System Requirements for Satellite Video Relays Supporting Unmanned Ground Vehicles

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The Unmanned Ground Vehicle Joint Project Office (UGV/JPO) has identified communications and control as the single most important issue concerning unmanned ground vehicle (UGV) deployment. This paper outlines needed capabilities for potential small satellite data relays for unmanned ground vehicle operations. Satellites could offer a solution to the inherent non-line-of-sight (NLOS), wide bandwidth dilemma.

Introduction

The Army Unmanned Ground Vehicle Joint Project Office manages the development of a tactical teleoperated unmanned ground vehicle, the TUGV, scheduled for production in 1998. Presently, the TUGV program is in the concept exploration phase of the weapon life cycle model. The UGV/JPO staff is writing a request for proposal for the TUGV development and follow on production. The UGV/JPO has already let a contract for the production of fourteen surrogate teleoperated vehicles, the STVs. Besides the STV effort, other US Army Missile Command (MICOM) efforts include system concept studies and other prototype vehicle construction.

The unmanned vehicle program is a joint program between the Army and the Marine Corps. Requirements for the TUGV are outlined in the Army's Operational and Organization Plan (O & O) and the Marine Corps Initial Statement of Requirements (ISOR). These documents are available through the UGV/JPO. All the requirements cited in this paper stem from these two documents.

The Real-Time Video Problem

One of the requirements stated in these two documents is the requirement for non line-of-sight communications, distances up to 30 kilometers. From the Army O & O,[1] "The (TUGV) should be able to conduct its remote mission....while operating non line-of-sight from the operator." From the Marine Corps ISOR,[2] "Provide secure non-jammable communications when the remote platform is beyond the line-of-sight of the control station....of at least 10km (30km desired)."

One of the most challenging problems with the TUGV system is this non-line-of-sight requirement. To teleoperate the vehicle, the operator must see the environment around the vehicle with high fidelity in real-time. Driving a ground vehicle remotely is not a trivial task. The problem is the vehicle, unlike unmanned air vehicles (UAVs) or even proposed space-based teleoperated construction robots is that the environment is unknown and noncompliant. UAVs are not "flown" remotely by a human operator. They are controlled via way-points in navigation program. Its environment (air) is compliant. Space-based robots, like the Shuttle remote manipulator system (RMS) are in a compliant environment, and it is also a known one. The human operator has practiced many times exactly what needs to be done for that evolution.

Teleoperated ground vehicles aren't like UAVs or the RMS. The vehicle operator has a high band-width control problem. The operator needs to know in real-time what he or she is driving over. Most of the operators senses are curtailed or eliminated. With this in mind, it is imperative that the remaining senses of human vision and hearing be the best technology can provide. For vision, the only practical solution considered available now is fiber optic tethering.

What kind of video will the TUGV need? The Marine Corps ISOR states for the vision requirement as "...a sense of presence." which most people working with TUGVs understand to mean stereo vision.

Before video requirements are reviewed, it is important to understand the video requirement exists primarily for driving the vehicle. Once on station for overwatch, surveillance and/or NBC monitoring, the video requirement drops off considerably. The scene probably needs only updating to be useful, though not a lot of work has been done in this area. With this in mind, we can find out what kind of band-width this video needs.

Requirements for TUGV Video

Two NTSC cameras, digitized to 512 by 512, 24 bits color, refreshed 30 times per second. That gives 360 megabits per second. Even with real-time compression algorithms approaching 500:1, it is a prodigious amount of data for non line-of-sight VHF/UHF links. Moreover, the vehicle will have no armor, protection lies solely in speed and maneuver capabilities. Thus, the operator needs quality video.

This is what makes satellite relays attractive. In the EHF band, signals can be digital, encrypted, highly directional with no penalty of bandwidth and nc allocation problems. The UGV/JPO commissioned a study by the DOD Electromagnetic Compatibility Analysis Center (ECAC) concerning available frequencies with local and world-wide allocation potential for TUGV video. Based on the ECAC studies, frequencies above 40.5 gigahertz have excellent worldwide allocation potential.[3] New Army systems must have world-wide allocation before they are fielded.

A satellite-based communications relay concept would follow the requirements outlined below.

Mobile Base Unit

The mobile base unit (MBU) is the vehicle itself. Its size is constrained by the O & O and the ISOR to be "transportable by KC-130, C-141, C-5, CH-53 and medium lift aircraft." and "sized to fit in a standard MILVAN." The unit must also be air drop capable.

The MBU is, in the Marine Corps view, smaller than the Army High Mobility Multi-purpose Wheeled Vehicle. The satellite mobile ground station must be able to fit inside and on top of this vehicle. The MBU will have global positioning system built in, providing MBU onboard computers with some of the information required to track the satellite. The antenna could be a dish or a phased array system.

One of the features of the MBU is its modularity. The ISOR states the MBU must have the capability to exchange mission modules or payloads. A reconnaissance, surveillance and target acquisition (RSTA) module might be exchanged for an NBC monitoring module or a weapons module. With this feature, the satellite communications package must remain with the vehicle once the RSTA or other mission module is removed. This lowers the number of communications packages per MBU, since there conceivably will be many more mission modules than vehicles.

The satellite communications package must not degrade the mobility of the vehicle.

Operator Control Unit

The operator control unit (OCU) is what remotely controls the MBU and must be one man portable. What the ISOR or O & O does not state is set up time. There is no requirement for the OCU do be a single self contained unit. Once the OCU is set up for operation, there may be a central control unit with flat panel screens and vehicle control devices (handle bars, steering wheels, etc.), a separated power supply and the communications unit.

Once in tactical position, the operator will breakout his OCU, prep his vehicles and start his mission. Once the vehicles are deployed, the operator may package and relocate. The OCU must monitor up to three vehicles while permit driving a fourth.

The communications section of the OCU needs to receive data relayed by the satellite from the MBU. Transmission from the OCU to the MBU is not required through the satellite, though is an option. Existing Army communications may be used. The data rate requirements for vehicle control are considerably less severe from the OCU to the MBU.

Satellite Relay

With the exception of some local allocations in the UHF band, no worldwide frequencies are available for TUGVs except in the EHF bands. Unfortunately, EHF is line of sight and EHF equipment is expensive. Forest canopy and atmospheric absorption are other problems that must be examined. These issues surely will be addressed during testing of pilot EHF satellite systems in this decade.

What is promising though for EHF is this: The TUGV system will not be fielded until very late this decade. This gives time for EHF and satellite technologies to grow and mature.

Why use satellites? Balloons may give the OCU position away. UAVs tie the Battalion TUGV operators to Corp level UAV controllers, who will not be in the same combat unit. Also, UAVs don't have the endurance TUGVs will have. Satellites are generally removed from threats from the ground and offer most of the advantages of atmospheric relays.

To offer real-time video, a satellite based TUGV relay will not be geosynchronous. The delay time is too long for optimum real-time control of a fast moving (35 mph max) TUGV. Thus, some sort of low earth orbit is likely required with a minimum ground station elevation angle of 20 degrees. TUGV needs to operate in all the same places our mission forces will go. How many satellites will be necessary?

Ignoring for now arctic or antarctic coverage, good southwest Asian coverage can be made with six satellites in a three hour orbit. Good here means 24 minutes of communications down time six times per day. Presently, there is no requirement of operation time and standby time. Here, standby time is the time the MBU and OCU don't have an overhead satellite. We will not cover here what type of constellation is required for TUGV video links. However, the UGV/JPO for now expects 100% vehicle communication availability.

This paper does not advocate a dedicated EHF satellite link, small or otherwise. What it does advocate is the cooperation and consideration of other programs within the Department of Defense. For example, the Defense Advanced Research Projects Agency will probably demonstrate an EHF system on a small satellite within a few years.[4] There are other technology programs ongoing in the EHF small sat area. MIT Lincoln Labs is working on EHF satellite communications.[5] And the ECAC study points out EHF as the most promising area for TUGV use.

By the time TUGV rolls out in late 1998, there will probably be a small satellite EHF system in place. TUGVs will likely be fielded before the turn of the century. If these systems are used in combat, the satellite relay will need to be robust enough to handle relaying TUGV video transmissions.

Conclusion

TUGV strictly speaking is a NDI program. Most of the components for it exist today. The problem is frequency bandwidth and allocation for untethered video data links. Three areas will solve this problem eventually; data compression, machine intelligence and unallocated frequencies in the SHF or EHF bands. Even with wide band-widths, there will still be a desire to compress video data. Machine intelligence will certainly remove the need for an operator driving the vehicle, but the need for video communications is still there for mission module operation.

Satellite relays for UGVs solve some problems. EHF small satellites will probably be used throughout the services, with UGVs being a part of that community. The small satellite and unmanned vehicle community must continue to communicate and cooperate.

Acknowledgments

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References

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