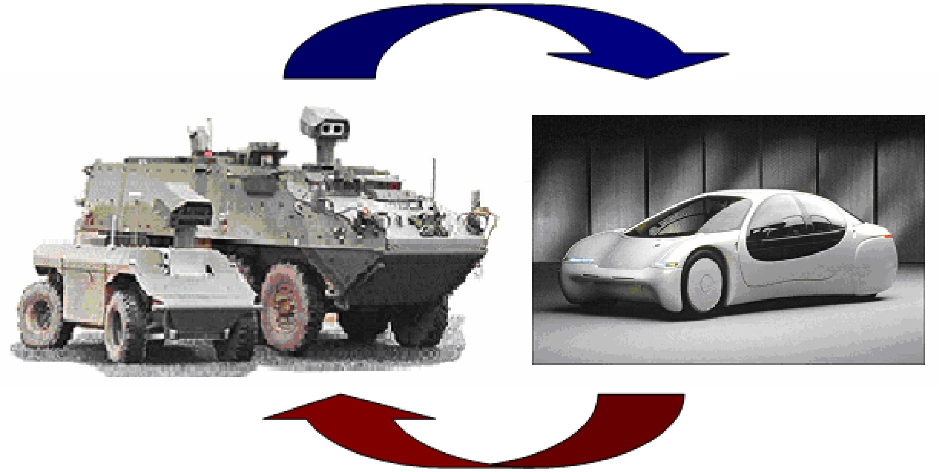
OVERVIEW:
INTELLIGENT VEHICLE TECHNOLOGY TRANSFER
Third Joint Military/Civilian Conference on Intelligent Vehicle Technology Transfer

Sponsored By: DOD Space and Naval Warfare Systems Center
Supported By: DOT Intelligent Transportation System Joint Program Office; Army Tank Automotive Research, Development, and Engineering Center; Association for Unmanned Vehicles International; and the Intelligent Transportation Society of America
Hosted By: DOC National Institute of Standards & Technology (Intelligent Systems Division)

13 February 2008

Presented By: Dr. Robert Finkelstein, President
Robotic Technology Inc.



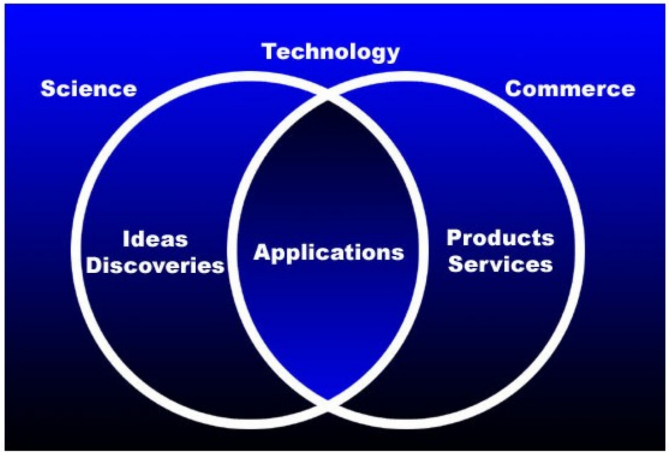
PURPOSE OF THE IVTT

To Facilitate Technology Transfer:

- To save lives
  - On the battlefield
  - On the roads and highways
- To save money
  - On systems and infrastructure
- To ease the emergence of a transformational (disruptive) technology
  - Which will impact military tactics, strategy, and doctrine
  - Which will impact the automotive industry and society in general
  - Which will lead to new systems and enterprise

OBJECTIVE OF THE IVTT

- Establish an intelligent vehicle technology transfer program
  - Among DOD and its stakeholders (government agencies, laboratories, industry, academia)
  - Among DOT and its stakeholders (government agencies, laboratories, industry, academia)
  - Among other agencies (NASA, DOE)
- Solicit ideas and approaches for the technology transfer program
- Determine key issues
- Develop a core constituency of participants
- Develop forums for technology transfer

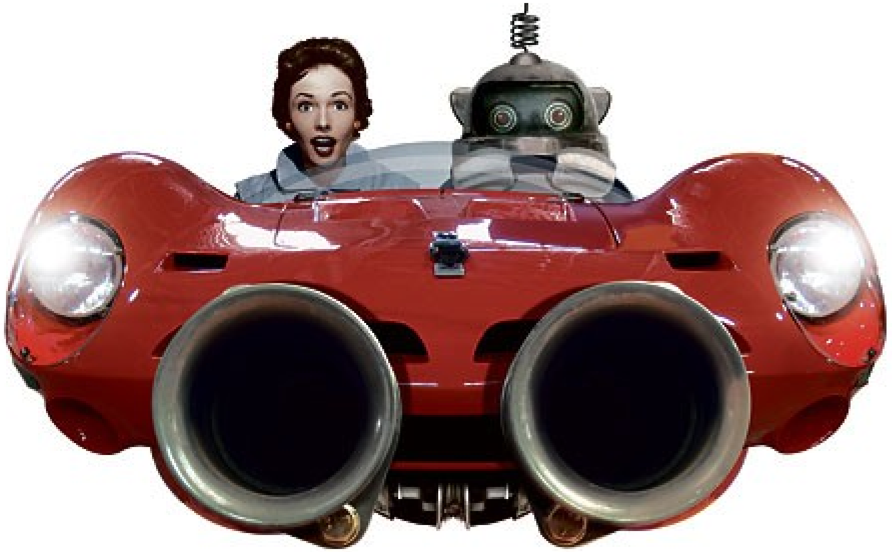


THINGS ARE CHANGING RAPIDLY

- The ground war in Iraq and Afghanistan sorely needs intelligent combat vehicles
  - RSTA/Intelligence
  - The U.S. force is wearing out: insufficient quantity, excessive deployments, continued casualties
  - UAVs proven valuable; UGVs will also prove valuable
- U.S. auto industry suffered in 2007
  - For first time, Toyota sold more cars in U.S. than Ford and worldwide than GM
  - GM had largest annual loss in automotive history ($38.7 billion)
  - Chrysler booted from Daimler
  - New global competitors (e.g., India)
- Disruptive technologies emerging
  - Energy
  - Electronics
  - Ergonomics

AUTOMOTIVE INDUSTRY: AWAKENING

- GM on Team which won the DARP Urban Challenge
  - Larry Burns, GM's Vice-President for R&D and strategic planning, said that developing cars that drive themselves is a key objective, where erstwhile drivers could talk on the phone, eat breakfast, handle emails, and leave the driving to the vehicle – and the cars won't crash
  - VP Burns believes that cars with that level of intelligence could be on the road by 2015 (GM Chairman/CEO is also a proponent)
  - Sebastian Thrun, computer scientist at Stanford (which placed first and second in the two DARPA challenges), said that within five years autonomous cars will be feasible (working reliably in several limited domains)

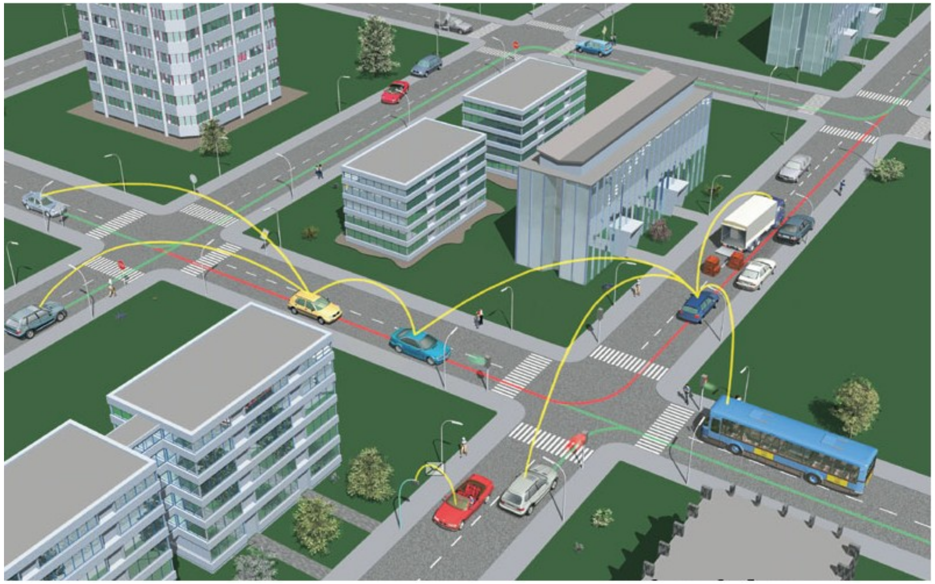


BACKGROUND

- Department of Defense (DOD) and Department of Transportation (DOT) both supporting development of **intelligent vehicles**
- DOD deploying a variety of **autonomous intelligent vehicles** (robots)
  - To **reduce human casualties** on the battlefield
  - Increase the global **combat efficiency and effectiveness** of the U.S. military against conventional and unconventional forces
- DOT supports **intelligent vehicle technology**
  - To **reduce human casualties** on the nation's highways
  - Increase the **efficiency and effectiveness** of the U.S. transportation system

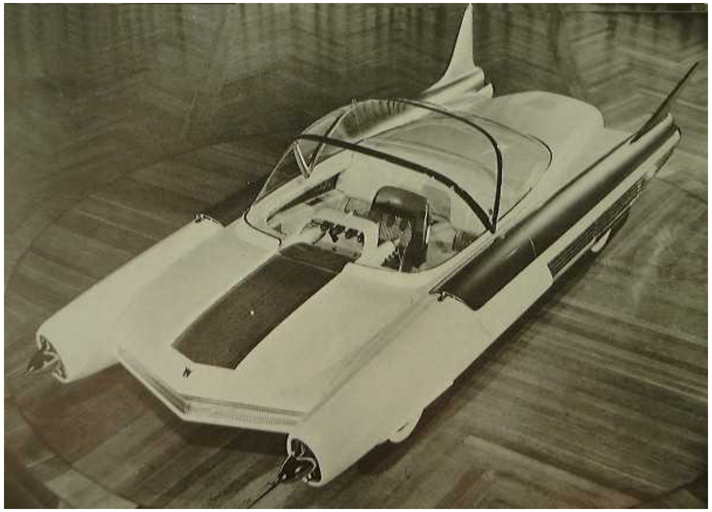
BACKGROUND

- DOD's rapid progress in intelligent vehicle technology can directly benefit the commercial development of intelligent cars, trucks, and buses
  - Reduce time and expense for the automotive industry
- Technology transferred from DOT and commercial sector to DOD and DOD contractors will reduce the cost and increase the availability of commercial-off-the-shelf (COTS) intelligent vehicle systems and components for military services



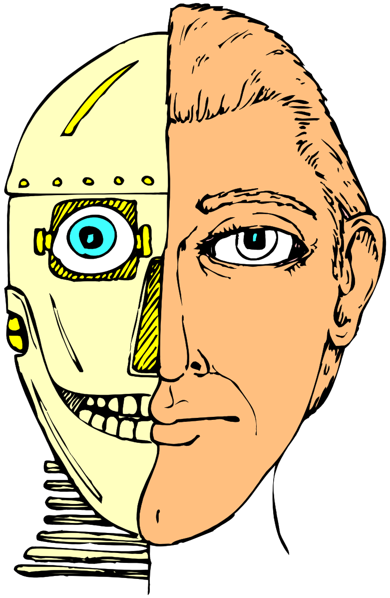
BACKGROUND

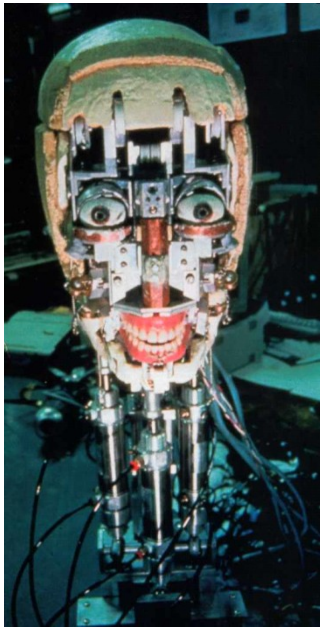
- Benefit of **mutual technology transfer**, between the military and commercial sectors, exemplified by computer technology
  - Expensive military computer technology became **faster, better, cheaper** – and **ubiquitous** – after **commercialization**
- A **formal process for sharing and leveraging** intelligent vehicle technology between **DOD** (and its stakeholders) and **DOT** (and its stakeholders)
  - **Will facilitate advent of intelligent vehicles**
- Intelligent Vehicle Technology:
  - **Quickly emerging disruptive technology offering enormous potential benefits for the military and civil sectors alike**

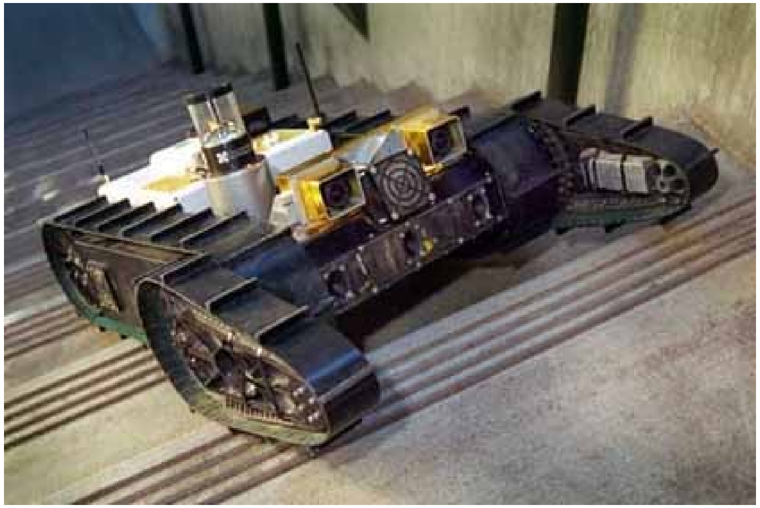


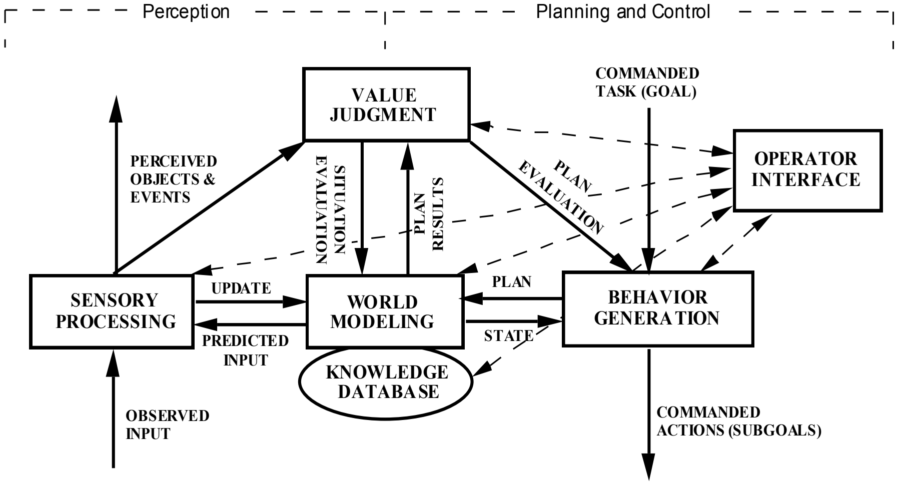
DOD INTELLIGENT VEHICLE TECHNOLOGIES

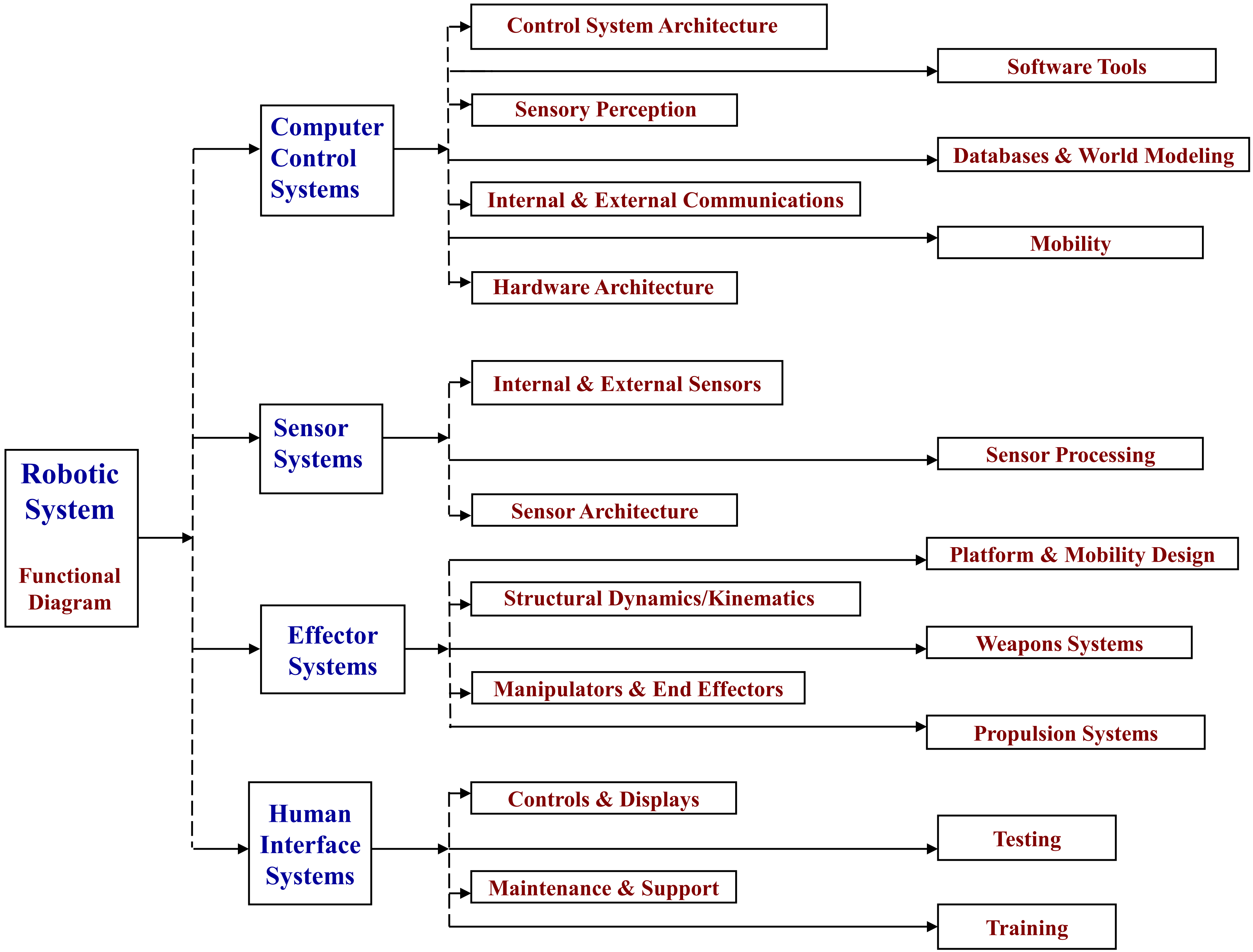
- Advanced intelligent vehicle technology which DOD can transfer to DOT includes:
  - Control Systems
  - Sensor Systems
  - Mobility Systems
  - Interface Systems









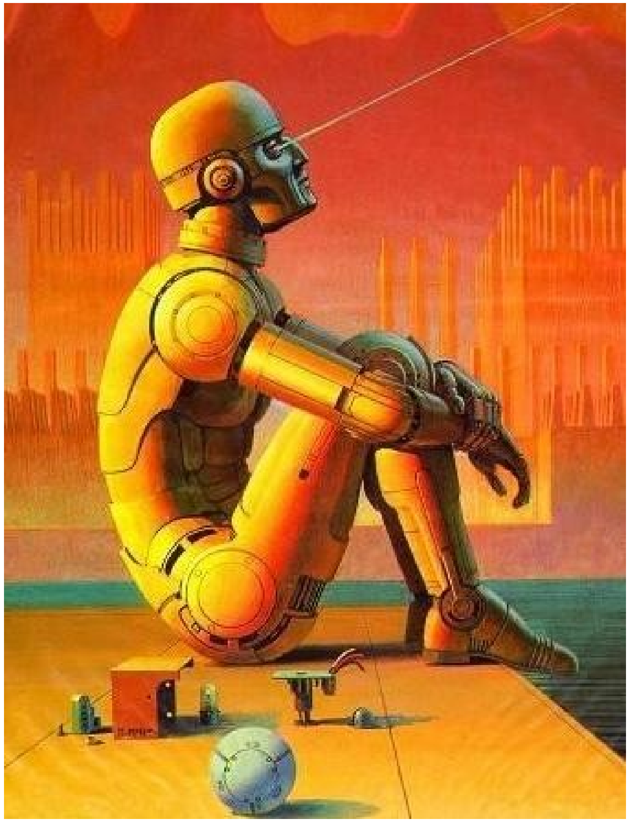

Robotic System
Functional Diagram
Computer Control Systems
Control System Architecture
Software Tools
Sensory Perception
Databases & World Modeling
Internal & External Communications
Mobility
Hardware Architecture
Sensor Systems
Internal & External Sensors
Sensor Processing
Sensor Architecture
Effector Systems
Platform & Mobility Design
Structural Dynamics/Kinematics
Weapons Systems
Manipulators & End Effectors
Propulsion Systems
Human Interface Systems
Controls & Displays
Testing
Maintenance & Support
Training

DOD TECHNOLOGIES: CONTROL SYSTEMS

- **Intelligent vehicle control systems encompass:**
  - **Control system architecture**
  - **Sensory perception and situation awareness**
  - **Software**
  - **Databases and world modeling**
  - **Communications internal and external to the vehicle**
  - **Vehicle mobility**
  - **Architecture of the computer hardware**
- **Resulting behavior of the intelligent vehicle includes:**
  - **Situation awareness**
  - **Collision detection and avoidance**
  - **Route planning**
  - **Task decomposition**
  - **Lane-following**
  - **Sign and obstacle detection**

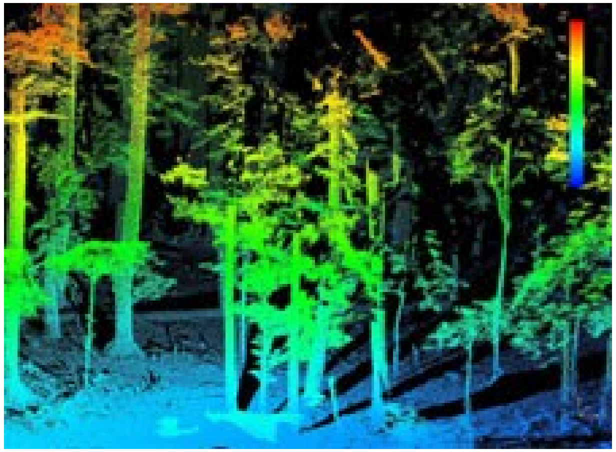
DOD TECHNOLOGIES: CONTROL SYSTEMS

- Control system architecture provides the framework for the vehicle's "intelligence"
  - Pragmatic definition of intelligence: "an *intelligent system* is a system with the ability to act *appropriately* (or make an appropriate choice or decision) in an uncertain environment."
  - An *appropriate* action (or choice) is that which maximizes the probability of successfully achieving the *mission goals* (or the *purpose* of the system)
- Intelligence need not be at the *human* level
  - *Appropriate* intelligence: ability of vehicle to perform as a skilled human driver would under a variety of conditions
  - Desired level of vehicle intelligence: depends on the user's requirements and technical, operational, and economical feasibility of achieving the desired level of intelligence



DOD TECHNOLOGIES: SENSOR SYSTEMS

- Major elements of a robotic vehicle's sensor system
  - Internal and external sensors
  - Processing needed to extract information from the sensors which can be used by the intelligent vehicle
  - Architecture of the sensor system
- Sensory perception
  - Ability to fully understand the object that is sensed in the context of the situation and environment
  - Depends on the sensors, sensor processors, and intelligent control system architecture
- Number and type of sensors needed by intelligent vehicle
  - Depends on its size and purpose



DOD TECHNOLOGIES: INTERFACE SYSTEMS

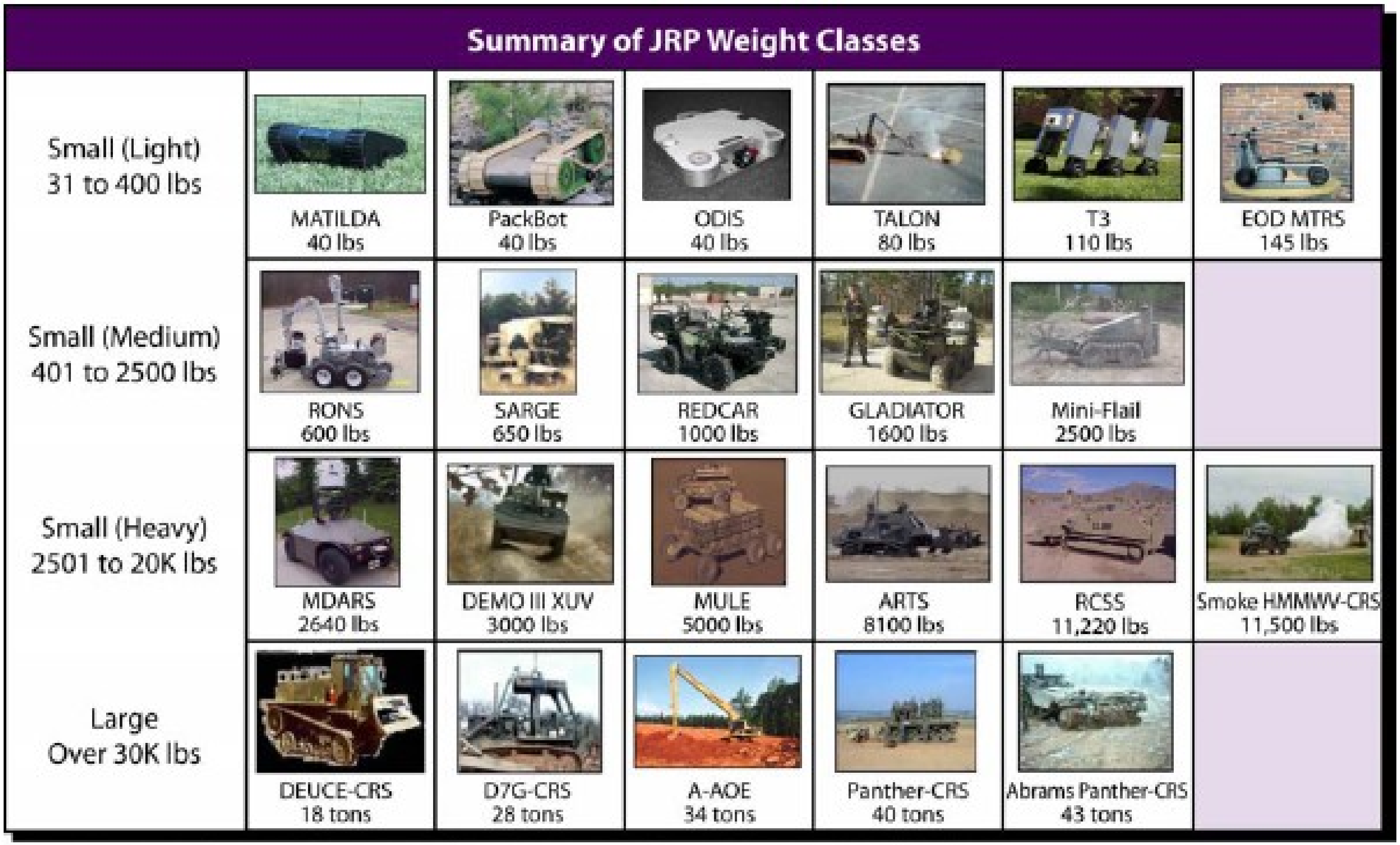
- Interface between the intelligent vehicle and the human consists of
  - Controls and displays
  - Attention which must be paid to the vehicle by people over its lifetime:
    - Testing, maintenance, and support
    - People associated with the robot must be trained in its operation, maintenance, and repair
  - Communications system (command, control, and data links, antennas, transmitters, receivers, power supplies, computers, signal processing, etc.) is also an interface system

DOD INTELLIGENT VEHICLE PROGRAMS

- DOD supporting development of a number of intelligent ground vehicles
  - Including Future Combat System (FCS) Program and programs supported by the Defense Advanced Research Projects Agency (DARPA), and other agencies
- DOD programs developing and fielding first-generation unmanned ground vehicles
  - With current technologies while pursuing advanced technologies critical to autonomous vehicles
  - Evolutionary improvement to first generation vehicles
- Followed by second generation intelligent, autonomous vehicles
- DOD 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)

A POTPOURRI OF ROBOTS

- **There are many taxonomies that have been used for robotic air, ground, and water vehicles: based on size, endurance, mission, user, C3 link, propulsion, mobility, altitude, level of autonomy, etc., etc.**

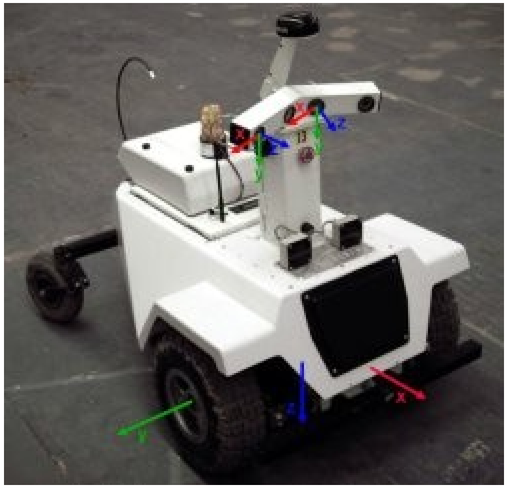


Summary of JRP Weight Classes						
Small (Light) 31 to 400 lbs	MATILDA 40 lbs	PackBot 40 lbs	ODIS 40 lbs	TALON 80 lbs	T3 110 lbs	EOD MTRS 145 lbs
Small (Medium) 401 to 2500 lbs	RONS 600 lbs	SARGE 650 lbs	REDCAR 1000 lbs	GLADIATOR 1600 lbs	Mini-Flail 2500 lbs	
Small (Heavy) 2501 to 20K lbs	MDARS 2640 lbs	DEMO III XUV 3000 lbs	MULE 5000 lbs	ARTS 8100 lbs	RCSS 11,220 lbs	Smoke HMMWV-CRS 11,500 lbs
Large Over 30K lbs	DEUCE-CRS 18 tons	D7G-CRS 28 tons	A-AOE 34 tons	Panther-CRS 40 tons	Abrams Panther-CRS 43 tons	

*No systems currently exist in the Micro (<8 lbs), Miniature (8-30 lbs), or Medium (20K-30K lbs) classes.

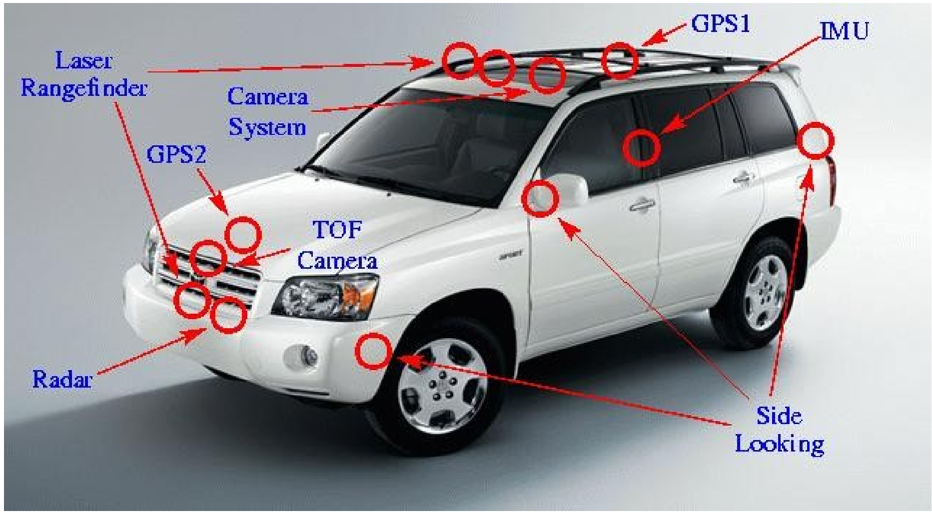
EXAMPLE DOD INTELLIGENT VEHICLES

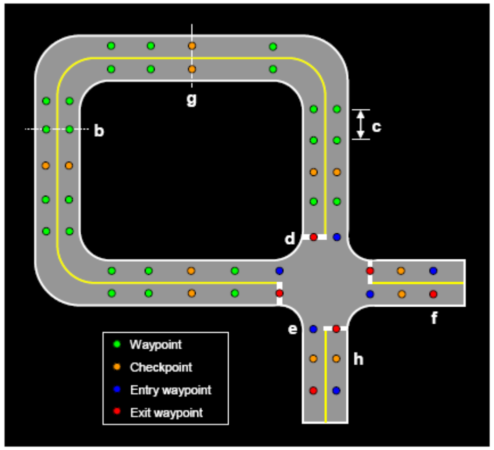
- Defense Advanced Research Projects Agency (DARPA)
  - Perception for Off-Road Robotics (PerceptOR)
  - Unmanned Ground Combat Vehicle (UGCV)
  - Learning Applied to Ground Robots (LAGR)
  - Grand Challenge and Urban Grand Challenge

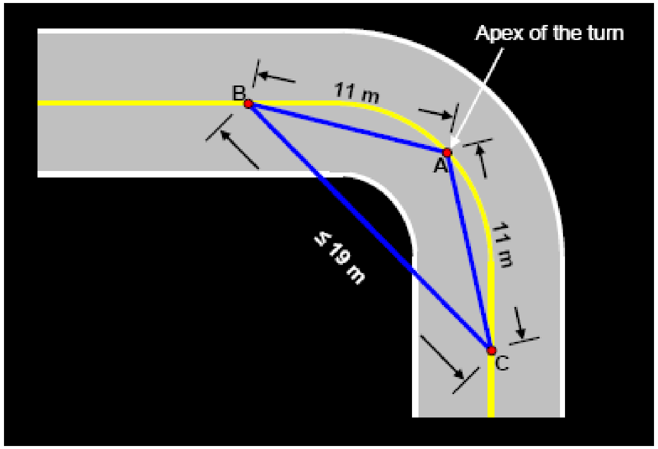


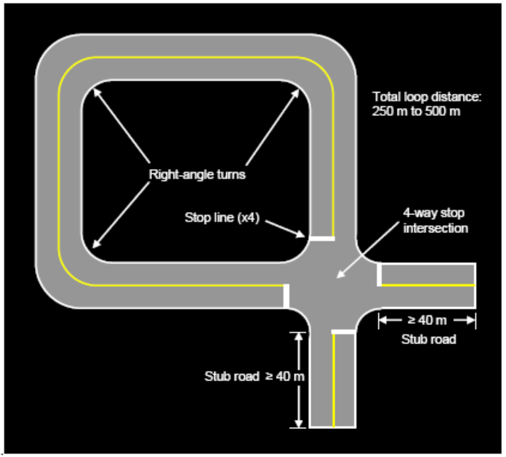
EXAMPLE DOD INTELLIGENT VEHICLES

- **Defense Advanced Research Projects Agency (DARPA) Urban Grand Challenge**



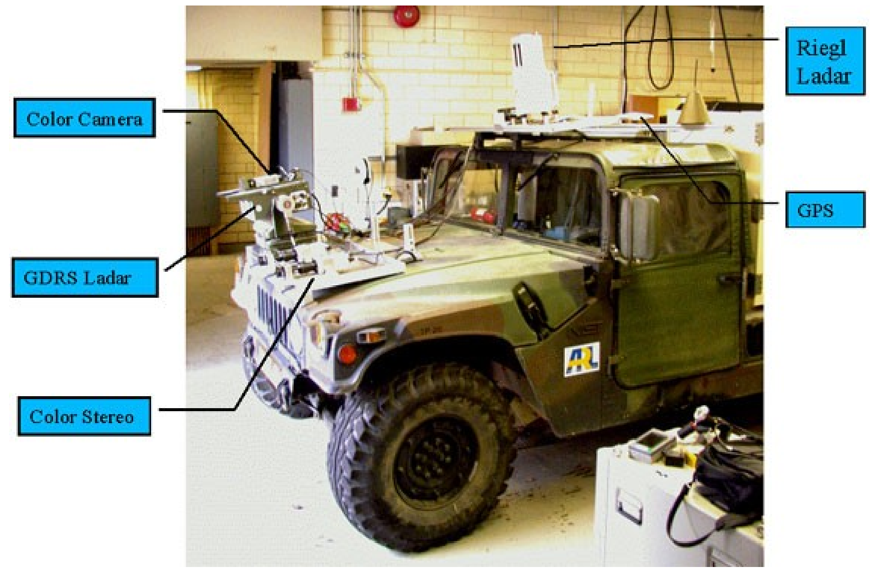






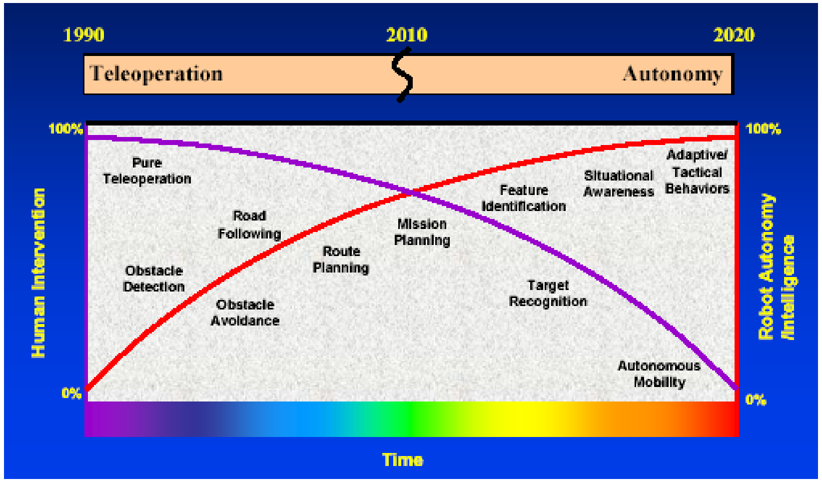
EXAMPLE DOD INTELLIGENT VEHICLES

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



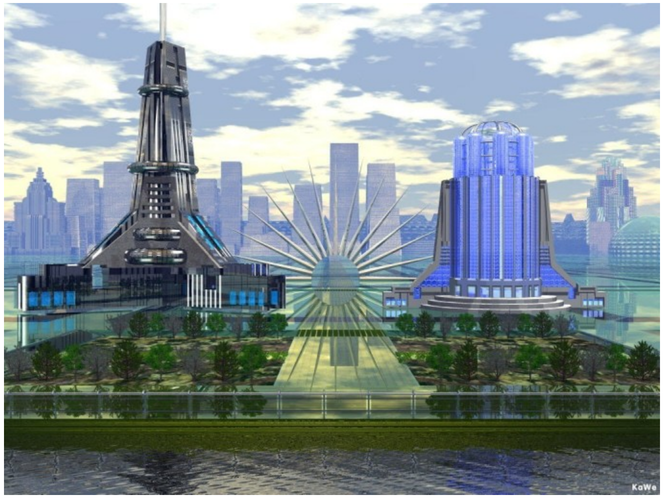
DOD ENABLING INTELLIGENT VEHICLE TECHNOLOGY PRIORITIES

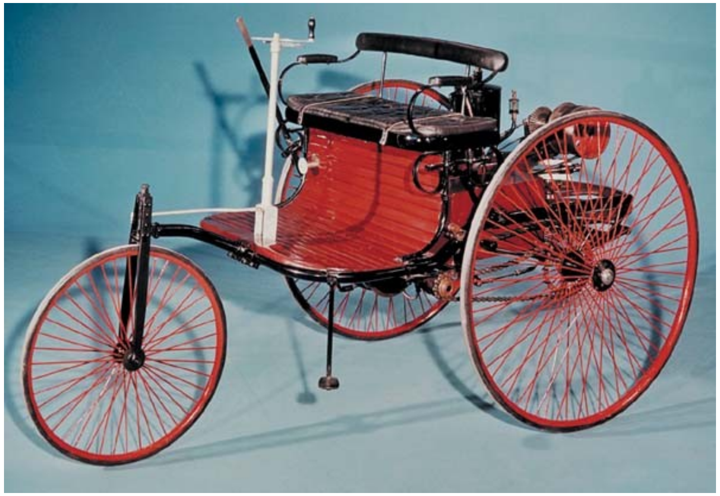
- Establishing common architecture
  - Open and modular
  - Standardized interfaces
  - Progress toward commercial standards
- Developing semi-autonomous mobility
  - With obstacle detection and avoidance, tactical behaviors, and man-machine interfaces
- Integrating mission payloads
  - Including manipulators, sensors, and weapons
- Vehicle intelligence sufficient for complete autonomy by 2020
  - Human intervention for missions will approach zero
  - By 2010: appreciable level of intelligent autonomy



DOT VISION FOR INTELLIGENT VEHICLES

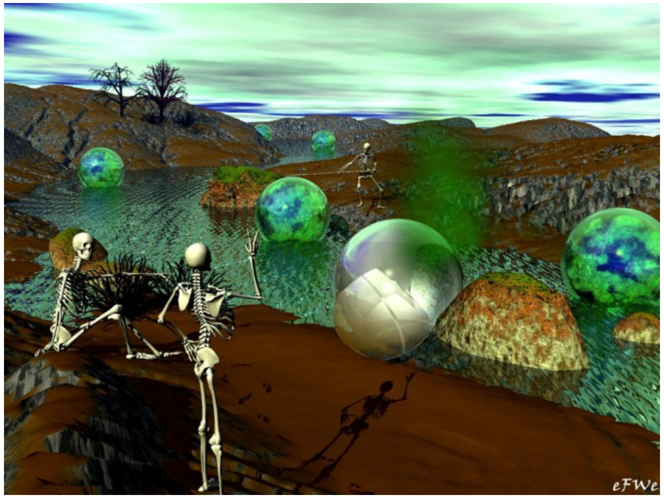
- A system involving roads, vehicles, and drivers, where drivers:
  - Operate in a significantly safer environment
  - Enjoy greater mobility and efficiency as a result of vehicle-based autonomous and infrastructure-cooperative *driving assistance* features





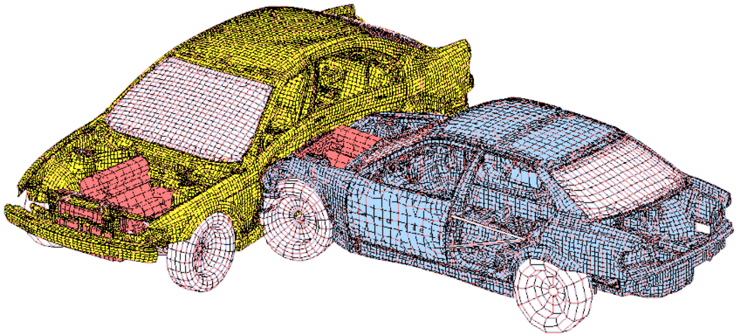
DOT MOTIVATION

- Can significantly reduce motor vehicle crashes
- Each year more than 41,000 Americans die as a result of about 6 million crashes
  - Equivalent of 115 each day, or one every 13 minutes
- Impact of highway injuries is horrendous
  - 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
  - Consume a greater share of national health care costs than any other cause of illness or injury
- Globally: 1 million deaths, 50 million injuries
- New technology offers potential safety solutions but poses new problems
  - Some in-vehicle technology may become a dangerous distraction to drivers



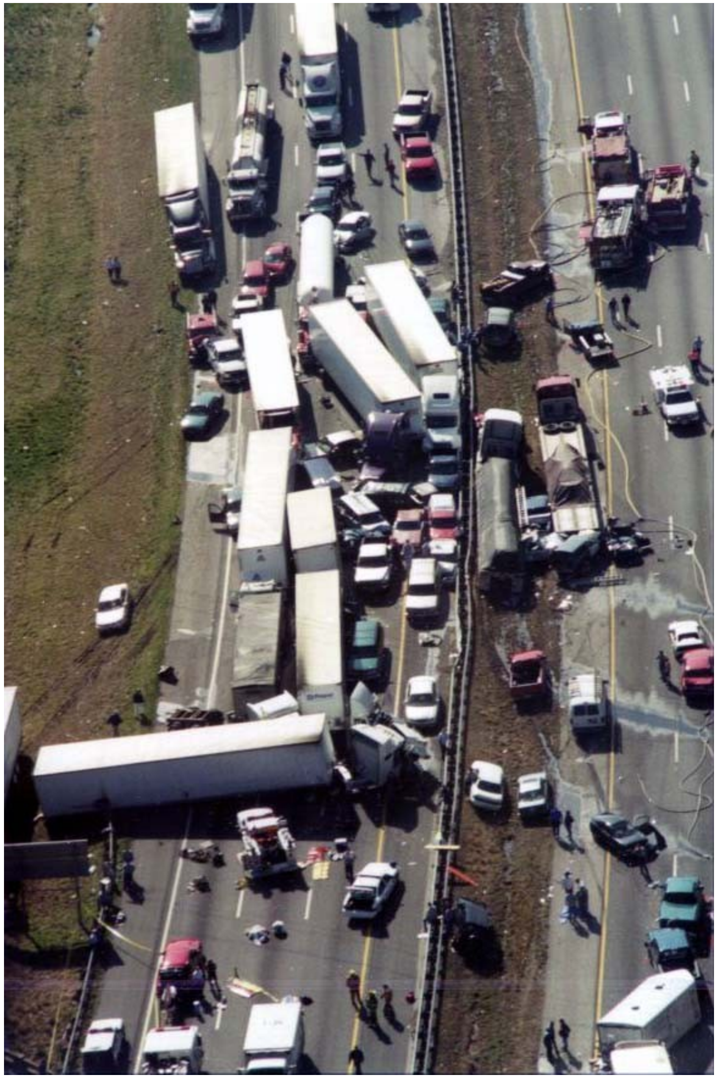
DOT MOTIVATION

- NHTSA estimates that driver inattention, from all sources, causes **20 to 30 percent** of the **6.3 million accidents** per year
- Driver error remains the leading cause of crashes
  - Cited in more than 90 percent of police crash reports
- 2007 Nationwide Mutual Insurance study
  - 73% of drivers use phones while driving and 20% text message
- Intelligent vehicle mission is to reduce the number and severity of crashes through driver assistance systems
  - Assume *partial control* of vehicles to avoid collisions
- Focus on *preventing* crashes, by helping drivers avoid hazardous mistakes, is a significant new direction for DOT safety programs
  - Previously primary focus was on crash *mitigation* (i.e., alleviating the severity of crash-related injury to persons and property)



DOT VISION: DRIVER ASSISTANCE

- Current DOT intelligent vehicle vision does not encompass fully-autonomous vehicles
  - Driver assistance systems only
- 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)
  - Can save many 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
  - As the military intends for combat vehicles

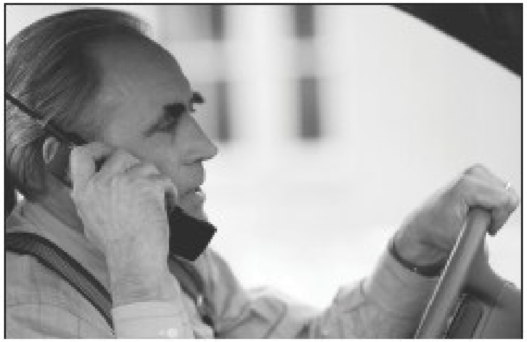


AN AUTONOMY SCENARIO

- Commuter enters car at home
  - Tells it where he wants to go
  - It takes him to his destination (while he reads, talks on the phone, works on the computer, sleeps, or watches videos)
  - Parks itself after dropping him off
  - After work (or a night out), commuter summons vehicle with phone
- "Built-in chauffeur" will be safer and more efficient than a human driver
- Will benefit millions of baby boomers who are becoming elderly and will lose driving privileges
- Handicapped of all ages will gain the freedom to travel in their own cars without the debilitating dependence on others

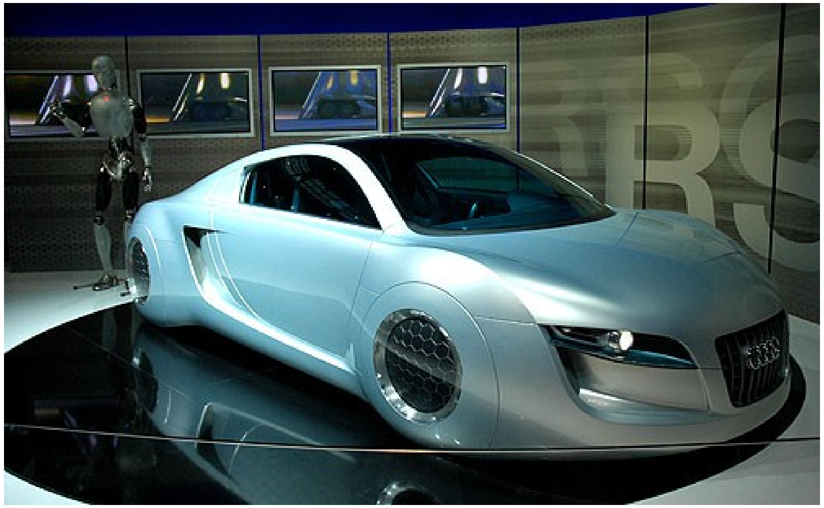






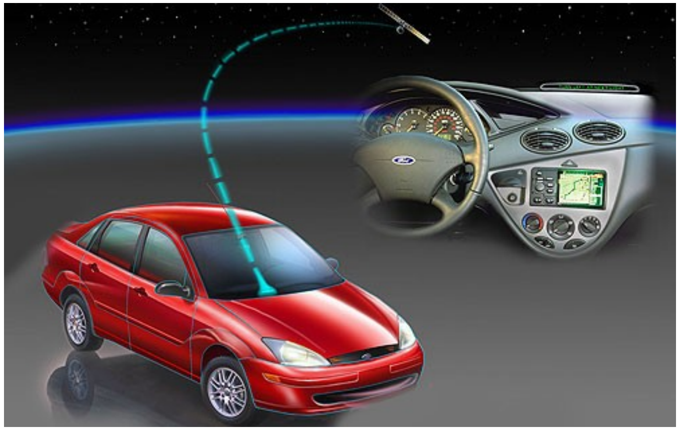
ITS PROGRESS

- Since the 1990 initiation of the DOT's Intelligent Transportation System (ITS) Program
  - Remarkable progress in commercializing advanced technology in vehicles and transportation system
  - Some of the technology, like the Global Positioning System (GPS), infrared sensors, sonar, and microwave radar originated with the DOD
- Much current and near-term commercially-feasible intelligent vehicle technology did not exist at the start of ITS in 1990



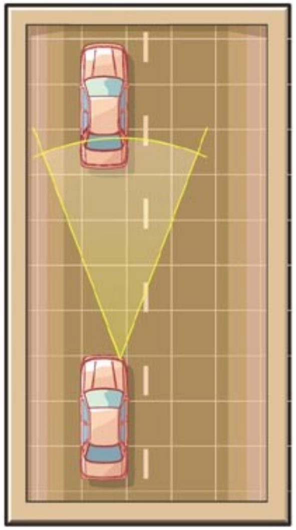
EXAMPLE ITS COMMERCIALIZED TECHNOLOGY

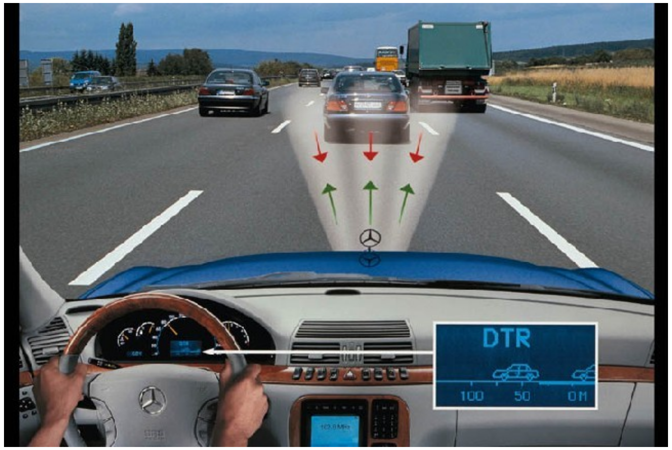
- GPS Navigation
  - Lost drivers are unsafe drivers
  - Automated crash notification (“Mayday”) system senses airbag deployment, knows GPS location, and calls for help via satellite phone link
  - Real-time information on traffic conditions displayed on navigation map
- Fleet management system
  - Trucks, buses, taxis, police and emergency vehicles, hazardous waste transporters, etc. tracked and routed by control center
- Adaptive cruise control
  - Maintains vehicle speed consistent with selected safe distance from vehicle in front
- Crash warning and automated crash avoidance
  - Senses objects and may automatically respond with brake and steering
- Back-up object detection
  - Avoids backing into bicycle or cat; helps with parallel parking

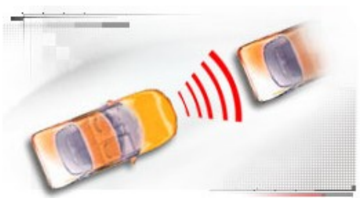


EXAMPLE ITS COMMERCIALIZED TECHNOLOGY

- Lane change warning
  - Senses oncoming vehicles in adjacent lane
- Automated lane tracking
  - Senses lane markers and may have automated steering
- Driver distraction and drowsiness detection and mitigation
  - Senses driver's eyes, head position, or steering
- Head-up displays
  - Projections onto windshield
- Road-departure crash warning
  - Senses movement across lane markers or vehicle movement
- Rollover prevention
  - Senses vehicle stability and attitude
- Haptic driver warning cues
  - Provides touch feedback to driver of danger signals

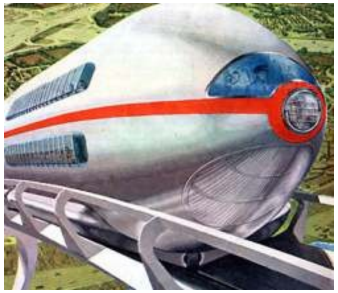


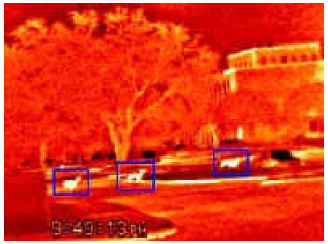


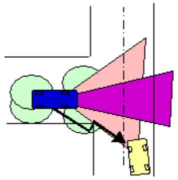


EXAMPLE ITS COMMERCIALIZED TECHNOLOGY

- **Automated bus systems**
  - **Semi-autonomous or autonomous buses on fixed bus lanes**
- **Intersection collision countermeasures (vehicles and pedestrians)**
  - **Senses and communicates among infrastructure/vehicles at intersections**
- **Night vision**
  - **Sensing to allow drivers or vehicle to detect objects at night**
- **Travel and service information**
  - **Available or transmitted to numerous sources (on buses and trains, home television, radio, Internet, public kiosks)**
- **Electronic weighing and inspection**
  - **Senses commercial vehicles in motion, enables electronic issuing and monitoring of permits, or tracking containers throughout multi-modal shipment**







EXAMPLE ITS COMMERCIALIZED TECHNOLOGY

- Traffic management systems
  - Monitor current conditions and adjust lane usage, speed limits, traffic signals, and roadway ramp access based on actual traffic conditions rather than historical patterns
- Public transit enhancements
  - Smart cards, real-time displays of service status, and systems for dynamic ride sharing
- Toll collection
  - Automatic, electronic collection of tolls, transit fares, and other transportation user fees

IMPACTS OF INTELLIGENT VEHICLES

- First order impacts: linear extrapolation – faster, better, cheaper
- Second and third order impacts: non-linear, more difficult to forecast
- Analogy: The automobile in 1907
  - Faster, better, cheaper than horse and buggy
  - Then industrial changes: rise of automotive industry, oil industry, road & bridge construction, etc.
  - Then social changes: clothing, rise of suburbs, family structure (teenage drivers, dating), increasing wealth and personal mobility
  - Then geopolitical changes: oil cartels, foreign policy, religious conflict, wars, environmental degradation and global warming