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Excepts from the history of unmanned ground vehicles development in the USA

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The military land robot plays an important role in the information age for the commander and for the warrior. It is an electro-mechanized equipment that moves across the battlefield and serves as a means of carrying. It can transport something, collect intelligence information, carry some weapons, broadcast video pictures, etc. Thanks to the technological evolution the human can use robots for saving human life, protecting against disasters, in inhuman condition, practically everywhere, in every time, so in war, too.
George Santayana said: "Those who cannot remember the past are condemned to repeat it". The purpose of this paper is to provide a brief survey of a number of different threads of development that have brought the unmanned ground vehicles field to its current state.

Vision: Military robotic systems will proliferate throughout the 21st century force structure, performing dirty, dangerous, and dull tasks, while providing a revolutionary capability across the spectrum of missions and conflict.[1]

Introduction

In the broadest sense of the word, unmanned systems are a group of military systems, their common characteristic being the fact that there is no human operator aboard. They may be mobile or stationary. They include categories of unmanned ground vehicles, unmanned aerial vehicles, unmanned underwater vehicles, unattended munitions, and unattended ground sensors.

Missiles, rockets and their submunitions, and artillery are not considered unmanned systems.

The unmanned ground vehicle is:

- a powered, mobile, ground conveyance that does not have a human aboard;

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- can be operated in one or more modes of control (autonomous, semi-autonomous, teleoperation, remote control);
- can be expendable or recoverable;
- and can have lethal or nonlethal mission modules.

The main goal of this paper is to provide a brief survey of a number of different threads of development that have brought the unmanned ground vehicles field to its current state.

Early efforts for robot development

The mobile robots – or the unmanned ground vehicles, as the academic community usually refers to them – could be based upon any of a number of characteristics of each system, including:

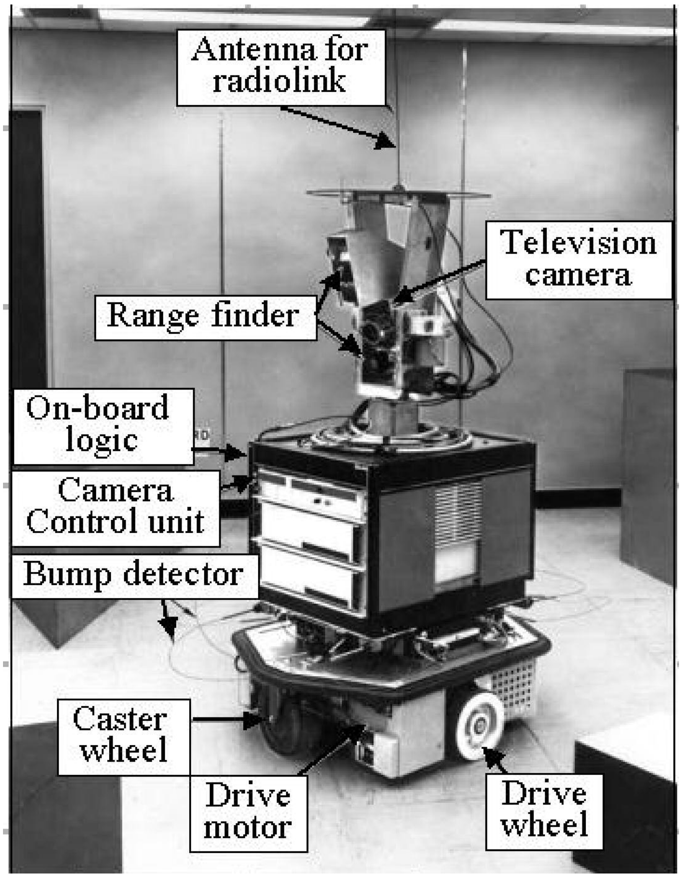
- the purpose of the development effort;
- the specific reasons for choosing an unmanned ground vehicles solution for the application (e.g. hazardous environment, strength or endurance requirements, small size);
- the intended working area (e. g. indoor environments, outdoors on roads, cross-country terrain, ruined field, etc.);
- the vehicle's mode of locomotion (e.g. wheels, tracks or legs);
- the mode of navigation and control, i.e. how the vehicle's path is determined.

The development of autonomous robots began as an interesting application domain for Artificial Intelligence researchers in the late 1960s.

The first major mobile robot development effort was SHAKEY,[2] developed in the late 1960s to serve as a testbed for DARPA-founded artificial intelligence. SHAKEY was a wheeled platform equipped with steerable TV camera, ultrasonic range finder, and touch sensors, connected via an RF link to its mainframe computer that performed navigation and exploration tasks.

The SHAKEY system could accept English sentence commands from the terminal operator, directing the robot to push large wooden blocks around in its lab environment "world". The action routines took care of simple moving, turning, and route planning. The programs could make and execute plans to achieve goals given to it by a user.

The SHAKEY program reemerged in the early1980s as the DARPA *Autonomous Land Vehicle* (ALV).[3] Under DARPA's Strategic Computing (SC) Program. The Autonomous Land Vehicle was built on a Standard Manufacturing eight-wheel hydrostatically-driven all-terrain vehicle capable of speeds of up to 45 mph on the highway and up to 18 mph on rough terrain. The ALV could carry six full racks of electronic equipment in dust-free air conditioned comfort, providing power from its 12-kW diesel power unit. The initial sensor suite consisted of a color video camera and a laser scanner from the Environmental Research Institute of Michigan. The ALV Program's focus was moved in early 1988 away from integrated demonstrations of military applications and toward the support of specific scientific experiments for off-road navigation.

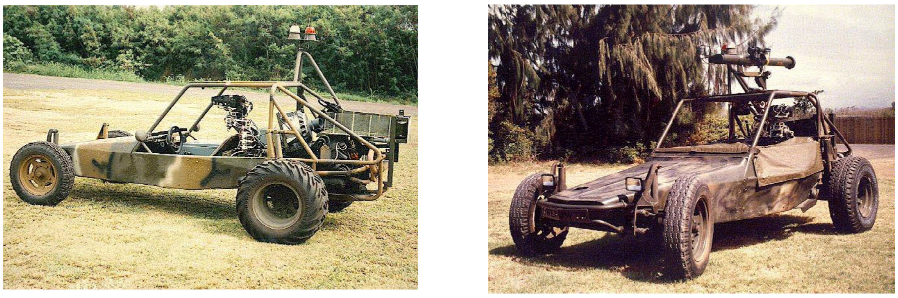


Picture 1. SHAKEY

The Reconnaissance, Surveillance and Target Acquisition (RSTA) application has long drawn the attention of UGV developers, since a UGV solution for RSTA would provide a battlefield commander with a direct sensing capability on the battlefield and even behind enemy lines, without endangering human personnel. Two RSTA-oriented UGV projects were undertaken at the Naval Ocean Systems Center (NOSC) in the early 1980s: the *Ground Surveillance Robot* (GSR) at NOSC San Diego, and the Advanced Teleoperator Technology (ATT) *TeleOperated Dune Buggy* at NOSC Hawaii.[4]

The *Ground Surveillance Robot* project explored the development of a modular, flexible distributed architecture for the integration and control of complex robotic systems, using a fully actuated 7-ton M-114 armored personnel carrier as the testbed host vehicle. With an array of fixed and steerable ultrasonic sensors and a distributed blackboard architecture implemented on multiple PCs, the vehicle successfully demonstrated autonomous following of both a lead vehicle and a walking human in 1986 before funding limitations terminated its development.

The Advanced Teleoperator Technology *TeleOperated Dune Buggy*, on the other hand, concentrated exclusively on teleoperator control methodology and on "advanced, spatially-correspondent multi-sensory human/machine interfaces." With a Chenowth dune buggy as a testbed vehicle, the Advanced Teleoperator Technology project successfully demonstrated the feasibility of utilizing a remotely operated ground vehicle to transit complex natural terrain and of remotely operating vehicle-mounted weapons systems. In addition, the Advanced Teleoperator Technology effort demonstrated the efficacy of stereo head-coupled visual display systems, binaural audio feedback, and isomorphic vehicle controls for high-speed remote vehicle operations.



Picture 2. Teleoperated Dune Buggy

The success of the Advanced Teleoperator Technology and Ground Surveillance Robot vehicles led the Office of the Undersecretary of Defense for Tactical Warfare Programs/Land Warfare (OUSD/TWP/LW) in 1985 to initiate the Ground/Air TeleRobotic Systems (GATERS) program, under Marine Corps management and with NOSC serving as the developing laboratory. The thrust of the GATERS program was to develop a *TeleOperated Vehicle* (TOV)[5] to support the test and evaluation of UGV product concepts by prospective military users of UGVs. The TOV system consisted of a remote vehicle and an operator control station, connected by fiber optic cable to provide high bandwidth secure non-line-of-sight communications for distances up to 30 km. The TOV remote vehicle was a HMMWV, and up to three TOV control stations were housed in a shelter mounted on the back of another HMMWV. Building on the dune buggy experience, the TOV operator was provided with stereo head-coupled visual displays, binaural audio, and driving controls isomorphic to those found in an actual HMMWV.

A RSTA package (video and FLIR cameras and an active laser rangefinder/designator) was mounted on a pan/tilt unit atop a scissors lift that could be raised up to 15 feet off the ground. A high level control architecture was implemented to integrate the functionality of the system. Successful demonstrations of the TOV began at Camp Pendleton in May 1988, including long range RSTA, high-speed cross-country transit, detection of chemical agents, and remote firing of a 50-caliber machine gun.

The weapon could be manually controlled with the joystick in response to video from this camera, or slaved to the more sophisticated electro-optical sensors of the Surveillance Module. One of the remote HMMWVs had a Hellfire missile launcher instead of a Surveillance Module, the idea being that one platform looked and designated while the other did the shooting. Meanwhile, all the humans could be up to 15 kilometers away, which is important in chemical or biological warfare scenarios.

These successful demonstrations led to the formulation of the *Teleoperated Mobile Anti-Armor Platform* (TMAP) program, and prototype systems were procured in 1987/1988 from Grumman and Martin Marietta. Both systems were joystick-controlled via fiber optic link, the operator navigating via the returned TV image. The Grumman system was a hybrid diesel-electric drive with its four wheels in an articulated diamond pattern, while the Martin vehicle was a diesel-powered hydrostatic four-wheel drive with skid steering.

Unmanned Ground Vehicles/Systems Joint Program Office (UGV/S JPO)[6]

The miscellaneous unmanned ground vehicles development efforts were consolidated in one hand. The Unmanned Ground Vehicles Joint Program Office (UGV JPO) was organised as the centrum for the development and fielding of DoD unmanned ground vehicles systems at 1990. The word "systems" was later added to the program office name, so the organization is the Unmanned Ground Vehicles/ Systems Joint Program Office (UGV/S JPO.)

The first project of Joint Robotics Program was the *Tactical Unmanned Ground Vehicle*. Toward this end, a Memorandum of Understanding between the Army and Marine Corps was established.

The Tactical Unmanned Ground Vehicle program continued work on the *Surrogate Teleoperated Vehicle*. It was designed to be small enough to be helicopter- and HMMWV transportable, but fast enough to keep up with a tactical vehicle convoy. It was built on a six-wheel drive. The operator drives the vehicle using stereo TV head mounted display via both RF or fiber optic cable datalink, and a GPS receiver to help the operator navigate. The Reconnaissance, Surveillance, and Target Acquisition mission module contains a color TV for day time, and a black and white TV for night, FLIR imager, laser rangefinder/designator, chemical weapons detector, and acoustic detection system, mounted on a scissors lift.


Picture 3. Surrogate Teleoperated Vehicle

The Unmanned Ground Vehicles Systems Joint Program Office had three additional vehicles in the Tactical Unmanned Ground Vehicle program.

The *Surveillance and Reconnaissance Ground Equipment* (SARGE)[7] provided a roll cage, two video cameras for surveillance, two cameras for driving, a pan/tilt mechanism and used a four-wheeler platform.

The GECKO[8] program is intended to support the evaluation of a supervisory-level vehicle driving scheme called Feedback Limited Control System (FELICS). The operator marks the desired driving path on the driving display screen and the vehicle then automatically follows the commanded path. FELICS uses a 3-Hz to 1/3-Hz video frame rate and JPEG compression of up to 50:1 to drastically reduce the required video data rate. Performance: Max speed >20 mph, climb 45 ° and sideslope, amphibious, low pressure footprint. Data link: 915 MHz band, up to 3 km range.

The technology Test-Bed built on a HMMWV will serve to support the evaluation of various system architectural concepts and candidate component technologies.

Picture 4. SARGE

Picture 5. GECKO

ARPA DEMO programs[9]

DEMO I, was a demonstration of a near-term teleoperated UGV capabilities and technologies led by the Army Research Laboratory in the spring of 1992. DEMO II demonstrated multiple vehicles operating cooperatively under supervised autonomy.

The first milestone, DEMO A demonstrated basic system operation and precision navigation on a single vehicle while conducting a movement-to-contact and bounding overwatch operation in a military scenario. The *Surrogate Semi-autonomous Vehicle* successfully conducted road following on both paved and dirt roads using the Autonomous Land Vehicle in a Neural Network (ALVINN) road-following computer algorithm. Cross-country teleoperated waypoint navigation was done using STRIPE (supervised telerobotics using incremental polygonal earth geometry).

The second milestone DEMO B was on 28–30 June 1994. The *Surrogate Semi-autonomous Vehicle*, in a supervised-autonomous mode, successfully transitioned from road-following on a dirt road to road-following on a paved road and then to a cross-country route without stopping. In the cross-country mode, the SSV transmitted target data back to the operator. Using the on-board FLIR, the operator successfully tracked a moving target and relayed target information to an attack helicopter. The SSV was able to detect and maneuver around large rocks that were encountered on the planned path.

The last milestone DEMO C was the final DEMO II demonstration during 25–28 July 1995. This was the first time that two *Surrogate Semi-autonomous Vehicles* (SSV) worked together in a scout mission. The two SSVs moved autonomously over a cross-country route negotiating obstacles at a speed of 5mph. Once the SSV's arrived at their designated location, the vehicles began a search of the area providing information back to the multi-vehicle operator control vehicle. The first SSV detected a moving target and the second SSV confirmed the target location in order to provide an accurate "call for fire" to an Apache. The operator in the command and control vehicle would then verify the target and forward the call for fire to the attack helicopter.

Picture 6. DEMO C

DEMO C demonstrated a number of other technologies: Obstacle Detection (stereo video, FLIR stereo, Ladar), Stereo Obstacle Avoidance (positive and negative obstacle avoidance), and both Moving and Stationary target detection.

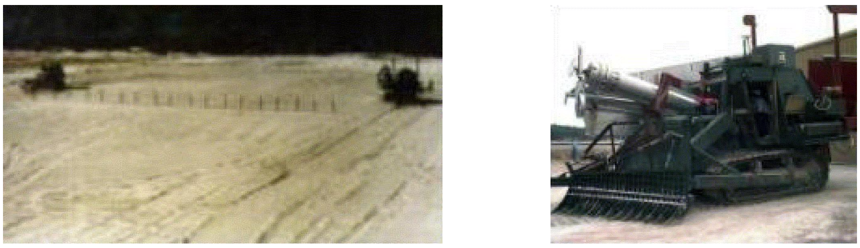
One of the biggest challenge for engineer troops in the world is mine warfare. Mines are brutal and clandestine tools of warfare. The *Vehicle Teleoperation Capability* (VTC) program turned its immediate attention to the soldiers being deployed to Bosnia. VTC prototype kits were incorporated into seven M60 tank chassis (Panther) and used for route proofing by soldiers assigned to the 1st Armored Division in support of Operation Joint Endeavor. In addition to Panther, the JPO deployed four Miniflails to Bosnia. The *Miniflail* provided a smaller system to proof for anti-personnel mines in places where the Panther cannot be deployed. The Miniflail is also used for the evacuation of wounded soldiers from minefields. The Miniflail was originally developed for the Special Forces under the Office of Science and Technology and has since been deployed to other areas in the world.

Picture 7. Panther

Picture 8. Miniflail

In August 1997 four Panthers and miniflails continued to support forces in Bosnia as part of Operation Joint Guard. The Panthers were used to proof an area, and it detonated 71 antipersonnel mines in the two-day period.

In September 1997. the Joint Countermine Advanced Concept Technology Demonstration demonstrated four reconnaissance systems and five breaching/clearing systems. The *Joint Amphibious Mine Countermeasures* (JAMC) consisted of a teleoperated D7G dozer with a folding minerake, marking system, explosive net array, and a complex chain array, which was dragged between two vehicles to clear wire obstacles and detonate both tilt rod and magnetically fused mines. The system received failing marks for being difficult to operate and was cancelled as a program. However, it should be noted that this mission for obstacle and mine clearance in an amphibious craft landing zone is a difficult mission. From a robotic perspective, the teleoperation capability was described as successful.



Picture 9. JAMC D7G dozer

The remote ordnance neutralization vehicles play an important role in the family of unmanned ground vehicles. The *Remote Ordnance Neutralization* (RON)[10] program received and tested its first system in 1999.

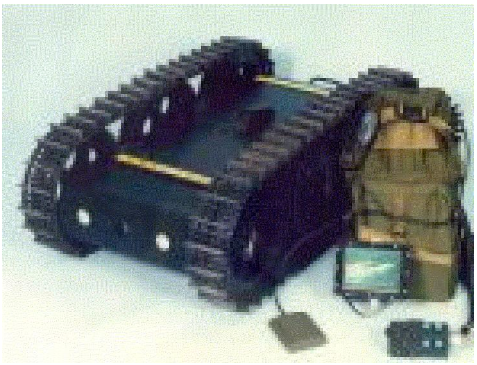
Picture 10. RONS

One hundred twenty systems have been fielded with 50 more systems to be procured.

Man-Portable Robotic Systems (MPRS)[11]

The operational use of *Man Portable Robotic System* continued to expand in the last years. The MPRS program goal is to develop lightweight, man-portable mobile robots for operation in urban environments (indoor, outdoor and underground).

This first-generation MPRS prototype was evaluated in conjunction with the US Army Combat Engineers Tunnel and Sewer Concept Experimentation Program (CEP). The purpose of the CEP was to validate the concept of employing small robots to conduct tunnel, sewer, and bunker reconnaissance in urban combat.



Picture 11. MPRS platform with control units

Picture 12. URBOT at tunnel complex

The US National Guard Civil Support Teams Weapons of Mass Destruction units purchased some MATILDA system to evaluate the system and explore other uses. The use of robots will assist to locating, identifying, and disposing of dangerous chemical, biological, and nuclear materials.

Picture 13. MATILDA

Picture 14. MATILDA with robotic arm

Currently, MPRS is involved in an exploratory development effort in *marsupial robotics*.[12] What does the marsupial mean? Marsupial is a design concept for UGVs where the larger UGV carries one or more smaller UGVs, either inside it or attached to it for later deployment.

The URBOT is a low-profile tracked robot that is controlled by an operator via an RF link. It is fully invertible, completely waterproof, and employs four video cameras. Its small size (can fit through a 24-inch manhole) and excellent maneuverability make it ideal for tunnel and sewer reconnaissance in the below-ground infrastructure associated with urban warfare. The onboard nickel-metal-hydride rechargeable batteries provide average mission durations of between 4 and 5 hours. The remote operator can communicate with the URBOT by relaying through the longer-range MDARS RF network, which uses the same integrated format for all-digital transmission of video, audio, and control data.

Picture 15. MDARS-E with iSTAR

Picture 16. URBOT with micro iSTAR

The marsupial robotics effort involves the integration of UAV and UGV. Successfully launched the 29-inch iSTAR UAV developed by Micro Craft from atop the MDARS-E vehicle in September of 2002. The second phase of this effort, currently underway, will demonstrate automatic landing of the UAV on the UGV. The third phase will involve the launching, re-capturing, refueling, and relaunching of the UAV. Follow-on plans call for integrating the smaller 9-inch model of iSTAR onto the URBOT.

Summary

In this article I have sought to demonstrate some programs and some interesting models of UGV development from USA. I know it was not complete. It was only a flash from about one hundred programs.

In my opinion the research and development of unmanned ground vehicles is very interesting and very important segment of military technical modernisation. We have to theoretically follow the significant foreign efforts, and from time to time review their products.

At the end I want to cite one sentence from STAR 21 report, *Strategic Technologies of the Twenty-First Century*: "The core weapon of the 20th century has been the tank. The core weapon of the 21st century may well be the unmanned systems".

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