REQUIREMENTS FOR MOBILITY OF PLATFORMS AND POWER SUPPLY SYSTEM FOR UNMANNED GROUND VEHICLES

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Abstract

This paper presents many varied mobile platform suited for different kinds unmanned ground vehicles applications. The Unmanned Ground Vehicle's platform is the glue that holds together all the other aspects of a field able tactical military unmanned ground vehicle. Unless the platform exhibits a high degree of mobility and outstanding ruggedness it will fail to achieve its target location. If the UGV can not deploy its sensors at the correct location then the mission is rendered useless. The platform should merge the drive system, a power supply system sufficient for the required mission period, an advanced communication system capable of returning real-time information to the user and a user friendly Human Machine Interface that allows long term, stress free operations. The platform must have a very high immunity to electro-magnetic interference, and logistically any tactical UGV must not impose a heavy load on available systems or manpower.

Unmanned Ground Vehicle technology areas, platforms for reconnaissance, surveillance and EOD missions, the first dedicated IED disposal robotic platform "Wheelbarrow", remotely controlled French tank (AMX30B2) for mine clearance operations, All terrain vehicle Gamma Goat, schematic of typical hybrid electric power train for UGVs, AHED 8x8 Phantom view revealing power and propulsion are presented in the paper.

Keywords: *unmanned ground vehicle, mobility, power supply system*

1. Introduction

An Unmanned Ground Vehicle consist of a mobility platform with sensors, computers, software, communications, power, and a separate mission package depending upon the UGV's combat role. The main components of the UGV system are illustrated in Fig. 1.

Fig. 1. Unmanned Ground Vehicle technology areas

The mobility platform is highly application dependent. Platforms for different mission applications will have to be designed based on differences in the mission requirements. While a UGV has the advantage of not needing to be designed around human crew limitations, it also has the disadvantage of needing mechanisms to replace human driving judgment. Thus, salient uncertainty platforms can be integrated with perception technologies to provide the capability to avoid obstacles, that the platform is not hardened to overcome. The overall risk associated with building different mobility platforms will be less than that of developing sensors and software capable of successful mobility.

2. Division of unmanned ground vehicles with respect to weight

As it soon became evident from the user requirements that no single unmanned ground vehicle could fulfil all possible requirements, the state of the art on UGV platforms is broken down by vehicles weight.

1. Featherweight Robotic Vehicles:

The user group identified the need for small easily deployable UGVs for use in an urban environment. Such battlefield UGV vehicles, commonly known as the featherweight size weigh in at under 5kg. These platforms are very easily transportable by a single person, exceptionally rugged and a few are light enough to be thrown by the user into the area of interest. Because of their low mass their operating time and capabilities are also reduced as such this scale of robotic devices is usually used for short term surveillance, local situation awareness and tactical information gathering.

These light weight robotic platforms exist today, they contain small, low power audio and video picture transmitters allowing troops the opportunity to throw one of these onto the roof of a building or drive it around a blind corner into an area of high risk before committing troops. The returning picture can show topography, target location, strength and state of readiness, et cetera.

a) b)

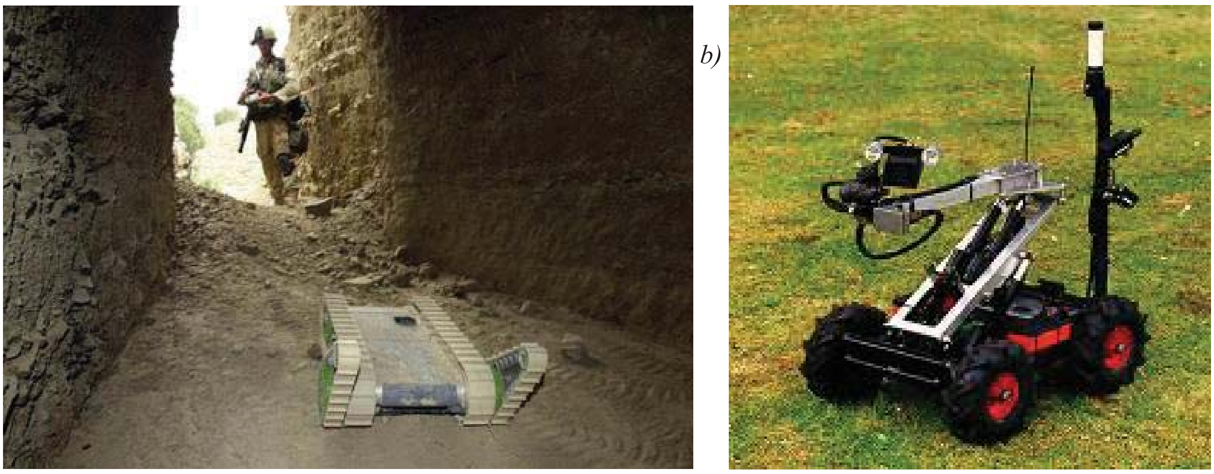

Fig. 2. Platforms for reconnaissance, surveillance and EOD missions: a – PackBot robot used by US Army; b – Groundhog robot in service with UK Forces

Some of these featherweight UGVs can climb vertical steel structures, or traverse the upside down across the ceiling of steel structures such as containers, ships hulls, industrial buildings et cetera.

2. Man Portable UGVs:

These UGVs weigh in between 5 kg and 50 kg. With their increased size and weight they also have increased capability in that they have an extended mission life, can cover a larger operational area and while the featherweight size of UGV is usually restricted to monitoring its surroundings. Robots of this size are capable of supporting a low specification manipulator and are capable of carrying and deploying ordnance.

The limiting factor governing the use of these current man portable vehicles is the need for the operator to drive all of their functions, they have very little autonomy and can not make any command decisions. This means that they can not sense their environment and drive around obstructions or holes requiring the user to take all corrective actions during deployment. Early versions of battlefield robots had often a failure system and missions were often aborted when the UGV failed. As more robots have been field tested their reliability has increased, however the scientific community believes that the user has an unrealistically high expectation on the capability of battlefield vehicles of this size.

3. Medium Weight UGVs: 50-500 kg

By numbers in use this grouping has by far the highest number of tactical robotic platforms currently in use by armies throughout the world. With the threat of car bombs in the Northern Ireland in 1970's the British army commissioned the design of the first dedicated IED disposal robotic platform and over the years this was developed into the family of "Wheelbarrow" EOD UGVs which are now in use throughout the world (Fig. 3). As the threat has changed so too must the response. Military robotic vehicles designed to operate against traditional explosive IEDs or UXOs must now be capable of being configured to operate against new threats such as the release of radioactive materials (Dirty Bombs) and the use of chemical and biological devices by terrorists. This has spawned the next generation of these vehicles.

Fig. 3. The first dedicated IED disposal robotic platform "Wheelbarrow"

4. Heavy Weight UGVs: Above 500 kg

This section contains most of the tele-operated battlefield engineering machines. The smaller vehicles include skid steer dumpsters like "Bobcats" and "JCB170's". These are based around commercially available building machine modified by the fitting of an "appliqué kit" to allow remote control from a safe distance. Larger civil engineering machine can also be converted for operation under remote control and radio controlled back hoe diggers and excavation machines have been converted by many defence industry contractors. Where such conversion takes place experience has shown that the need to allow the driver to be able to drive the vehicle as normal from the cab is a high priority.

3. The important gaps and essential user requirements

There are several gaps on UGV's platforms were identified that are important for military operations, some of them are presented.

Limited damage by AT mine and RPG

The users required no mobility reducing damage due to Anti Tank (AT) mine of 10 kg and the capability of sustaining a hit from a Rocket Propelled Grenade (RPG).

Fig. 4. Remotely controlled French tank (AMX30B2) for mine clearance operations

Very steep slopes

The users requested the possibility to ascend or descend a slope of more than 60% or drive parallel to a slope of more than 50%. (Fig. 5).

High barriers

The users required the possibility to cross step shaped barrier of over 50 cm or to cross barricade of debris (rubble) stones of over 50 cm. This request is highly dependant on the size of the UGV and can range from very difficult (for very small units) to trivial (for big units). The step should be defined in terms of % of body height/length.

High speeds in light terrain

The users specified the possibility for some tasks to move forward in light terrain at speeds of above 70 km/h. While speeds above 70 km/h can be accomplished, the lack of an upper limit to this request makes it impossible to achieve this requirement as stated.

Polar climatic circumstances

The users required the reconnaissance and equipment carrying vehicle to be usable under polar climatic circumstances. However, electronic systems in general and batteries in particular have severely degraded performances below –10°C and, as the user community has identified this as a highly unlikely environment.

Pay load capabilities of more than 100 kg

The pay load is related to the scale of the UGV and should not be expressed only in absolute terms. There is suggesting indicating desired payload capacities in terms of % of platform weight and size.

Although a wide variety of user requirements to a UGV's platform are established, even to a great level of detail, many of them can be summarized into following list of features for a tactical UGV's platform to be accepted into the battlefield environment:

1. platform ruggedness, reliability and availability,
2. modularity, a platform must be able to be configured to match its mission,
3. operational tempo must be compatible with the speed of battle,
4. must operate in a real world environment where climatic conditions change as do topography and tactical protocols,
5. should be intuitive to use, smart enough to avoid dangers but not undertake any unexpected or uncommanded operations,
6. needs to be safe when working in close proximity to troops, public and wildlife,
7. platforms must communicate to other resources, to share information,
8. needs to be able to accept the current and next generation of sensor suites,
9. needs to be EMC hard to withstand the electronic aggression associated with a modern battlefield,
10. needs to be capable of decontamination post mission/conflict,
11. support and training infrastructure to operate the vehicle systems must be kept to a minimum,
12. must be cost effective.

Fig. 5. All terrain vehicle Gamma Goat

Some user requirements on vehicle's platforms as found during the evaluation process are inconsistent in that they conflict with each other, at least given the current state of technology. For instance the required ability to negotiate great obstacles and to have a very long endurance, while at the same time the vehicle should be very small. At least with current technologies the same of the vehicle and the obstacle are hard to combine, even more if a long endurance is required, usually meaning too great and heavy battery packs.

Essential for the reconnaissance scenario are stealth features, meaning low detection of the vehicle in visible light, infrared, radar and sound. The reconnaissance vehicle should be able to drive on all sorts of roads and terrains, negotiate slopes of up to 45 percent and barricades of several types of 0.5 meter and more in height. It should have only limited damage when being hit by an AT mine of 10 kg. It should have an endurance of several days without the need to refuel and should even be able to operate about 5 hours without the need to run the engines. Therefore, the UGV for reconnaissance has very high user requirements.

4. Power supply system for unmanned ground vehicles

The energy source and the rate at which it can be utilized are key to UGV's operating in the battlefield. At present, there are several options for energy sources, depending on the application. For small units the energy source can be a battery, rechargeable and non-rechargeable. For larger units the energy train can be fuelled, allowing for motor-generator or hybrid-electric systems. His selection of the appropriate technology for use in any given UGV's application must take into account all of the relevant factors that could influence mission success. These factors must be considered early in the development cycle.

The most obvious factors impacting the energy supply are mission environment, mission time, vehicle mass, signature, cost, logistics support, size, and efficiency. These factors are not independent and they may be more severe and mission limiting for small vehicles with the energy supplies that make up most of the mass and volume of the system.

The mission environment is taken to mean the local environment associated with any place in the world the military will conduct operations. Given that definition, the energy system must perform over a temperature range from approximately 250 K to well over 315 K in the desert Further, sand, dust, salt fog and spray, and the possibility of chemical and biological environments are factors that could be superimposed on local environmental conditions.

In most cases the power train of choice should be one consisting of a fuelled system that provides the primary energy store and an intermediate store that for stealth reasons will probably need to be a rechargeable battery. Current development efforts focus on hybrid systems coupled with a secondary battery in the configuration shown in Fig. 6.

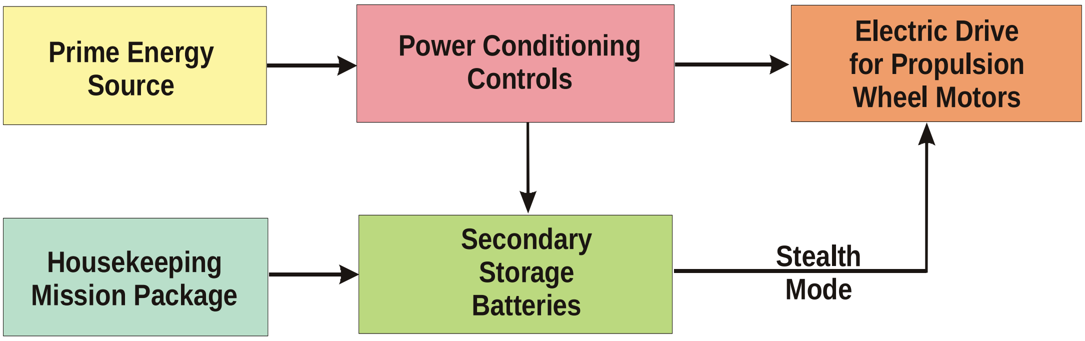

Fig. 6. Schematic of typical hybrid electric power train for UGVs

The mission energy supply is contained within the fuel carried on the vehicle. In the near term a motor generator will be used to convert the energy to electrical energy usable by the UGV. In the far term, reformed logistic fuel coupled with a fuel cell may provide the initial electrical energy. Part of the energy is stored in the intermediate storage unit, usually a high-specific-energy, high-specific-power rechargeable battery. This unit is sized to give the UGV a predetermined amount of energy that will maintain power to the mission package and provide stealthy movement for some tactically significant time.

In the far term fuel cells offer the possibility of better fuel economy and inherently more stealthy operation. Due to the dynamics of reforming battlefield fuels and the operation of fuel cells in general, it will still be necessary to retain the battery-driven intermediate storage unit. The critical issue driving application of fuel cells in military systems is the problem of hydrogen generation and storage. Storage in hydrides is at most a few percent efficient by weight. Reforming of battlefield fuels is hampered by the sulphur content of the fuels. Recent progress in micro channel reformers indicates that small efficient, poison-tolerant systems can be built that will enable the use of battlefield fuels in reformers for fuel cells.

For small UGVs, such as those needed for tunnel investigation and building search and clearing, the energy requirements are much less than those for the large units. Small hybrid systems would be the choice for dismounted soldier systems whose mission-time requirements exceeded a certain number of kWh.

For larger systems the hybrid systems chosen are 40 kW and 160 kW with a motor generator with a high-specific-power, high-specific-energy intermediate storage battery for stealth mode, housekeeping, and mission package power for the near term, and a reformer fuel cell, intermediate storage unit that can be developed in the far tern.

General Dynamics Land System and the US Army-TARDEC National Automotive Centre have teamed to pursue in-wheel electric drive and advanced hybrid electric systems for the 20 ton class of wheeled and hybrid vehicle configurations. Figure 7 shows a model of the demonstrator indicating the power and propulsion elements. Modular wheel drives with motors provided by Magnet Motor are installed in each wheel hub [2].

Motor Controllers are Insulated Gate Bipolar Transistor based, rated at 110 kW. Full "H" bridge topography is used to allow the wheel motors to be operated as generators for regenerative braking, steering, and traction control. These controllers are packaged in modular dual channel packages that interface into a distribution manifold. This distribution manifold brings cooling, power distribution, motor conductors, and control interfaces together in a quick disconnect interface.

A 360 kW permanent magnet generator is mounted on engine in place of a traditional flywheel. The system uses a generator controller that is both co-located and interchangeable with the motor controllers.

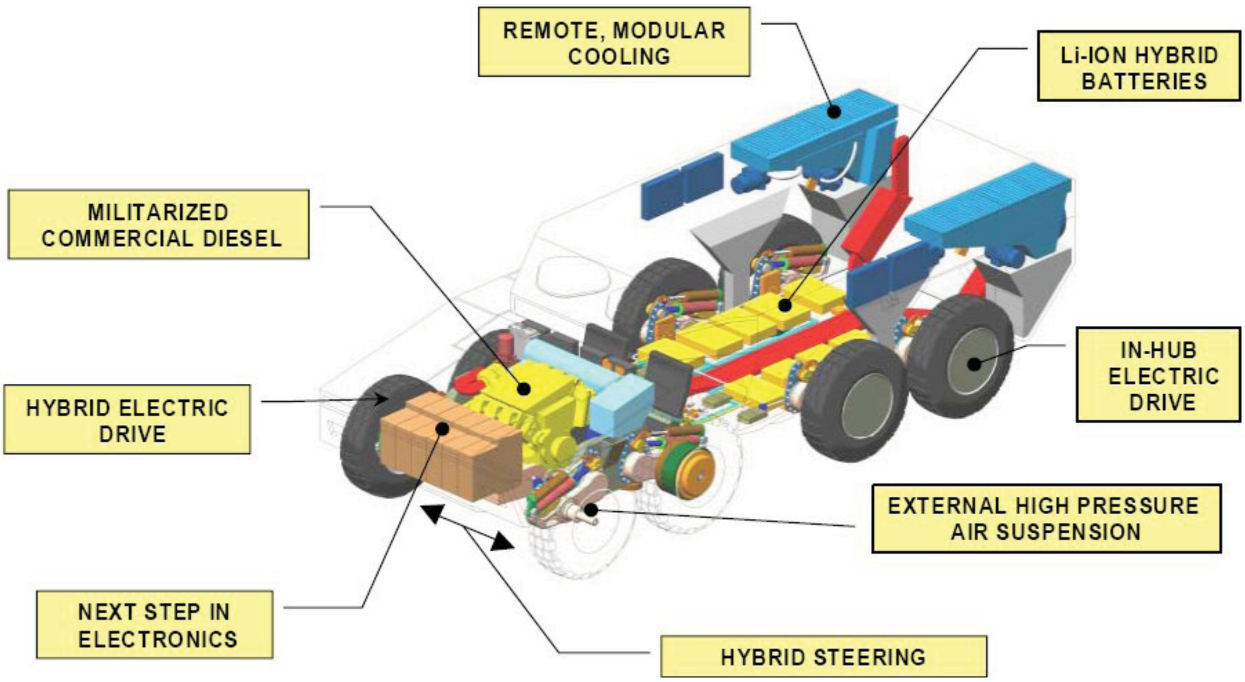

Fig. 7. AHED 8x8 Phantom view revealing power and propulsion elements

Energy storage is provided through use of lithium-ion batteries. The bank developed for the demonstrator utilizes Saft HP 16 cells that are packaged into modular batteries 24 V, 23 kW each. Five battery packs make up the operating bank. The platform is designed to host two parallel K banks to allow tailoring of the power and energy per mission requirements.

Power Conversion requirements are met utilizing SatCon Technologies DC/DC converters. For the demonstrator, two 90 kW units are being used. These bi-directional converters pass power between the fixed battery voltage and the floating (300-800V) DC Link.

5. Conclusions

The science of operation of tactical UGV's equipment in a real world environment is now mature enough to enable the military to field such equipment with confidence, provided the user defines his task and requirement in detail and has a realistic understanding of the capability of battlefield robotics. This means that at this time and date only for a limited number of relatively simple military tasks UGV's platforms may be used, especially those tasks that do not require a high level of vehicle autonomy.

By careful choice of the appropriate size of platform almost all requirements can be met but not in a single entity. As size reduces, so does the capability and potential for extended operations, the limiting factor usually being the battery. As the platform size increases its potential to cause unintended injury or extensive collateral damage also increase but so does the system capability.

While the science is mature enough to deploy vehicles platforms today continued research and technical support will greatly enhance their capabilities in the future. Better sensors and algorithms will allow the vehicle to identify dangers and take the actions necessary to protect it. Developments in battery technology will allow extend mission time, improved computation capabilities will allow full integration into ISTAR systems and advanced mission planning.

Acknowledgements

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