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An Overview of the Accident Response Mobile Manipulation System (ARMMS)

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Abstract

The development of a high mobility platform integrated with high strength manipulation is under development at Sandia National Laboratories. The mobility platform used is a High Mobility Multipurpose Wheeled Vehicle (HMMWV). Manipulation is provided by two Titan 7F Schilling manipulators integrated onboard the HMMWV. The current state of development is described and future plans are discussed.

Background

The need for a telerobotic vehicle with integral manipulation capabilities has been identified for use in transportation accidents where nuclear weapons, hazardous chemicals, hazardous wastes, etc., are involved. Realistic accident scenarios of this type are highly unstructured and may engage terrain requiring significant mobility to reach the accident site and require the vehicle to have ample payload capabilities. Although there are Unmanned Ground Vehicles (UGV) with integral manipulation, none exist with the desired off road stability and payload capabilities in conjunction with the high strength manipulation necessary to perform salvage and recovery operations at hazardous accident sites [1]-[10].

The ARMMS (Accident Response Mobile Manipulation System) vehicle is presently under development in support of the Accident Response Group (ARG) at Sandia National Laboratories. ARMMS primary mission is to support ARG salvage operations; roles such as research utilization and new technology integration are strictly secondary. ARMMS' mission priorities have driven its design to address

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environmental conditions, reliability, and maintainability. These primary design concerns are evidenced by the system design described herein.

The ARMMS' base vehicle platform is the High Mobility Multipurpose Wheeled Vehicle (HMMWV) configured for a two man crew with an open bed, and is also fully actuated for teleoperation. ARMMS is equipped with two high strength Schilling Titan 7F manipulators [11] as shown in Figure 1. The design for the hydraulic system includes, mechanical interface hardware, vehicle platform control system, and the advanced remote portable driving station.

Figure 1. ARMS at F-4 Wreckage Site

Hydraulic System

The ARMMS hydraulic system provides both 1500 psi fluid for steering control and 3000 psi, 6 gpm, fluid for the Schilling manipulators. The hydraulic system schematic is shown in Figure 2. The system uses a pressure compensated variable displacement pump rated at 3000 psi, and 19 gpm at 1800 RPM. The pump is driven off the HMMWV engine through a jack shaft pulley and electric clutch configuration. As configured the hydraulic system provides required fluid and pressure across the entire spectrum of engine RPMs. Because required fluid and pressure is available independent of engine RPM, concurrent vehicle movement and manipulator operation is possible. The ARMMS hydraulic system provides significant flexibility as is illustrated by the various possible operational modes: (1) manual onboard local control with manipulators non-operational, (2) manual onboard local control with the manipulators operational, (3) teleoperation with the manipulators non-operational, and (4) teleoperation with the manipulators operational.

3000 psi fluid is plumbed both forward and aft enabling multiple manipulator configurations, e.g., two arms front, two arms aft, one arm front and aft, two arms front and aft, etc. Fluid is teed off the 3000 psi system and reduced to 1500 psi for steering control eliminating the need to modify the HUMMV's existing power steering hydraulic system. A Hydro-Line hydraulic cylinder is connected to the HMMWV steering linkage to provide steering actuation. Fluid to the steering cylinder is controlled by a Vickers proportional valve with integral electronics designed to provide dead band compensation, spool dither, and solenoid preamplifiers.

The hydraulic system is notably absent of an accumulator and associated dump valve that are typically included in a system such as this. The effects of dual and single manipulator operation with and with out an accumulator has been studied by Sandia. It was observed that the pressure compensated pump's dynamic response was sufficient to meet varying manipulator fluid demands to a degree that the effects of an accumulator in the system was unnoticeable. This provided the operational basis for not including an accumulator in the ARMS system which saved considerable space, reduced part count, and eliminated accumulator gas charging concerns.

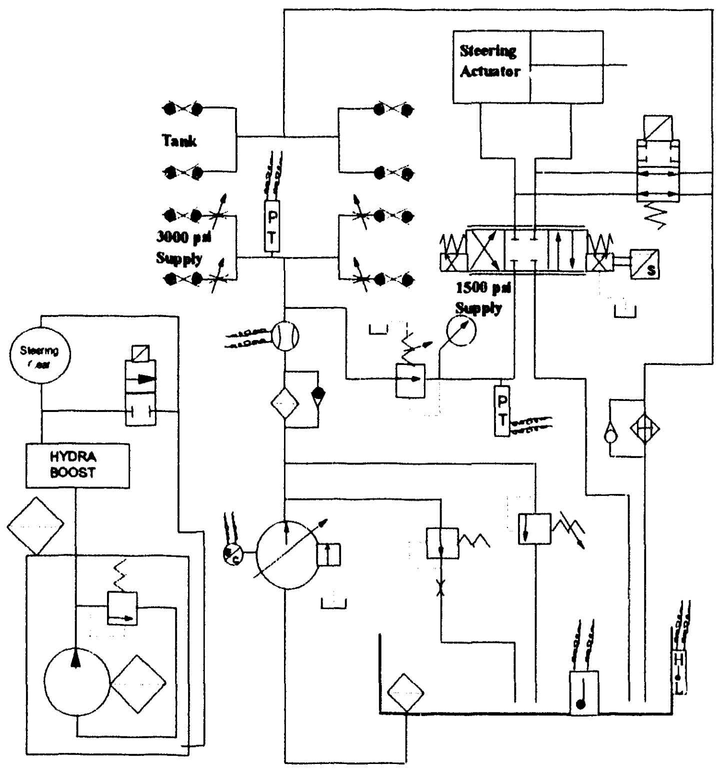

Figure 2. ARMMS Hydraulic System

Manipulator Base Platform

The manipulators are secured to the HMMWV by an enclosed square aluminum tube mounting platform weighing approximately 130 pounds. The platform provides five possible mounting positions to maximize operational flexibility. Unused mounting positions are covered with bolted on pad eyes to facilitate rigging operations. The platforms design not only provides structural rigidity but also convenient packaging for the manipulator slave controllers, hydraulic solenoid isolation valves, hydraulic filters and outrigger electronic controls. The platform has a removable front face plate permitting easy access to its contents. The platform is affixed to the HMMWV's frame by bolt-on brackets. Additional mounting brackets are quickly interchangeable allowing rapid in-field reconfigurations for both front and rear mounting.

Incorporated with the manipulator mounting platform are outriggers located on both ends. These outriggers allow for the stabilization of ARMMS during precision or other operations requiring the vehicle's suspension to be isolated.

Arms Vehicle Control System

The ARMMS' vehicle control system consists of six basic functional subsystems: (1) closed-loop actuator control, (2) open-loop control, (3) sensory data acquisition, (4) Supervisory Control Computer (SCC), (5) manipulator slave control, and (6) communications. A block diagram of the ARMMS control system is shown in Figure 3.

A dedicated DSP board is used for low level closed-loop servo actuator control realization. The DSP implements a PID position control loop for each actuator at a sampling frequency of 2K Hz. The Supervisory Control Computer (SCC) transmits command positions into the DSP via dual ported RAM over the STD-32 bus. Vehicle actuators include: Warner Eltrack-1 24Vdc linear actuators series for brake, throttle, transmission, and transfer case actuation; Vickers proportional valve KA series for steering actuation; and Pan/Tilt dc brush type servo motors. Position feedback for the linear actuators and hydraulic steering control is by precision resistive potentiometers.

Open-loop control activities are coordinated by the SCC through optically isolated relays. These on/off functions include control of the fuel pump, starter, electric clutch, and hydraulic steering tank dump valves.

Sensory data acquisition includes thermal couple devices for engine temperature and alternator temperature, pulse trains for RPM and speed, and analog voltage signals for the 1500 and 3000 psi hydraulic pressure, hydraulic flow rate, reservoir temperature and level, and engine oil pressure. Dedicated data acquisition devices have been configured for analog to digital signal conversion, thermocouple temperature conversion, and pulse train frequency conversion. The SCC has direct access to this registered data over the STD-32 bus.

Communications to and from the vehicle is by RF data modems at 9600 baud full duplex or fiber optic tether. In accidents involving nuclear weapons or any explosive devices RF transmission are not permitted.

The entire SCC hardware exists in a NEMA 12 enclosure that is 16 inches wide, 6 inches high, and 10 inches deep. It has a 24 slot STD 32 bus card cage containing: a Ziatech 8902 486 33 MHz with 8 meg of RAM; a Motion Engineering Inc. 8 channel Std Bus DSP control board; a WinSystem's LPM-COM4 providing the system with four additional RS-232 COM ports (six total); a Ziatech 8921 PCMCIA card; three APIX I/O Std Bus Card Carriers containing digital I/O, A/D, thermocouple, and counter modules; a Ziatech 8842 LCD display board; four Advance Motion Control Std Bus cards each containing two 10A8 PWM preamps; and a custom designed Std Bus emergency kill relay card.

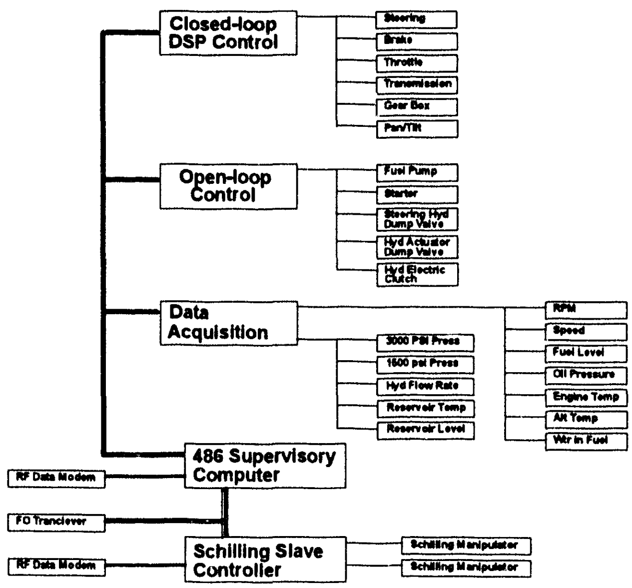

Figure 3. ARMMS Vehicle Control System

Advanced Remote Control Station (ARCS)

The design of the ARCS for the ARMMS was based on the need for field portability. The equipment selected is primarily small profile equipment that has low power requirements. Also, it is likely that the vehicle will have to be maneuvered in tight quarters around accident debris, and because manipulators will require good visual perception, stereo vision is a requirement of the ARCS. Functionally, the ARCS will accept user inputs of: steering, throttle, brake, gear, transfer case, camera pan, camera tilt, engine start/kill, system kill, voice command, and manipulator arm commands. The outputs are stereo vision for driving and manipulation, and audio (both voice and sound). The vehicle control inputs will be via a small handle bar type unit. Manipulator input hardware is yet to be determined, but will likely be a strapped on anthropomorphic mechanism that tracks the motions of the arm joints. Figure 4. illustrates the ARCS.

Most of the electronics and the processor for the ARCS are PC/104 format. This format allows compact implementation of the PC bus and software. PC/104 units require only 5 VDC and have low power requirements. The individual board are 3.6 " X 3.8 ", and each board stacks on the header of the previous board. Therefore, most of the ARCS electronics will fit inside an enclosure approximately 6 inches on a side. The electronics will consist of a 486 processor, a data module board (containing A/D, D/A, and parallel I/O), a voice module board, and a hard disk (that may be removed following development).

The video is typically either large and power hungry (CRTs), or is still large and less power hungry (LCDs). Regular CRTs were unacceptable because of their size, weight, and power requirements. LCDs are unacceptable because in bright light the display washes out and also, to be usable their size would also have to be rather large. The choice was made to use a Head Mounted Display. Many of these HMDs have been recently developed for virtual reality research and games. The HMD selected uses two small CRT mounted in front of the eyes on an open frame similar to a hard hat frame. The unit weighs 28 ounces and consumes 3.75 watts. Stereo earphones are mounted on the frame and a microphone will be added for the voice functions.

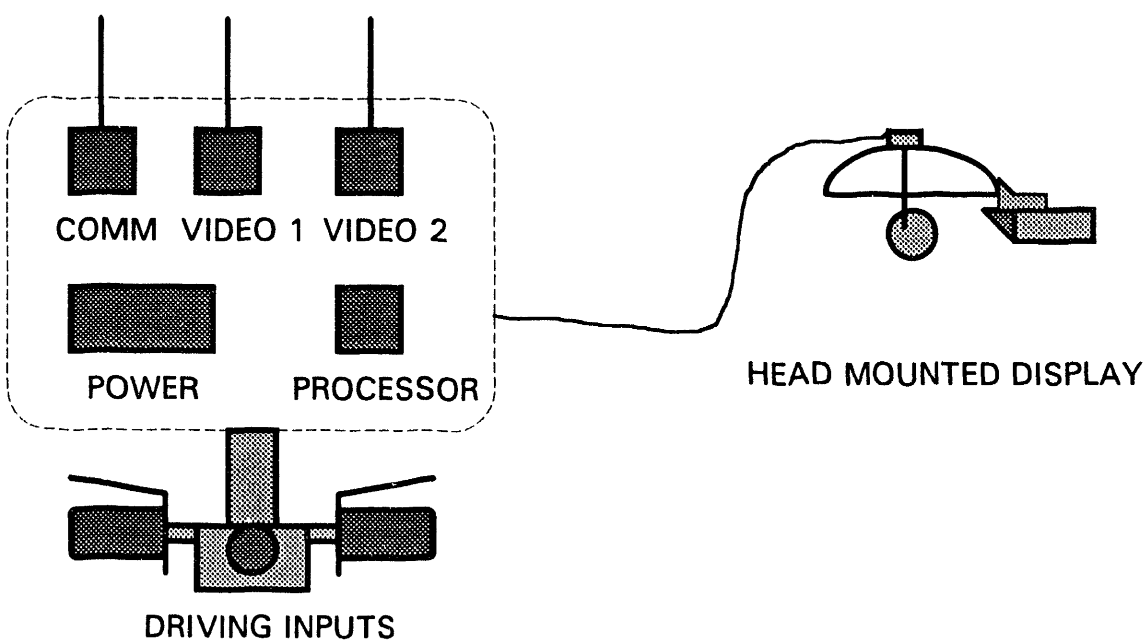

Figure 4. Advanced Remote Control Station

Future Plans

Future plans for Arms include: the implementation of coordinated vehicle and manipulator control; upgrading to Schilling Titan 2s, upgrading to Schilling's bilateral force reflective feed back and eventually to the full blown Advanced Telerobotic Controller (ATC), differential GPS location and attitude system.

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