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PROJECT JINGOSS[1]

A TELE-OPERATED METALLIC MINE DETECTOR (U)

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#149671

Abstract

On 14 January, 1993, the Canadian Forces Vice Chief of Defence Staff authorized the development of three remotely operated metallic mine detection systems, now nicknamed Jingoss. These were to be deployed with the Canadian contingent serving in Somalia. These units were to fulfil an urgent operational need for the detection and location of metallic anti-tank and anti-personnel land mines.

The Jingoss is a remote tele-operated vehicle which tows electromagnetic sensors. The sensors are optimized for the detection of metallic land mines. When a detection is made, the system automatically marks the ground and alerts the operator in the command vehicle which can be up to 5 km away. The electromagnetic signature of the object is displayed on the control station monitor, and the time and location of the detection are automatically recorded. A pan-and-tilt mounted video camera is mounted on the remote vehicle and the video signal is sent back to the operator's monitor. The operator controls the motion of the vehicle and the video camera with joystick controls.

Defence Research Establishment Suffield was tasked to develop and produce the units and ready them for deployment on a priority basis by 1 May, 1993. The systems were based on the integration of two technologies, the Vehicle Mounted Ordnance Detector and the Ancaeus Command and Control System, which were both under development at DRES. The two fields of ordnance detection and tele-operation of remote vehicles required accelerated development and integration to improve their performance for the mine detection role. The primary objective was to provide mine clearance personnel with a method of detecting mines which was faster and much safer than existing detection methods using hand-held mine detectors. The resulting Jingoss system provides a reliable system of detection which greatly improves the safety and productivity of personnel employed in this hazardous work of clearing mines during peacekeeping operations.

Introduction

The problem posed by land mines is of considerable concern to Canadian Army units. More recently, this threat has been experienced during peacekeeping operations, often with disastrous results. In order to at least partially counter this threat, Defence Research Establishment Suffield (DRES) was tasked by National Defence Headquarters (NDHQ) to develop and manufacture three tele-operated systems for the detection of metallic land mines. This requirement was authorized in January 1993 by the Vice Chief of Defence Staff as an urgent operational need for the Canadian contingent deployed in Somalia. The primary criteria for the remotely operated metallic mine detection system, nick-named "Jingoss" , was to improve the overall safety for personnel working or travelling in areas suspected of having emplaced land mines or boobytraps. Other significant criteria were that military engineer personnel were to be trained to operate and maintain the system and that the systems

[1] "Jingoss" is an Algonquin word describing "the actions of a ferret".

be ready for deployment to Somalia no later than 1 May, 1993. This paper describes the development, operating characteristics, and introduction into service of the Jingoss system. Particular emphasis has been given to the operational usage or application of a tele-operated system in a military peacekeeping scenario.

Development and Concept of Employment

Over the years, close communication has developed between the military engineer requirements directorate, Director Military Engineering 4, and DRES. This working relationship enabled the rapid exchange of information and technical details during the feasibility phase of the project. DRES had been working in two technological areas which could be directly applied to the mine detection application. These areas were the vehicle mounted ordnance detector (VMOD) and a semi-autonomous ground vehicle control system (Ancaeus).

It quickly became apparent that if the assigned timetable were to be met, maximum use had to be made of the existing VMOD and Ancaeus technologies. Development had to be limited to adapting the existing systems to the mine detection role and integrating them into a reliable system which could be fielded in a peacekeeping scenario. To minimize support requirements in Somalia, the basic chassis for the Jingoss system was to be an eight-wheeled all-terrain vehicle called the ARGO. This vehicle was already in the Canadian Forces inventory and its simple, robust construction made it desirable from the users point of view. The command vehicle likely to be used was an eight-wheeled armoured personnel carrier known as the Bison. This vehicle would operate as the base station during remote operation of the Jingoss system and as the carrier for the combat engineer section. A combat engineer section of eight men were to operate and maintain the Jingoss system and to provide an immediate response capability to deal with any detections that were made.

The concept of employment that evolved during the feasibility phase of the project was that a tele-operated vehicle would tow a metallic mine detector array. The remote vehicle would be controlled by an operator located in a command vehicle which remained at a safe distance from the remote vehicle in the event of any detonation of mines or other ordnance. The operator is warned in real time of any detections made by the unit, and the location is automatically recorded and marked by the system. The commander of the engineer section would then determine the best method of investigating the detection and take any necessary action to neutralize, dispose of, or bypass any hazardous ordnance which may be present. A summary of the required operating characteristics of the system is given in Table I.

Table I. Operating Characteristics

PARAMETER	VALUE
Scan Width	4 m (reducible to 2m)
Scan Speed, typical	5 km/hr
Detection Capability	
-Large metallic AT mine	>98% to 0.7 m depth
-Large metallic AP mine	>95% to 0.3 m depth
-Fragmentation Grenade	>95% to 0.1 m depth
Marking Accuracy	2 m radius
Operating Day	up to 12 hours
Remote Operation Range	up to 5 km
Terrain	roads or smooth terrain
Crew Size	2 persons

System Overview

A photograph of the complete Jingoss system in operation is shown in Fig. 1. The system consists of three major components: the remote controlled vehicle (RCV); the command vehicle carrying the Ground Control Station (GCS) and Jingoss operator; and the transport trailer described below:

Remote Controlled Vehicle

The tow vehicle is a commercial skid-steered vehicle manufactured by Ontario Drive and Gear, Ltd., which had to be substantially modified for integration into the Jingoss system. The vehicle is used to tow the mine detector sensor platforms and carries all the electronic subsystems of the detector as well as those of the Ancaeus control system. Mounted in front of vehicle is a "chain sweep" that drags a heavy steel chain over the ground to disrupt or detonate small anti-personnel mines. The overall weight of the vehicle and point loading has been kept well below the activation pressure required to detonate pressure fuses

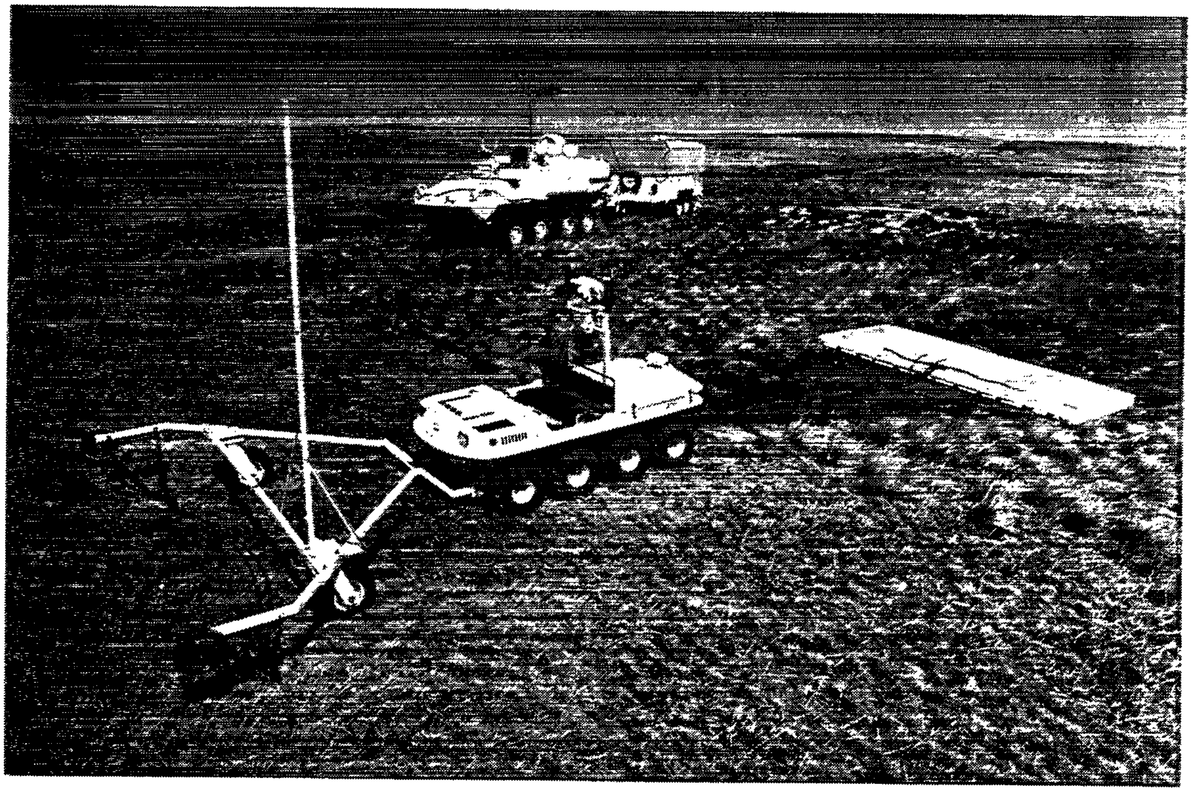

Figure 1. Complete JINGOSS system.

of anti-tank mines. The tall mast on the chain sweep is used to engage overhead trip wires before the command vehicle encounters them.

Command Vehicle

The ground control station is mounted inside a Bison APC. The operator observes the monitor and controls the movement of the remote vehicle with a custom joystick control. In addition he controls the functions of the mine detection and marking systems through a sophisticated user interface. The operator is presented with all relevant status and performance information for the remote vehicle and the detection system.

Trailer

A specialized trailer is provided for each system which will transport the entire system and all the spare parts and supplies required for operation and maintenance. The remote vehicle is stowed in the main compartment of the trailer and the sensor platforms are stowed beneath the main compartment floor. The chain sweep disassembles and stores in the main cargo area. Other smaller components, spares, fuel, tool kits, etc. are stored on shelves or in compartments. In essence, the Bison and trailer form a self-contained system which can be easily transported. The Jingoss system can be quickly deployed by road to a given location or airlifted by C130 transport aircraft.

The Detector System

The detector system was already in an advanced stage of development in the form of the VMOD. More detail on the VMOD system are given in Refs [1] and [2]. Ref [3] provides a detailed description of the changes and the rationale for those changes to the VMOD system to prepare it for the mine detection role. This paper summarizes the detection and marking system features and characteristics which were incorporated into the Jingoss system to optimize its detection performance against metallic land mines. The modifications were made to the VMOD system by Pylon Electronics Limited of Ottawa, Ontario. Pylon also produced a total of three detection units and spares for the Jingoss systems.

It had to be accepted from the outset that there was no known practical technology available in the world which would reliably detect non-metallic mines. The nature of the mine threat in Somalia was known to be primarily older generation mines and therefore had a significant metal content. This factor made the use of a metallic detector a practical system for use in the Somalia peacekeeping scenario.

A primary requirement was provision of a scan width wide enough to be practical for scanning roads or other wide surfaces but still retain the required capacity and reliability for detection of the threat mines. Feasibility tests were conducted at DRES to verify whether or not a modified VMOD could detect mines at the rate and detection probabilities required. This required testing of new sensor coil design and configurations. Another issue that had to be addressed was the discrepancy between the data rate used on the VMOD (19.2 kbaud) and the data rate used by the Ancaeus control system (9600 baud). Estimates were made and confirmatory testing was done to ensure that sufficient detector sensitivity and data rate transfer could be achieved by using the lower 9600 baud rate. Once these issues were resolved, Pylon was contracted to produce the revised detector systems. Some important operational features retained by the Jingoss system which were available on the original VMOD include:

a. Indication that the detector system is operating properly.
b. Audio and visual indication of detection.
c. Running display of two channels of response vs time data (compressed to be compatible with Ancaeus baud rate).
d. Ability to change system sensitivity (coarse selections only, i.e. low, medium and high).
e. Ability to turn lane markers and detection markers on/off and to adjust the interval between lane markings.
f. Ability to adjust threshold detection levels based on ambient conditions.
g. Indication of hitch disconnect.
h. Ability to start/stop system operation with ease.
i. Ability to recalibrate/test detector system easily.

The VMOD operates at 50 Hz and appropriate digital filtering is used to minimize interference due to 60 Hz power lines. The Jingoss was to be deployed in an area using 50 Hz power, and therefore the operating frequency was changed to 70 Hz and appropriate digital filter parameters were applied. This allows the system to operate in both 50 and 60 Hz environments. As well, since the detectors work directly in the RF environment of the Ancaeus system transmitters, great care was taken to provide proper grounding and shielding to minimize interference. The ARGO vehicle itself was not designed with stringent electrical noise suppression in mind. In addition, the ARGO engine is in close proximity to the sensor platform during operation. During modifications to the ARGO vehicle, considerable effort was devoted to reduce the noise levels generated by the ARGO to an acceptable limit.

The VMOD utilized a marking system which deployed a foam as a marking agent. The foam-based system was known to behave poorly in a very hot climates and a substitute marking agent had to be identified. Several alternatives were considered such as chalk, water-based paint, diesel-based aluminum paint, and dyes, however, a marking system using only diesel fuel was selected. This was based on the transient nature of the fuel which would evaporate within days and the availability of the diesel in Somalia. A marking system using pressurized diesel with no additives was designed and built by Pylon for integration into the Jingoss system.

The Ancaeus Control System

The concept and preliminary development of the Ancaeus control system were described at the Third Conference on Military Robotic Applications in September 1991 [Ref. 3]. That presentation described the Ancaeus concept which is a generic control system capable of guiding practically any surface vehicle and navigating semi-autonomously to deliver an application payload. The Ancaeus electronics package which was utilized in the Jingoss project is outlined in Figure 2. The package is modular in nature which facilitates rapid repair of the system in the field and provides a wide scope for system flexibility and adaptation. These features made the Ancaeus control system ideally suited for integrating the tele-operated vehicle and the mine detection system into a Jingoss system package.

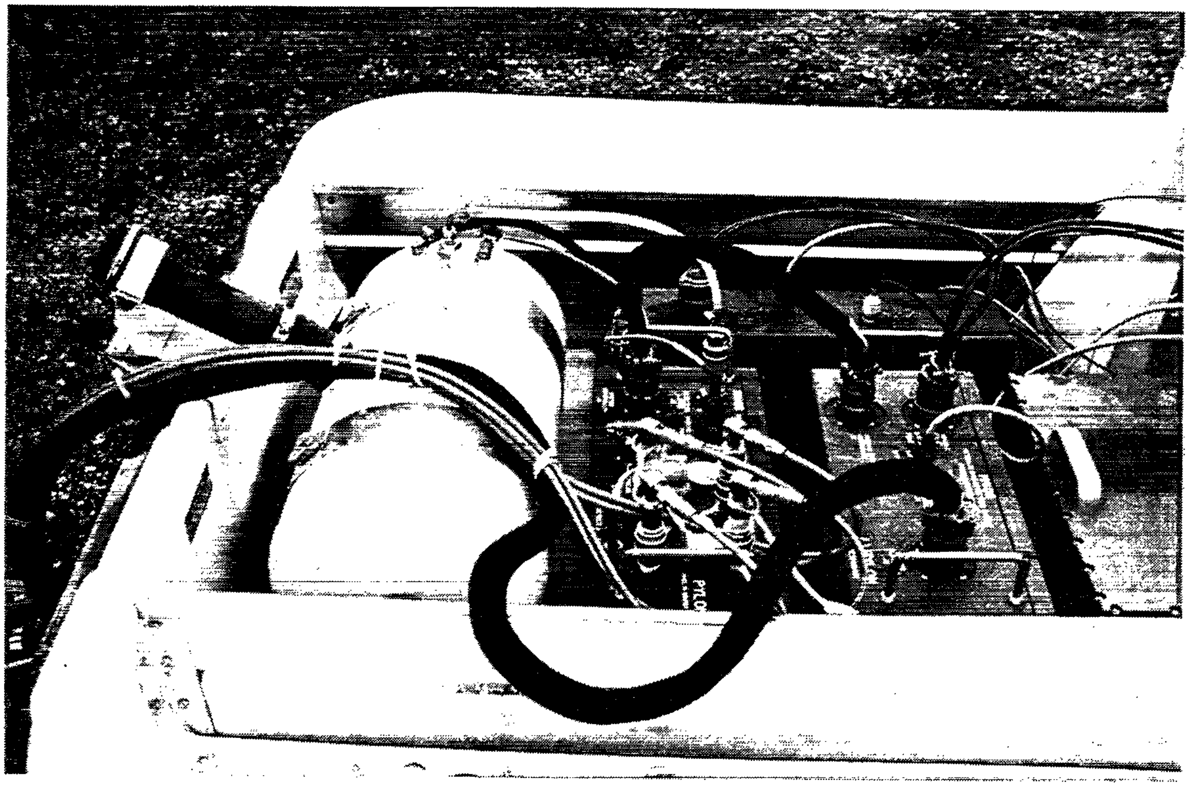

Figure 2. Remote vehicle electronics compartment

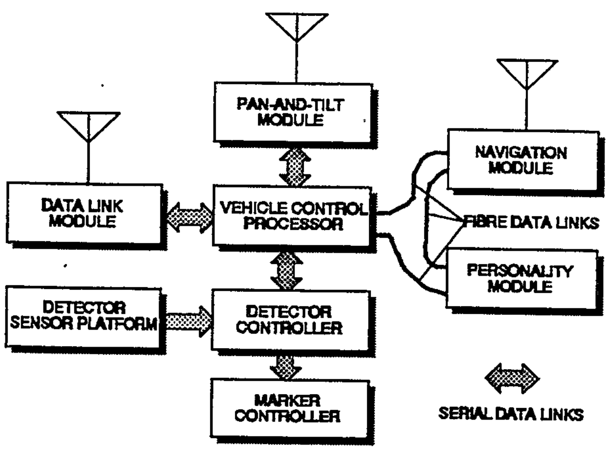

Figure 3. Remote vehicle electronics block diagram.

The Ancaeus remote vehicle hardware consists of five major modules plus the application modules, i.e., the mine detection and marking systems which were described above. The majority of the electronics package for the vehicle is carried in the rear cargo compartment of the ARGO. (Figure 2). This compartment was covered with a plastic shield to protect the contents from the direct rays of the sun and inclement weather. Interconnection between the various modules is by cables or fibre optic links when high data volumes must be passed. Twenty-four volt DC power is supplied to each module from storage batteries which are charged by a separate alternator on the ARGO vehicle engine.

Vehicle Control Processor Module

The vehicle control processor module functions as a network gateway between the control data link and the fibre optic data link. Higher level functions of the vehicle such as semi-autonomous navigation also reside in this module. The module is housed in a rugged, temperature controlled, weather proof enclosure. Temperature extremes are controlled by the use of a thermo-electric heat pump which provides heating or cooling as required. This controlled environment allowed the use of commercial grade components on the remote vehicle despite planned deployment to extremely hot or cold climates. DC to DC converters convert the 24 volt DC vehicle power to the required voltages for the on-board processors. The software for the vehicle control processor is written in "C" and speed critical routines have been written in assembler. The code resides in Erasable Programable Read Only Memory (EPROM).

Vehicle Personality Module

The Ancaeus concept makes maximum use of common modules in all its potential applications. A minimum number of changes to specific modules is all that is reqired to make an operating command and control system. The vehicle personality module was specifically designed for remotely controlling the ARGO vehicle. In the process it was "ruggedized" to endure the harsh environment of being mounted in the engine compartment of the vehicle and greatly simplified from previous versions to enhance reliability. The personality module controls all vehicle functions such as starting and stopping the engine, steering, cruise control, and braking. It also monitors the status of the vehicle by transmitting status reports on items such as engine temperature, charging current and voltage, vehicle speed, and other useful vehicle parameters. The cruise control feature was most useful in the Jingoss application because the operator could set an optimum search speed for the vehicle which would be accurately maintained without operator input. This allowed the operator to concentrate on the mine detection aspects rather than having to regulate vehicle speed. In actual operation, the driving consists mainly of simply guiding the vehicle down roads or across relatively smooth terrain.

Navigation Module

All functions associated with determining the position of the vehicle reside in the navigation module. The module uses a global positioning system (GPS) receiver to obtain navigational data from orbiting satellites. The GPS location data is accurate to a distance of approximately 75 metres and can be displayed in longitude/latitude or military grid reference format. This accuracy could be improved upon using differential GPS techniques; however, the main purpose of the GPS was to assist in the reporting of hazardous areas. The actual location of each mine would be marked as described above. The navigation module also contains a tilt and a roll sensor to alert the operator of a dangerous vehicle condition.

Data Link Module

The data link module contains the RF modem and RF amplifier. The data link communicates all guidance commands, status reports and detection data between the remote vehicle and the command vehicle. Sufficient power was provided in the Jingoss system for data and video transmission at distances up to 5 km. During the familiarization training and the development of clearance procedures it was found that a distance of approximately 200 metres was optimal. This allowed visual contact with the remote vehicle most of the time and allowed the command vehicle and personnel to remain outside the lethal radius of any ordnance that might be detonated.

Pan-and-Tilt Module

A pan-and-tilt unit fitted with a CCD colour video camera is the "eyes" of Jingoss. The upper head of the module will rapidly turn left and right 180 degrees to provide all-round vision for the operator. The head can be tilted up or down to view objects above or below the horizontal plane. The camera has a fixed wide angle lens and an aperture control which can be manually adjusted for varying light conditions. Two banks of flood and spot lights are supplied for night operation and supplement the vehicle headlights. The base of the pan-and-tilt module houses the video transmitter, cooling fans, and supports the video antenna. Immediately below the pan-and-tilt unit is a warning strobe light to indicate when the vehicle is operating under remote control.

Command Vehicle and Control Station

Virtually any vehicle can be used for the command vehicle. The only modifications required are: the provision of an inverter to change vehicle power to 110 volts AC; mounts for the video and data link antennas; space to mount the control station; and, room for the Jingoss operator. If the ambient temperature inside the vehicle is likely to exceed 40 degrees Celsius, air conditioning should be provided to keep the electronic equipment cool. The air conditioning would no doubt be appreciated by the personnel operating the system as well. The Canadian Forces have selected an eight-wheeled armoured personnel carrier known as the Bison for the command vehicle. This is due to the inherent protection offered by the vehicle's armour and the fact that it can transport a

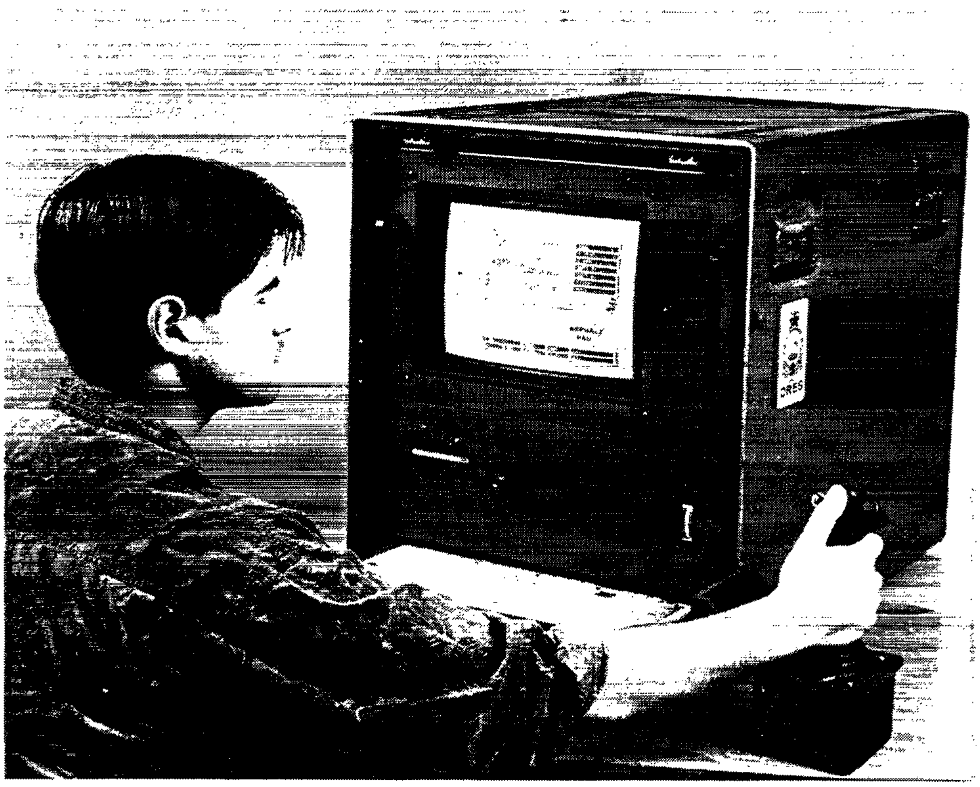

Figure 4. Control station

field engineer section together with the Jingoss system. The engineer section will provide the operators for the Jingoss as well as providing an immediate capability to investigate detections and deal with them as necessary.

The control station (Fig. 4) is shock-mounted in a durable weather resistant cabinet within the command vehicle. The components within the cabinet are modular and assembly is largely a matter of plugging in the appropriate module. The modular approach was taken to facilitate maintenance by the field engineers operators. All communication between the tele-operated vehicle and Jingoss operator takes place via the control station through a RF modem and a video receiver. The computer used has been configured with "ruggedized" components including the monitor, hard drive and keyboard. It has been equipped with the necessary video insertion hardware to provide a relatively sophisticated display for the operator. The operator observes the monitor which shows whatever displays he selects. He selects the displays by means of pull-down menus, keyboard inputs, or by pointing a cursor and selecting the appropriate icon on the computer screen. The vehicle steering, braking and acceleration are controlled by means of a sophisticated joystick. On the handle of the joystick control is a thumb-operated mini-joystick which controls the movement of the camera pan-and-tilt unit on the ARGO vehicle. An emergency stop button is located on the joystick handle and right and left mouse buttons are replicated by another button on the joystick handle and a joystick trigger respectively. Cursor movement on the monitor is done using a standard computer mouse or can be done using the joystick.

When the field engineers were being trained on the operation and maintenance of the Jingoss system, it was apparent that the operation of the vehicle was not going to present any problems. This was primarily due to the effort which was put into the "C" software to make it "user friendly" and convenient for the operator. With a minimum of practice, personnel became quite adept at the control of the vehicle and interpreting the data which was sent back from the detection system. The number of displays or data that the operator views on the monitor is at his discretion and can be arranged on the screen according to his personal preference.

Among the displays available to the operator are:

a. The view from the video camera mounted on the ARGO vehicle for remote operation of the vehicle. The camera can be rotated or tilted in whatever direction the operator desires.

b. A video-audio window which permits the operator to turn on and off the camera, spot and floodlights, and the audio microphone on the pan-and-tilt unit.

c. A vehicle system status window which provides the operator with information such as engine temperature, vehicle speed, transmission gear selected, engine RPM, fuel level, battery voltage and current, and vehicle pitch and roll. The real time location and heading of the vehicle are also displayed and continuously updated.

d. The mine detector control panel gives the operator complete control over the detection and marking systems mounted on the remote vehicle. He can turn the right and left lane markers on/off and adjust the interval between the marks. He can manually mark points on the ground in addition to the automatic marking of detections made by the system. The mine detector is calibrated during the initial start-up of the system and remotely recalibrated periodically to adjust for the background level of magnetic signal in a particular area. The recalibration takes approximately 15 seconds to perform. Sensitivity of the detectors can be adjusted to a high, medium or low level. The display will also indicate if the platform has separated from the remote vehicle when a solid obstacle triggers the release of the hitch to prevent damage to the detector platforms.

e. A graphic display is available for any detection received by the unit. Detections on the left or right coils are differentiated by different colours for the profile lines shown on the display. The slope and amplitude of the line displayed gives the operator a rough indication of the nature of the object detected.

f. A history panel can be called up to display a record of the detections and their location. This can also be printed out as a permanent record by the on-board printer.

g. The operator can call up a moving map display for the operational area that the system is operating within. The actual position of the vehicle and the vehicle heading is overlaid on the map display. The map data must be scanned onto floppy disks and loaded into the control station computer via a port on the front of the computer.

Introduction Into Service

A great number of factors had to be considered during the equipment development and production to permit its deployment to a harsh environment half-way around the world. Furthermore, the situation in Somalia would not permit sending DRES support personnel during the initial fielding of the equipment. Throughout the design and development, components were specified to the highest practical level for robustness and reliability. Some components were simply not available and additional protection was provided. A good example of this was the air conditioned enclosure provided for more fragile components on the remote vehicle.

The remote theatre of operations for the Jingoss system meant that many other precautions had to be taken to ensure equipment serviceability. The modular nature of the system allowed easy replacement of defective components in the field. Therefore a higher than normal scale of spare parts were to be provided. Defective components would have to be sent back to Canada for diagnosis and repair because the support agencies in Somalia were not trained or equipped to maintain most of the Jingoss components. As a general rule the crew of field engineers would be responsible for replacing components or sealed "black boxes" in the field and ensuring that an adequate stock of spares was maintained. To assist in the re-ordering of spares and repair parts an illustrated spare parts list was issued to the crew deployed with the equipment. Provision of this essential item was a real challenge because of the short time available and the many modifications being made to the system right up to the date of deployment. Similarly, operator manuals and aide memoirs were being written at the last minute to incorporate the knowledge and experience gained from the training of the CF engineer section who would be going to Somalia with the equipment.

The enthusiasm and professionalism of the field engineer personnel being trained on the Jingoss system was most appreciated by the people at DRES. They displayed a keen willingness to learn and a cooperative attitude which enabled the necessary knowledge and unfamiliar material to be digested in a minimum of time. The engineer trade is traditionally employed on tasks such as demolition and bridge building, and therefore much of the remotely operated hardware and electronic equipment was very new to them. In spite of this, their collective skills and experience were applied to the training and they became proficient operators and skilled at maintenance and repair of the unit in a very short time. In addition to this, the field engineer section of eight men developed and verified detailed operating procedures for the use of the equipment in an operational scenario. They produced a comprehensive aide memoir which included routine maintenance and servicing, daily inspections, equipment assembly, and troubleshooting charts for on-scene diagnosis and repair. Detailed procedures were developed for the handling of mines and other hazardous items which were detected by the system. During the practical exercises conducted as part of their training, data was collected on detection rates and how to maximize the productivity of the crew without jeopardizing personnel safety. Much of the enthusiasm displayed by the field engineers was the result of confidence gained in the reliability of detection of all of the dummy mines utilized during the training and the speed relative to existing methods using hand-held mine detectors.

Conclusion

There were many observations and conclusions derived from the Jingoss Project. Foremost was the fact that an operational need can generate the required impetus to field in a very short time a practical tele-operated system based on currently available technology. The existence of the VMOD and Ancaeus technologies in an advanced state of development greatly reduced the technical risk and the equipment design was sufficiently flexible to permit modification for use in the metallic mine detection application.

The Ancaeus system with its modular construction and inherent versatility was a key element in the rapid integration of the current overall system. Those characteristics permitted concurrent development of the many system modules which were then integrated rapidly as the project neared completion. The powerful capability of the Ancaeus system was never overloaded by the mine detection application and it exhibited considerable growth potential for add-on capability to the Jingoss system or use in other applications. Other applications being pursued at DRES include a hazardous material handling robotic vehicle, mobile target systems, and tele-operated anti-tank mines. The Jingoss equipment itself showed a potential for other uses such as a robotic reconnaissance vehicle and a detection system for unexploded ordnance in range or old battlefield clearance tasks. It is clear that simplistic tele-operated robotic systems are well within the capability of today's technology and can provide a valuable service in numerous military scenarios.

References

1. Das, Y., Toews, J.D., and McFee, J.E., "Vehicle Mounted Ordnance Locator: An Experimental Prototype (U)", Suffield Report No. 434, DRES, Ralston, Alberta, Canada, February 1988.

2. Das, Y., McFee, J.E., and Toews, J.D., "Development of a Vehicle Mounted Ordnance Detector (U)", Proceedings of the ABCA-5 Meeting, Toronto, Ontario, Canada, June 4-6, 1991.

3. Das, Y., Carruthers, A.R., Toews, J.D., McFee, J.E., and Elliott, J.R., "Remotely-Operated Metallic Mine Detector System (ROMMIDS) (U)", Presentation to the ABCA-5 Meeting, HMAS WATSON, Watsons Bay, Sydney, Australia, October 11-15, 1993.

4. Eirich, R., and Kramer, A., "A Generic Semi-Autonomous Ground Vehicle Control System", Proceedings of the 3rd Conference on Military Robotics Applications, Medicine Hat, Alberta, Canada, September 9-12, 1991.