White Paper

INTELLIGENT VEHICLE TECHNOLOGY TRANSFER

By

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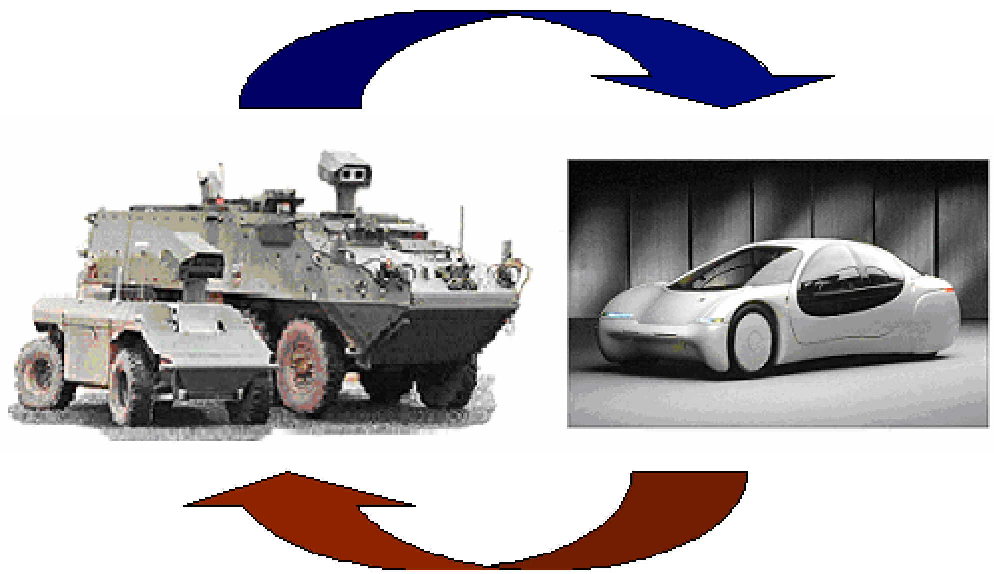

November 2005

BACKGROUND

The U.S. **Office of the Secretary of Defense**, Joint Robotics Program, has supported the development of a process for intelligent vehicle technology transfer since 2003. In 2005, an initial summer Workshop was followed in the fall by the first Conference on Intelligent Vehicle Technology Transfer Conference, which was also supported by the U.S. **Department of Transportation** Intelligent Transportation Systems Joint Program Office (DOT ITS JPO) and the Intelligent Systems Division of the U.S. **National Institute of Standards and Technology** (ISD NIST), and was hosted by the U.S. **Army Tank Automotive Research, Development and Engineering Center** (TARDEC). During 2006, a **website** for intelligent vehicle technology transfer will be inaugurated and additional workshops and conferences will be held. **Robotic Technology Inc.** initiated the concept for the Intelligent Vehicle Technology Transfer Process and was tasked to support **OSD** in accomplishing its objectives**.**

MOTIVATION

The Department of Defense (DOD) and the Department of Transportation (DOT) are both supporting the development of what are known as ***intelligent* vehicles**. The **DOD** intends to deploy a variety of autonomous intelligent vehicles (robots) to **reduce human casualties** on the battlefield and **increase the global combat efficiency and effectiveness** of the U.S. military against conventional and unconventional forces. The **DOT** supports intelligent vehicle technology to **reduce human casualties** on the nation's highways and increase the **efficiency and effectiveness of the U.S. transportation system**. The military's rapid progress in intelligent vehicle technology can directly benefit the commercial development of intelligent cars, trucks, and buses, reducing time and expense for the automotive industry. Conversely, technology transferred from the commercial sector to DOD, and its industry contractors, will reduce the cost and increase the availability of commercial-off-the-shelf (COTS) intelligent vehicle systems and components for military services. Society as a whole will benefit from the **mutual technology transfer** between the military and commercial sectors.

A **formal process** for sharing – and leveraging – intelligent vehicle technology between DOD (and its stakeholders) and DOT (and its stakeholders) will facilitate the advent of intelligent vehicles, a **quickly emerging technology**, which offers enormous potential benefits for the military and civil sectors alike in the 21st century. The **objective** of the first conference, which followed a successful initial workshop held during July 2005 at NIST, was to provide a foundation and framework for establishing a **technology transfer process** that will be useful for the development of intelligent vehicles for **military and civilian applications and markets.**

DOD INTELLIGENT VEHICLE TECHNOLOGY AND PROGRAMS

Advanced intelligent vehicle technology which the DOD can transfer to DOT includes:

- **Control Systems**
- **Sensor Systems**
- **Mobility Systems**
- **Interface Systems**

The **intelligent vehicle control systems** encompass: the control system architecture, sensory perception and situation awareness, software, databases and world modeling, communications internal and external to the vehicle, vehicle mobility, and the architecture of the computer hardware. The resulting behavior of the intelligent vehicle includes such abilities as: situation awareness; collision detection and avoidance; route planning; task decomposition; lane-following; and sign and obstacle detection. The **control system architecture** provides the **framework** for the vehicle's **"intelligence."**

The major elements of a robotic vehicle's **sensor system** are its **internal and external sensors**, the **processing** needed to extract information from the sensors which can be used by the intelligent vehicle, and the architecture of the sensor system. **Sensory perception** is the ability to fully understand the object that is sensed in the context of the situation and environment. Perception in intelligent vehicles depends on the sensors, sensor processors, and intelligent control system architecture.

Intelligent vehicles may be based on conventional vehicle platform **mobility design** (chassis, engine, transmission, etc.), or they may incorporate **"intelligent mobility"** concepts where the inherent design (intrinsic, physical mobility assets) of the vehicle allows it to move well (especially in an unstructured, off-road environment) without the need for excessive active participation of the intelligent control system.

The **interface** between the intelligent vehicle and the human consists of **controls and displays**, as well as the **attentions** to the vehicle which must be paid by people over its lifetime: testing, maintenance, and support. People associated with the robot must be trained in its operation, maintenance, and repair. The communications system (command, control, and data links, antennas, transmitters, receivers, power supplies, computers, signal processing, etc.) is also an interface system.

The DOD is supporting the development of a number of intelligent ground vehicles through several **intelligent vehicle programs**, including the **Joint Robotics Program (JRP)**, including the **Future Combat System** (FCS) Program and programs supported by the Defense Advanced Research Projects Agency (DARPA), and other agencies. The DOD programs are developing and fielding first-generation unmanned ground vehicles with current technologies while pursuing advanced technologies critical to autonomous vehicles that can be inserted into first generation vehicles in an evolutionary manner, to be followed by second generation intelligent, autonomous vehicles. The JRP is currently developing **22 distinct intelligent vehicle systems** across a variety of weight classes, from less than 8 pounds (micro) to more than 30,000 pounds (large). DOD expects **vehicle intelligence** to be sufficient for **complete autonomy** to be achieved by 2020, whereupon human intervention required for the vehicles to perform their missions will approach zero. Well before 2020 – perhaps as soon as 2010 – DOD expects vehicles to possess an appreciable level of **intelligent autonomy**.

The **JRP Coordinator** supports the development of intelligent vehicle technology and systems in a **multiplicity of DOD agencies**, including:

- Joint Architecture for Unmanned Systems (JAUS)

- US Army Product Manager Force Protection Systems
- US Army Aviation & Missile Research, Development & Engineering Center
- Robotic Systems Joint Project Office (Army/Marine Corps)
- Agile Combat Support (USAF AAC/YBC)
- Air Force Research Lab (Robotics Group)
- Space & Naval Warfare (SPAWAR) Systems Center (Navy)
- Program Management Office for EOD Robotics (Navy)
- US Army Research, Development & Engineering Command (RDECOM) Tank Automotive Research, Development & Engineering Center (TARDEC)

The robotics **Technology/Tech Base** consists of:

- DARPA
- Army Research Lab (ARL)
- Special Operations Command (SOCOM)
- Military R&D Centers
- Academia
- Product Manager for Robotic & Unmanned Sensors (PM-RUS);
- National Center for Defense Robotics (NCDR)
- National Unmanned Systems Experimental Environment (NUSE2)
- Advanced Concept Technology Demonstrations (ACTD)
- Office of Naval Research (ONR)
- Army RDECOM Simulation Training Technology Center (STTC)

Examples of intelligent vehicle systems under development or completed by **DOD agencies** include:

- **Robotic Systems Joint Project Office**
  - Common Robotic System (CRS)/Panther
  - Robotic Combat Support System
  - Tactical Unmanned Ground Vehicle (TUGV)
  - Future Combat System Unmanned Ground Vehicles

- **Air Force Research Laboratory (Robotics Group)**
  - Robotics for Agile Combat Support (RACS)
  - Advanced Robotic Systems (ARS)
  - Next Generation EOD Remote Controlled Vehicle (NGEODRCV)
  - Remote Detection, Challenge, and Response System (REDCAR)

- **Program Management Office for EOD (Navy)**
  - Remote Ordnance Neutralization System (RONS)
  - Explosive Ordnance Device, Man-Transportable Robotic System (EOD MTRS)

- **US Army Tank Automotive Research, Development and Engineering Center (TARDEC)**
  - Intelligent Mobility

- Crew Integration and Automation Testbed (CAT) Advanced Technology Demonstration (ATD)
- Armed Robotic Vehicle (ARV) Robotic Technologies (ART) Army Technology Objective (ATO)
- Robotic Follower (RF) ATD
- Human-Robot Interaction (HRI) ATO

☞ **Space and Naval Warfare Systems Center (SPAWAR)**
- Mobile Robot Knowledge Base (MRKB)
- Robotic Systems Pool (RSP)
- Novel Unmanned Ground Vehicle

☞ **Air Armament Center Agile Combat Support (AAC/YBC) Program Office**
- All-purpose Remote Transport System (ARTS)

☞ **Product Manager, Force Protection Systems**
- Mobile Detection Assessment Response System (MDARS)

☞ **Aviation and Missile Research, Development & Engineering Center (AMRDEC)**
- Joint Architecture for Unmanned Systems (JAUS)
- Cooperative Unmanned Ground Attack Robot (COUGAR)
- Collaborative Robotics Operations Initiative

☞ **Defense Advanced Research Projects Agency (DARPA)**
- Perception for Off-Road Robotics (PerceptOR)
- Unmanned Ground Combat Vehicle (UGCV)
- Learning Applied to Ground Robots (LAGR)

☞ **Product Manager, Robotic and Unmanned Sensors**
- Tactical Unmanned Vehicle Payloads
- FCS Unmanned Systems Sensors
- Remote Battlefield Sensor System (REMBASS) II and Ground Surveillance Radar (GSR)

☞ **Army Research Laboratory (ARL)**
- DEMO III (Experimental Unmanned Ground Vehicle (XUV))
- Semi-Autonomous Robotics for FCS
- Robotic Collaborative Technology Alliance (CTA)

DOT INTELLIGENT VEHICLE TECHNOLOGIES

The **DOT's vision for intelligent vehicles** is a system involving roads, vehicles, and drivers, where drivers:

- Operate in a significantly **safer** environment

- Enjoy **greater mobility and efficiency** as a result of the widespread use of vehicle-based autonomous and infrastructure-cooperative ***driving assistance*** features

DOT predicts that the widespread deployment of advanced **driver assistance** systems can significantly reduce motor vehicle crashes. Each year more than **41,000 Americans die** as a result of about **6 million crashes** – the equivalent of 115 each day, or one every 13 minutes. While the magnitude of the highway death toll is shocking, the impact of highway injuries is even greater. Traffic crashes injure more than 3.2 million Americans per year, with crash survivors often sustaining multiple injuries and requiring long hospitalizations. Crashes cost the U.S. economy more than **$230 billion a year** and consume a greater share of national health care costs than any other cause of illness or injury. While new technology offers potential safety solutions, it also poses new problems - some in-vehicle technology may become a dangerous distraction to drivers. The National Highway Traffic Safety Administration (NHTSA) estimates that **driver inattention**, from all sources, causes 20 to 30 percent of the 6.3 million accidents per year.

Because **driver error** remains the leading cause of crashes, cited in more than 90 percent of police crash reports, the intelligent vehicle mission is to reduce the number and severity of crashes through driver assistance systems. These safety systems, now in various stages of development, assume *partial control* of vehicles to avoid collisions. The focus on ***preventing*** crashes, by helping drivers avoid hazardous mistakes, is a significant new direction for DOT safety programs; in the past the primary focus was on crash ***mitigation*** (i.e., alleviating the severity of crash-related injury to persons and property).

The current DOT intelligent vehicle vision **does not encompass fully autonomous vehicles** – only **driver assistance systems**. Driver assistance systems warn drivers of danger or, in more advanced versions, intervene to prevent or mitigate accidents (e.g., intermittent automated braking or steering). They can save lives. But the technology transfer between DOD and DOT should include consideration of the technical, economical, and social issues concerning ultimate autonomy for cars, trucks, and buses, just as the military intends for combat vehicles. In a future **civil version** of the military's autonomous vehicles, the commuter will be able to enter his or her car at home, tell it the destination, have it proceed to the destination (while the owner reads, talks on the phone, works on the computer, sleeps, or watches videos), and then park itself. The "built-in chauffeur" will be **safer** and **more efficient** than a human driver. Also, the increasing millions of baby boomers who will soon transform into infirm elderly and lose their driving privileges will gain the freedom to travel in their own cars without the debilitating dependence on others.

A **technology transfer** between DOD and DOT would cover the spectrum of interim technology for driver assistance and semi-autonomy, as well as advanced technology for full autonomy. **Autonomous ground vehicles** have been successfully demonstrated many times – but in constrained circumstances. They can travel at high speed on roads with light traffic. They can stay in a lane, or safely change lanes to pass slower vehicles (checking traffic in the adjacent lane before doing so). They can travel off-road, over rough terrain and through vegetation, day or night. As part of the Future Combat System (FCS), the DOD intends to field autonomous ground vehicles within the decade. However, autonomous vehicles cannot yet deal with the complexity of intersections, traffic, and pedestrians, whether of Times Square or downtown Istanbul.

Since the 1990 initiation of the DOT's Intelligent Transportation System Program, there has been remarkable progress in commercializing advanced technology in the nation's vehicles and transportation system. Some of the technology, like the Global Positioning System (GPS) and infrared sensors, originated with the DOD. **Current** and **near-term commercially-feasible intelligent vehicle technology** (which largely did not exist at the start of ITS in 1990) includes:

- **GPS navigation & automated crash notification**
- **Fleet management system**
- **Adaptive cruise control**
- **Crash warning and automated crash avoidance**
- **Near object detection system (back-up object detection)**
- **Lane change warning**
- **Automated lane tracking**
- **Driver distraction and drowsiness detection and mitigation**
- **Head-up displays**
- **Road-departure crash warning**
- **Rollover prevention**
- **Haptic driver warning cues**
- **Automated bus systems**
- **Intersection collision countermeasures (vehicles and pedestrians)**
- **Night vision**
- **Travel and service information**
- **Electronic weighing and inspection**
- **Traffic management systems**
- **Public transit enhancements**
- **Toll collection**

TECHNOLOGY TRANSFER PROCESS

Technology is the **totality of the means** employed to provide objects necessary for human sustenance and comfort. It consists of **products and processes** and encompasses **technical and managerial knowledge** which is embodied in **physical and human capital** and in **published information** and is **transmitted in various ways.**

The **technology transfer process**, however designed, must be **mutually beneficial** between DOD and DOT and their stakeholders, such that DOT gains **advanced** technology while DOD gains **affordable** technology. The **technology transfer process** must be: established from the top down and bottom up; made permanent and continuous; designed to be simple and robust; supported mutually and beneficially for all stakeholders.