles. Some semi-autonomous Reconnaissance and Surveillance mission equipment operations may be provided.

Deliverables

- Software Development Plan - 9/29/11
- System and Software Requirements Spec - 9/29/11
- System and Software Architecture - 12/3/11
- Preliminary Design Review - Early Second Semester
- Software Test Description and Report - April or May 2012
- Live Demonstration - April or May 2012