THE APPLICATION OF SATELLITE COMMUNICATIONS TO THE DATA LINK REQUIREMENT FOR UNMANNED GROUND VEHICLES

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ABSTRACT

The Advanced Communications Technologies Satellite (ACTS) Mobile Terminal (AMT) developed by NASA at the Jet Propulsion Laboratory (JPL) was applied as a unique solution to the data communications link requirement between an unmanned ground vehicle (UGV) and its remote control station (RCS) in Project Mustang. "Project Mustang" is the short title for a U.S. Army Research Laboratory (ARL) research effort to provide a robotic scout for field exercises with the 1st of the 8th Cavalry Battalion (The Mustangs), 1st Cavalry Division at Ft. Hood, Texas. The AMT performed well in its robotic application during three separate exercises, and will provide the primary communications link for a technology demonstration to be performed in July 1995.

INTRODUCTION

A critical technology area in the development of UGV systems is the data communications link between the vehicle and its RCS. Teleoperated UGVS require near-real time video to be passed back to the RCS. This puts a heavy bandwidth requirement on the data link system even when pushing the current technology limits of video data compression. Various forms of autonomous UGV navigation make less of a demand on data link bandwidth, but bandwidth requirements upwards of 10 kbps can still be expected. A UGV mission package also often makes heavy bandwidth demands; for example, the current mission package in the Advanced Research Projects Agency (ARPA) UGV program is reconnaissance, surveillance, and target acquisition (RSTA) - an application that calls for real time video images to be sent back to the RCS. The common problem with all of these situations has been finding a radio frequency data link solution with adequate bandwidth capable of operating at beyond line of sight distances.

The data link issue was recently addressed in Project Mustang. Mustang was fielded at Ft. Hood on several occasions during the period December 1994 through May 1995. This effort was undertaken in response to a request from LTG Paul E. Funk, Commander III Corps, for an opportunity to experiment with a robotic vehicle with a RSTA mission package.

[n order to meet the mission requirements of Project Mustang, a unique solution to the data link problem was developed. Instead of focusing on the normal terrestrial radio approach,

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mobile satellite technology, specifically the AMT, was developed as the primary link for the UGV to RCS communications. This paper describes the results of the communications portion of Project Mustang as well as future plans for a terrestrial auxiliary communications capability.

PROJECT MUSTANG SYSTEM

The robotic vehicle is a modified High Mobility, Multi-purpose Wheeled Vehicle (HMMWV) with a RSTA mission package. The regular vehicle driver's station remains unencumbered and could be used by a soldier in the normal manner with all robotic actuators automatically disengaged. For robotic navigation, the vehicle is equipped with a autonomous retro-traverse capability. Using a combination of differential global positioning and inertial navigation systems, the vehicle can retrace a previous "learned" path when driven as a "manned" vehicle. The vehicle's velocity is controlled to match the speed previously used by the human driver. E lectric actuators for steering, brake, throttle, transmission, transfer case, and park brake, along with various dashboard sensors, are used during the retro-traverse process.

There are two target acquisition systems on the UGV. The first uses an infra-red (IR) camera to perform moving target detection and tracking. The IR camera is mounted on a turret head that has left and right traverse of 135° from the vehicle centerline, and ±10° in elevation and depression. The IR camera is panned to each of the operator-selected areas-of-interest (AOI) and stabilized IR imagery is compared to a background image of the AOI. If moving targets are detected, the Operator Work Station (OWS) in the RCS is alerted and the targets are tracked until they move out of the AOI or are engaged with the Modular Integrated Laser Engagement System (MILES). When the tracker determines that there are no more targets in an AOI, it pans the camera to the next AOI.

The second target acquisition system uses an array of four acoustic sensors mounted on the hood of the vehicle to detect targets, determine their bearing, and determine whether they are tracked, wheeled, fixed-winged, or rotary-winged threats. Both target acquisition systems and the mobility system are implemented on VME based Spare cards and other processors. The onboard communications system between the various processors, sensors, and control systems is based on a combination of Ethernet and wired digital/analog links.

With the information provided by the two target acquisition systems, hostiles can be engaged with the MILES weapon simulator, or target UTM coordinates can be generated for indirect-fire weapons. The UGV turret head carries a visual modification representing a 25mm cannon and appropriate MILES components to allow it to both "shoot" and be "shot at". The turret control system is capable of compensating for processing and communication delays, can calculate target lead, predicts an intersection point at which to fire, and triggers the firing circuitry of the MILES weapon simulator.

The primary communication system used on the UGV is the AMT. The AMT consists primarily of the modem, IF converter (IFC), RF converter (RFC), antenna controller, and antenna [1]. The modem used as part of the UGV system is a commercially developed satcom modem that includes such features as coherent BPSK with concatenated convolutional and Reed-Solomon coding, and interleaving. It is operational at data rates ranging from 9.6 kbps to 2.048 Mbps.

The vehicle antenna is a "passive" elliptical reflector-type antenna used in conjunction with a separate high powered amplifier, Complete with a spherical radome, it stands approximately 5 inches in height, and is approximately 8 inches in diameter at its base. This antenna is fully tracking in azimuth, and manually positioned in elevation to one of five distinct settings.[1] Combined with a 10 W TWTA, this antenna system provides at least 32 dBW transmit EIRP on boresight. The 3 dB beamwidth is 12° in azimuth and 18° in elevation. The on boresight G/T achieved by this antenna is -3 dB/K.

Preceding the antenna, the RFC converts an IF signal around 3.373 GHz to 30 GHz for transmit purposes. The IFC translates signals between 3.373 GHz and a lower 70 MHz IF at the output of the modem. Another key function of the IFC is pilot tracking and Doppler compensation for the return communications link.

The antenna pointing system enables the antenna to track the satellite for all practical land-mobile vehicle maneuvers (< ±6°). The antenna is mated to a simple, yet robust, mechanical steering system. The antenna is smoothly dithered about boresight by one degree at a rate of 2 Hz. The pilot signal strength is measured through this dithering process, and is used to compliment the inertial rate sensor's information. This information allows the antenna to track the satellite while experiencing a shadowing event up to 10 seconds in duration.

The interface to the UGV onboard systems is an Ethernet link. The communications system requires a serial interface. To allow the two systems to communicate, and provide additional robustness in the land mobile satellite channel [2], a Xyplex bridge/router was integrated into the system. The interface on the vehicle side of the bridge/router (the LAN) is an Ethernet interface, on the communication system side (the WAN), it is an RS-449 serial interface. The bridge/router implements the standard Point-to-Point Protocol (PPP) for reliable packet transfer or a proprietary protocol, Xyplex, which optimizes the packet size for the network bandwidth. Initially, the Xyplex has been set up as a bridge, with the parameters set to attain an approximate 80% channel throughput.

For Project Mustang, the communications system was integrated on the back of the HMMWV with the onboard systems as illustrated in the picture shown in Figure 1. The antenna radome is visible behind the gun turret.

Figure 1. The Unmanned Ground Vehicle

[1] These five settings allow for complete elevation coverage for the continental United States.

The RCS is housed in a converted HMMWV ambulance as illustrated in Figure 2. The OWS in the RCS is a portable computer workstation that fully controls the UGV. The OWS has a color, touch sensitive flat panel display that is used to depict video from the tracking system along with "push buttons" for system control. The OWS screen allows the operator to simply "press" buttons on the screen for vehicle control, and to "press" on targets to designate engagement with weapon, laser range finder, or camera. The OWS contains audio and visual signals to alert the operator of targets detected by the UGV mission package. The communications equipment in the RCS is identical to that on the UGV with the exception of the antenna. A 1.2 meter dish is erected on the side of the HMMWV instead of the mobile antenna. This essentially converts the HMMWV into a transportable fixed station - allowing both terminals to be co-located in the same spot beam of ACTS. When disassembled, the antenna is stored in the ambulance. For rapid movement of the RCS during operations, the teardown/setup time was reduced to approximately 45 minutes for each. Real-time GPS data from the robot scout allows accurate positioning of the UGV on the terrain. All components of the visualization system give a real-time view of the battlefield at a particular instant in time.

The RCS has a second workstation that displays typical battlefield information such as elevation data, feature vector data, imagery, and military units in a 3D scene. The 5 meter resolution terrain can be viewed at any angle by "flying through" the scenes which are generated at about 15 frames per second. This second workstation assists the commander or scout with terrain familiarization and mission planning.

In a typical employment, the UGV was manually driven out to an appropriate observation location, about 8-20 km from the RCS, to cover a probable avenue of approach by enemy hostile forces. On the way out, the UGV driver used an on-board driver interface panel to record a retro-traverse path and electronically mark locations where the vehicle could safely turn around. Upon arrival at the observation point, the on-board RSTA interface panel was used to set up the UGV for its RSTA mission. After setting up the vehicle, control of the UGV was handed over to the RCS. The driver then left the UGV alone at the observation point. With the approach of the enemy force, targets acquired by the two target acquisition systems on the UGV were engaged with the MILES weapon simulator, or UTM coordinates are generated for indirect-fire weapons. When it appears to the RCS that the UGV position is about to be compromised, the operator initiates retro-traverse, causing the vehicle to autonomously return to some specified point, out of harms way.

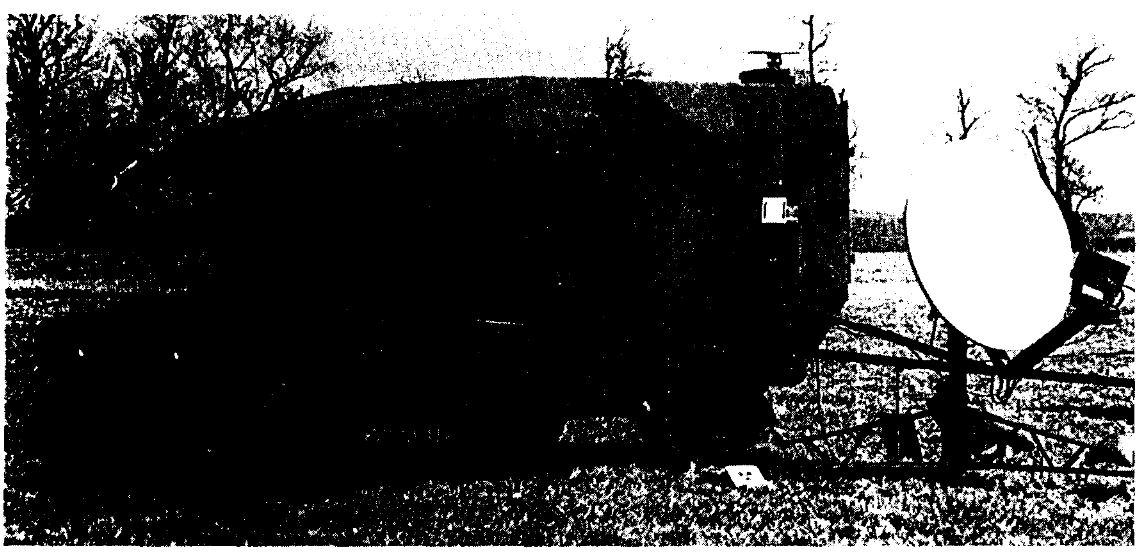

Figure 2. The Remote Control Station

PROJECT MUS1ANG RESULTS

A formal operation was carried out using the equipment described in the previous section. This operation was performed in April, 1995 at Ft. Hood, Texas. Operated by a scout platoon in an armored battalion, the UGV was used as an unmanned scout sensor platform giving early warning of enemy reconnaissance forces in the battalion security zone. The UGV was controlled from the RCS located near the battalion Tactical Operations Center (TOC). The robotic vehicle provided FLIR and visual images, autonomous target recognition, target tracking, and acoustic sensing from far in front of the forward edge of friendly forces.

The communication performance using ACTS and the AMT exceeded the expectations of ARPA and the 1/8 Cavalry Battalion. The UGV was used as a scout sensor on a reconnaissance mission with the Mustangs on a typical employment as described above. Virtually uninterrupted service was provided for the communications link between the UGV and the RCS at a data rate of up to 256 kbps with an E_b/N_o of approximately 11 dB. This allowed the commander to receive reconnaissance, surveillance, and target acquisition information through compressed real time video.

The exercise terrain at Ft. Hood, TX had many hills and sporadic trees and bushes making terrestrial line of sight communications difficult. By using the satellite system, the scouts were able to traverse any terrain and maintain or quickly re-acquire communications, continually providing the RCS with information. The link was lost on the occasional slope greater than 6° however within seconds of achieving a more desirable slope the link was re-established. The antenna would also re-acquire from any blockage within seconds. The communications protocol (PPP) provided robust communications between the RCS and the UGV - with the majority of fades due to blockage transparent to the UGV operators. The throughput achieved on the links due to the protocol overhead was in excess of 200 kbps. Because the link margin was high, a data rate of 384 kbps may have been possible but due to the mission, this was not attempted, All systems on the UGV communicated with the RCS and compressed real-time video was viewed at the Battalion TOC.

Recognizing the need for an alternate path, at the end of the exercise, a commercial 900 MHz terrestrial communications link was tested as part of the communications system. When the bridge/router is set for routing, two WAN connections can be utilized - allowing multiple radio communication links between the RCS and the UGV. The router then chooses the highest throughput link among the available communication links for transmission using the Xyplex protocol. In preliminary testing it was found that the switch from the primary link to a secondary link is transparent when both links are initially available and the primary link is lost. When operating over the secondary link and the primary link became available again, a delay of approximately 10 seconds to switch from the secondary to the primary link was observed. This crossover was again transparent to the RCS and UGV systems. This hybrid capability will be evaluated and optimized before a future series of exercises to be conducted in 1996.

CONCLUSIONS

The use of the ACTS and the AMT in the UGV as the solution to the data link problem has proven successful. Data rates upwards of 256 kbps have been demonstrated and more than adequately support the information flow from the UGV to the RCS including real-time video. With the further development of the auxiliary terrestrial link, a hybrid communications system based on ACTS and the AMT technologies would provide exactly the communications capabilities required for UGV operations.

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