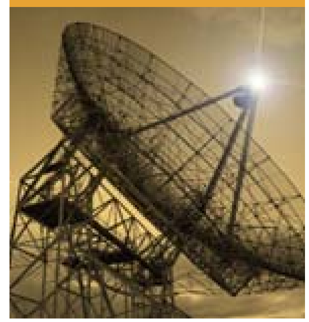
SRI International
SARNOFF



# Augmented Reality and its application to maintaining and repairing vehicles.

Rakesh  (Teddy) Kumar

Vision and Robotics Laboratory
SRI International Sarnoff
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Phone: 1-609-734-2832

April 12th, 2011

# Talk Overview

1. Introduction to SRI
2. Augmented Reality for Military Defense Training
3. Other Applications of Augmented Reality
4. Augmented Reality for Vehicle Repair and Maintenance
5. Conclusions

# Who We Are

## SRI is a world-leading R&D organization

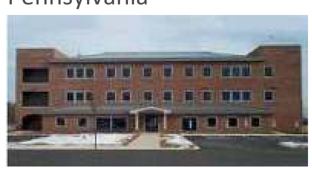
- An independent, nonprofit corporation
  - Founded by Stanford University in 1946
  - Independent in 1970; changed name from Stanford Research Institute to SRI International in 1977
  - Sarnoff Corporation acquired as a subsidiary in 1987; integrated into SRI in 2011
- 2,100 staff members
- More than 20 locations worldwide
- 2009 revenues: approximately $470 million

Silicon Valley - Headquarters

Washington, D.C.

Virginia

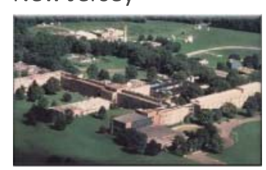
Pennsylvania



Florida

SRI International
SARNOFF

New Jersey



Tokyo, Japan

# Our Focus Areas

## Multidisciplinary teams leverage core technology and research areas

Information Technology

Health, Education, and Economic Policy

Engineering and Systems


Biotechnology

Advanced Materials, Microsystems, and Nanotechnology

# Clients throughout the World

## Providing value to our clients worldwide

**Mission:** **SRI is committed to discovery and to the application of science and technology for knowledge, commerce, prosperity, and peace.**

# Representative Clients and Partners

## SRI delivers innovation to governments

### *United States*

- Departments of Defense, Energy, Education, Homeland Security, Labor, Transportation, Commerce, Health and Human Services, and State
- Defense Advanced Research Projects Agency (DARPA)
- Departments of the U.S. Army, Navy, Marines, and Air Force
- Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Institutes of Health (NIH)
- National Science Foundation (NSF)
- Office of Naval Research (ONR)
- Palm Beach County, FL Business Development Board
- States of Connecticut, Illinois, Iowa, Kentucky, Oklahoma, and Pennsylvania
- University of California
- U.S. Agency for International Development (USAID)
- U.S. Postal Service

### *International*

- Business Victoria, Australia
- City of Kobe, Japan
- Government of Murcia, Spain
- Industrial Development Corporation of South Africa
- Inter-American Development Bank
- National Institute of Advanced Industrial Science and Technology, Japan
- National Institute for Material Science, Japan
- New Energy and Industrial Technology Development Organization, Japan
- King Abdul Aziz City for Science and Technology, Saudi Arabia
- Institute of Science and Technology, Korea
- Ministry for Science, Technology, and the Environment, Malaysia
- Ministry of Industry, Science, Technology, Canada
- Ministry of Science and Technology, Brazil
- Exporters Confederation, Philippines
- General Investment Authority, Saudi Arabia
- Industrial Technology Research Institute, Taiwan
- Tokyo University of Agriculture and Technology, Japan
- The World Bank

# Representative Clients and Partners

## SRI delivers innovation to established and start-up businesses

### *U.S. and International Businesses*

- Akzo-Nobel Chemicals
- Avery Dennison
- British Broadcasting Corporation
- C&H Sugar
- Charles Schwab & Co.
- Chevron Corporation
- Colin Medical Instruments
- Conoco
- CVS
- Delphi Interiors
- Drexler Technology
- FedEx Corporation
- Hitachi
- Hyper Drive Co., Ltd.
- Kajima
- Kuraray
- Leucadia Corporation
- Mazda Corporation
- Mitsubishi Heavy Industries
- Monsanto
- Ocean Spray
- Post, Buckley, Schuh& Jernigan
- Playback Media
- Samsung Corporation
- Sanofi Winthrop
- Taiho Pharmaceutical
- Thames Water
- Toray
- Toyota
- Tyco

### *Venture Capitalists*

- Kleiner Perkins
- Mayfield
- Morgenthaler
- Oak Investment Partners
- St. Paul Venture Partners
- U.S. Venture Partners

MAYFIELD FUND
Venture Capital with Impact

MONSANTO

charles SCHWAB

TAIHO

OAK INVESTMENT PARTNERS

HYPER DRIVE

JOHN DEERE

SAMSUNG

M
MORGENTHALER

# SRI Technology Spin-off Ventures

## Publicly Traded

- INTUITIVE SURGICAL® — Surgical robotics
- NUANCE — Speech recognition for customer service
- ORCHID CELLMARK — DNA testing services*

## Information Technology

- AgileVision — Digital TV equipment*
- CANDESCENT™ — Flat-panel displays*
- CIC. — Electronic and digital signature solutions
- discern — Customer service tools*
- DIVA — Video-on-demand services**
- NxtWave Communications — Digital TV technologies*
- PACKETHOP — Wireless mesh networks
- Pyramid Vision, A Sarnoff Company — Video enhancement systems
- SARIF — LCD technology*
- SENSAR — Iris biometric identification*
- Siri — Virtual Personal Assistant for smart phones*
- SocialKinetics — Enterprise social media technology
- VideoBrush — Panoramic image editing software*
- wavexpress — Secure content distribution*

## Materials

- ARTIFICIAL MUSCLE INCORPORATED — Electroactive polymers
- Averatek — Metal "print and plate" manufacturing process
- colorep — Digital color printing applications*
- lamina — Super-bright LED light engines*
- PolyFuel — Next-generation fuel cells**
- PowerZyme — Portable power systems**
- Princeton Lightwave — Optical network components
- SP Secure Products — Anti-counterfeiting systems

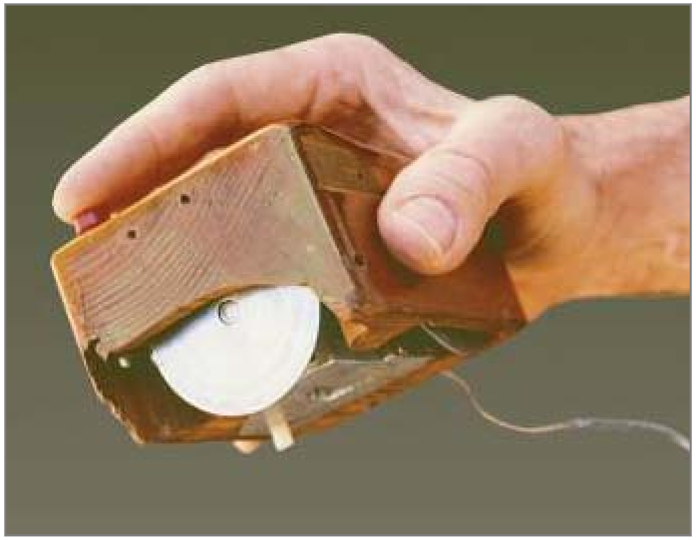
## Bio/Medical

- DELSYS — Drug dispensing system*
- LOCUS Pharmaceuticals — Drug discovery
- intuity MEDICAL (formerly Rosedale Medical) — Glucose monitoring system
- Songbird Hearing Inc. — Disposable hearing aid*

*Acquired or merged
** Dissolved

# Computing

## SRI invented the foundations of personal computing



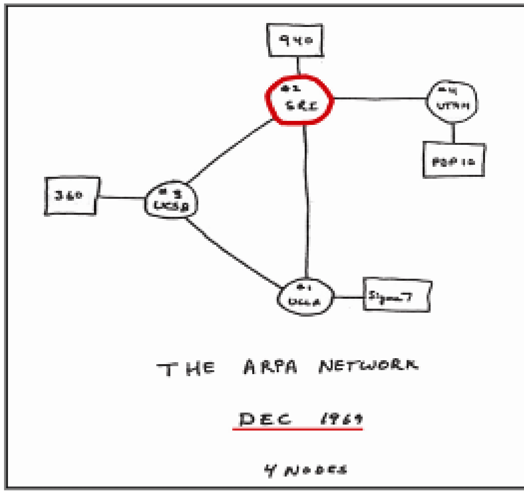
*1964–1968:* SRI's Doug Engelbart and team invented the computer mouse and demonstrated the foundations of personal computing.

*President Bill Clinton presents Doug Engelbart with the 2000 National Medal of Technology*

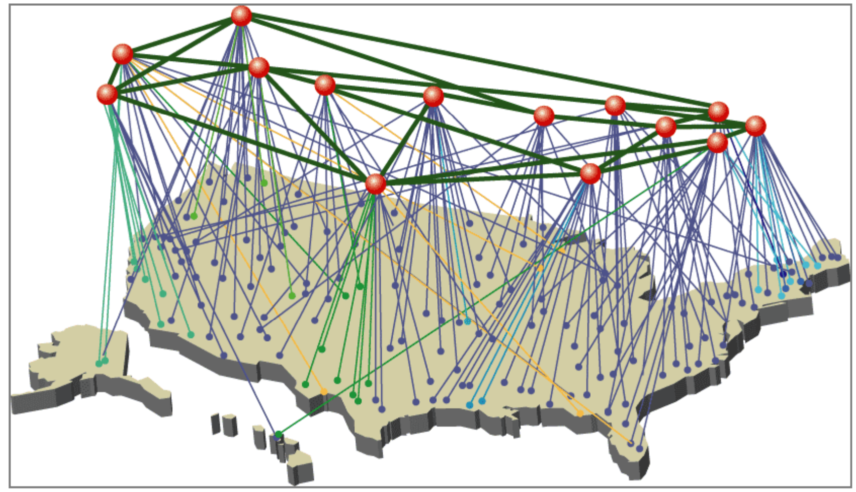

*Today:* SRI spin-off Siri, acquired by Apple in 2010, offers a virtual personal assistant—a new way to interact with the Internet on your mobile phone. Siri was born from the CALO project, an ambitious artificial intelligence program SRI led for DARPA.

# Internet and Networks

## SRI was there “before the beginning”




**.com**
**.gov**
**.org**



*1969:* SRI received the first logon to the ARPANET, predecessor of the Internet.

*1970–1992:* SRI ran the Network Information Center (NIC), the domain name registration clearinghouse for all computer hosts connecting to the ARPANET and Internet. SRI assigned all .com, .org, and .gov domain names.

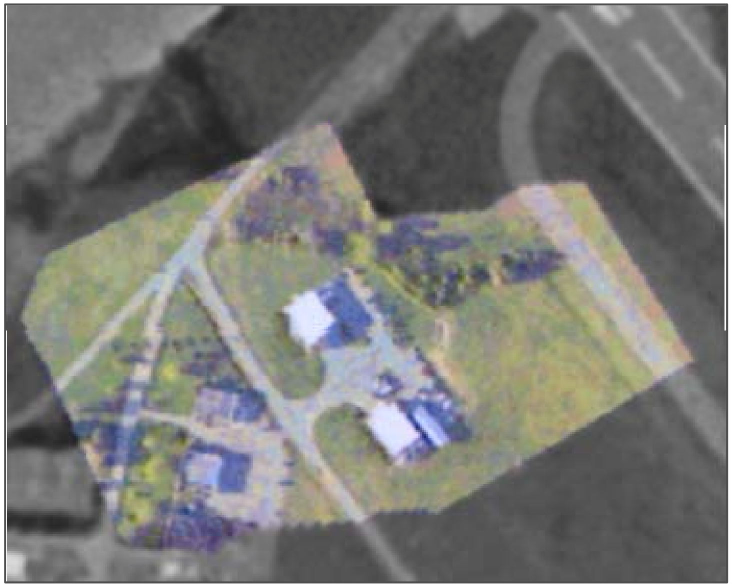
*1987:* SRI’s pioneering network intrusion detection technology protects against malicious attacks.

*Today:* For the Department of Homeland Security, SRI administers the Cyber Security R&D Center, which develops technology for protection of the U.S. cyber infrastructure through partnerships with industry, the venture community, and the research community.

*Today:* SRI’s online Malware Threat Center helps network administrators understand current and emerging computer security threats and provides key network defense information.

# Real-time Video Processing

## We are world leaders in real-time video analysis



*1984:* SRI Sarnoff's Pyramid Vision is the first computer system capable of performing sophisticated visual search tasks in real time.

*1996:* SRI Sarnoff delivered the first system to insert virtual advertising in live video broadcast as part of the scene.


*Today:* SRI Sarnoff's Acadia® II, developed to support the warfighter, performs real-time video enhancement, stabilization, multisensor video fusion, tracking, and image feature detection.

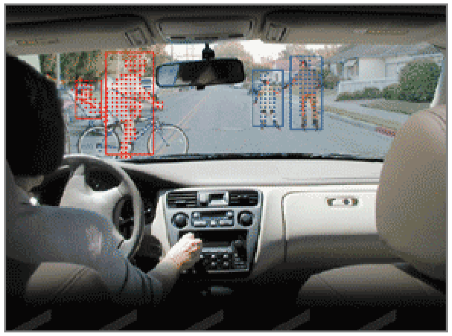
# Deep Technical Capabilities

SRI applies interdisciplinary skills to provide solutions to your needs

- Advanced materials and structures
- Automotive technologies
- Computational biology
- Cyber security
- Data collection and measurement
- Drug discovery and development
- Education, health, and economic policy
- Energy and environment
- Homeland security and national defense
- Imaging systems
- Information and computing
- Intelligence systems
- Marine science and technology
- Medical/surgical devices
- Microcircuit emulation
- Networks and communication
- Persistent surveillance
- Product development and fielding
- Product portfolio
- Robotics and automation
- Security and situational awareness
- Virtual personal assistants
- Vision technologies

# Automotive Technologies

Improving safety, comfort, cost, and environmental impact



Real-time 3-D sensing of people and objects

- Systems
  - Collision avoidance
  - Pedestrian detection
  - Intelligent airbags
  - Active noise cancellation
  - Chassis controls
- Informatics
  - Voice recognition
  - Peer-to-peer communications
  - GPS applications
- Sensors and actuators
  - Seat occupant sensors
  - "Artificial muscle" valve actuators
- Materials
  - Under-the-hood thermoplastics
  - Corrosion-resistant coatings
  - Failure mechanics and vibration analysis

# Robotics and Automation

From the world's first reasoning robot to the latest advances

Centibots, the first team of 100 mobile, coordinated robots

- Advanced materials for automation
  - Electroactive polymer "artificial muscle"
  - RF (radio frequency) tags
- Robots
  - Inspection systems
  - Micro robots
  - Collaborative robots
- Robotics
  - Video and image understanding
  - Safe operation
  - Machine vision systems for document understanding
  - Manufacturing and materials handling
  - GPS-challenged navigation
  - 3D modeling
- Transport
  - Ultra-clean transport
  - Medical laboratory automation

# Information and Computing

## Pioneering next-generation, disruptive technologies


**Handheld, speech-based language translation**

**Aerial vehicle tracking**

- Speech
  - Recognition and translation
  - Natural language understanding
- Networks and distributed computing
  - Information security
  - Mobile and wireless communications
- Artificial intelligence
  - Intelligent assistance
  - Real-time vision systems
  - Collaborative mobile robots
- System reliability
  - Formal methods for design and analysis
  - Integrated circuit (IC) and complex system verification
- Software systems
  - Intelligent project planning and tracking
  - Decision aids
- Vision technologies
  - Aerial video surveillance
  - Real-time video processing
  - 3D visualization
  - GPS-denied navigation systems

SRI International

# Augmented Reality for Training Warfighters

# Capability Gap for Military Training of Dismounts

Ft Bliss


Virtual

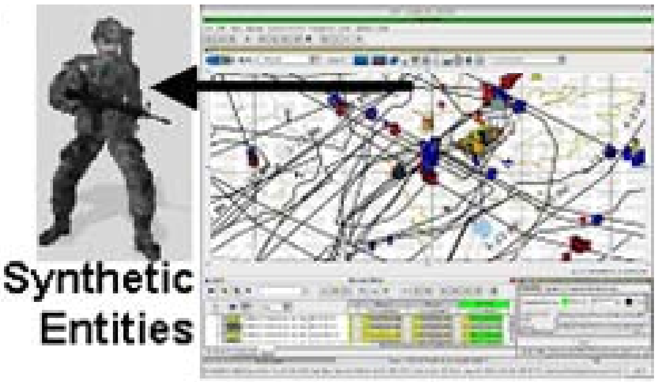
- Today: Training at highly instrumented MOUTs
  - Limited in number
  - Costly to run, with large numbers of role-players
  - Trainees required to schedule training and travel
- Requirement: Training any time, anywhere, low cost, high realism
  - Including unlimited variations, kinetic and non-kinetic effects, social and cultural situations

# Vision: *Making Live Training Come to Life*

Insert Tracers, explosions, muzzle flashes, and round "splashes" and "3D sound" in the real scene, *in both directions*!

Place *intelligent synthetic* actors into the ***real*** 3D scene

**Augmented outdoor scene**




War-fighter Worn Video & HMD

**Real scene**

Culturally realistic, reactive, dynamic, synthetic entities driven by simulation support non-kinetic and kinetic interactions

Seamless indoor/ outdoor and accurate 3D tracking of Marine and weapon position and orientation

Realistic depth mapping and occlusion

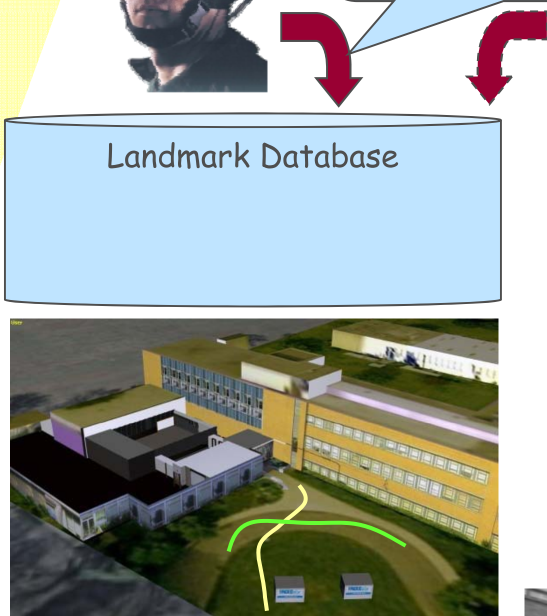
- Closed loop full spectrum collective training,
- Repeatable and scriptable, with unlimited amount of variation
- Rapidly deployable at home stations, CONUS and OCONUS outputs: Infrastructure free training.

- Immediate Performance Analysis and Feedback
- Exercise Review and Immersive After Action Analysis

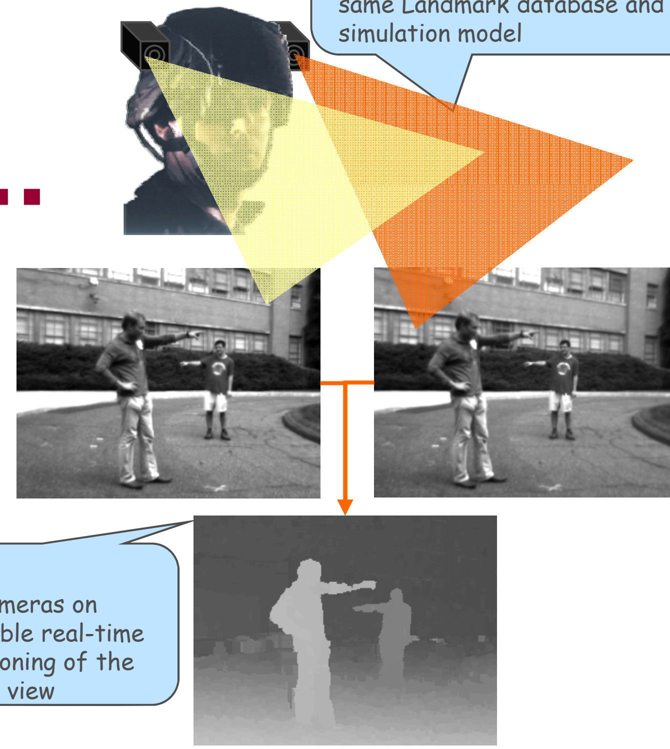
# Storyboard of Steps

Step 1:
- Helmet cameras capture video of what warfighter sees
- Navigation module tracks visual features to locate warfighter

Step 2:
- Visual Landmarks from warfighter video is matched to a pre-collected landmark database
- This establishes the position of warfighter in simulation model




Step 3:
•All the Warfighters are located with respect to the same Landmark database and simulation model



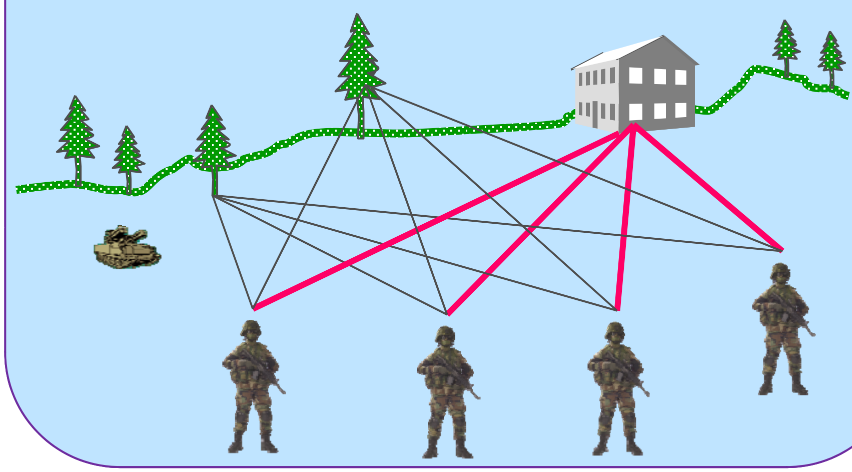
Step 4:
•Stereo cameras on helmet enable real-time depth reasoning of the warfighter view

Step 5:
•Simulation engine utilizes the depth sensing and localization to render synthetic characters into see-through head-mounted display

# Visual Aided Navigation, GPS denied or GPS limited

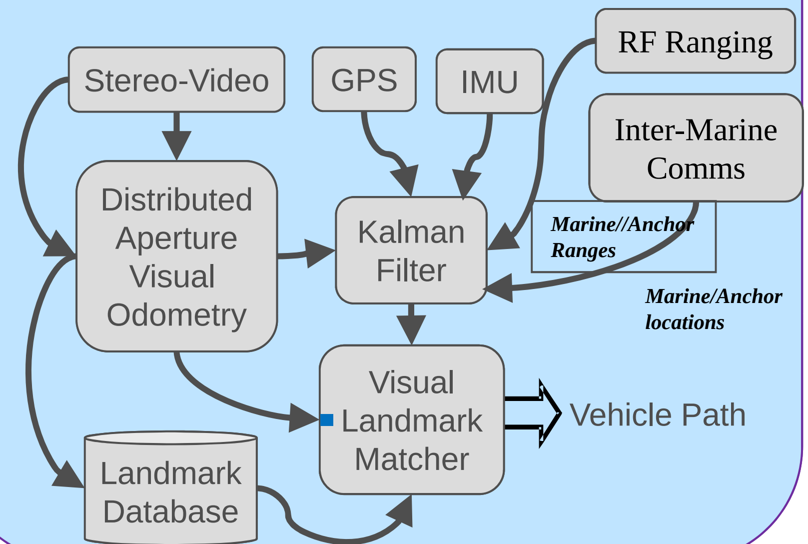
## Relative Pose Estimation:

3D ego-motion (6 DOF pose) estimated in real-time using stereo cameras



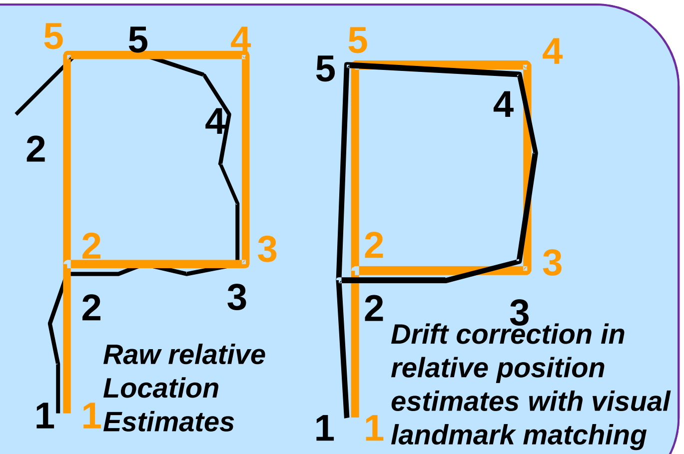
## Sensor Fusion:

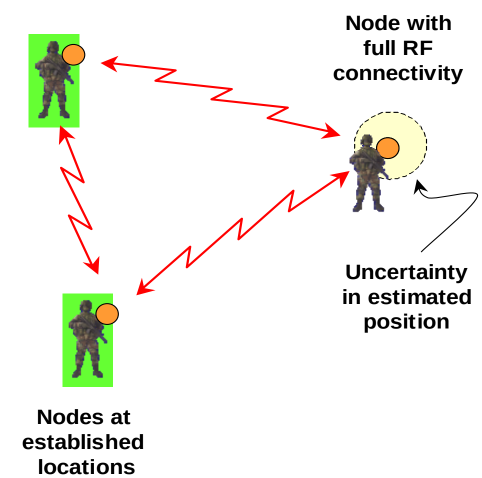
Kalman Filter Integrates Video, IMU and GPS



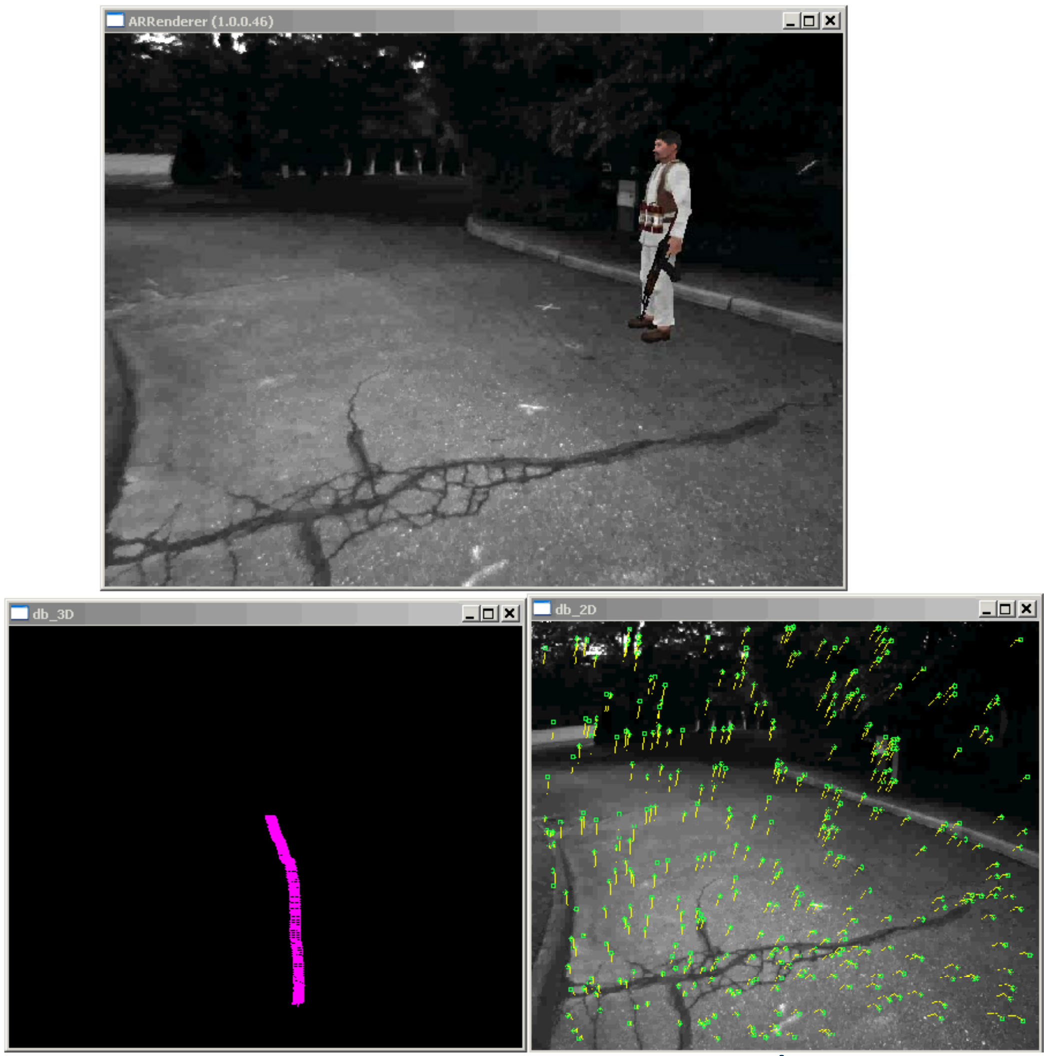

## Absolute Pose Estimation:

- Automatic Detection and Matching of Visual Landmarks
- Landmark database created on the fly
- Opportunistic use of GPS when available

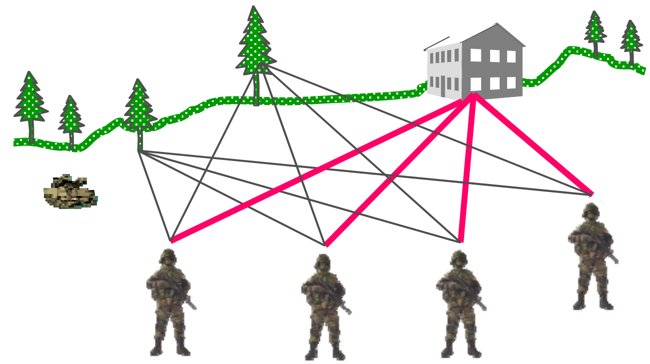


# Augmented Reality: How does it work




Insert Avatars in moving video



Automatically track distinctive scene points. Solve for 3D points and camera pose

Augmented Reality training

# Long Sequence Results with Landmark Matching

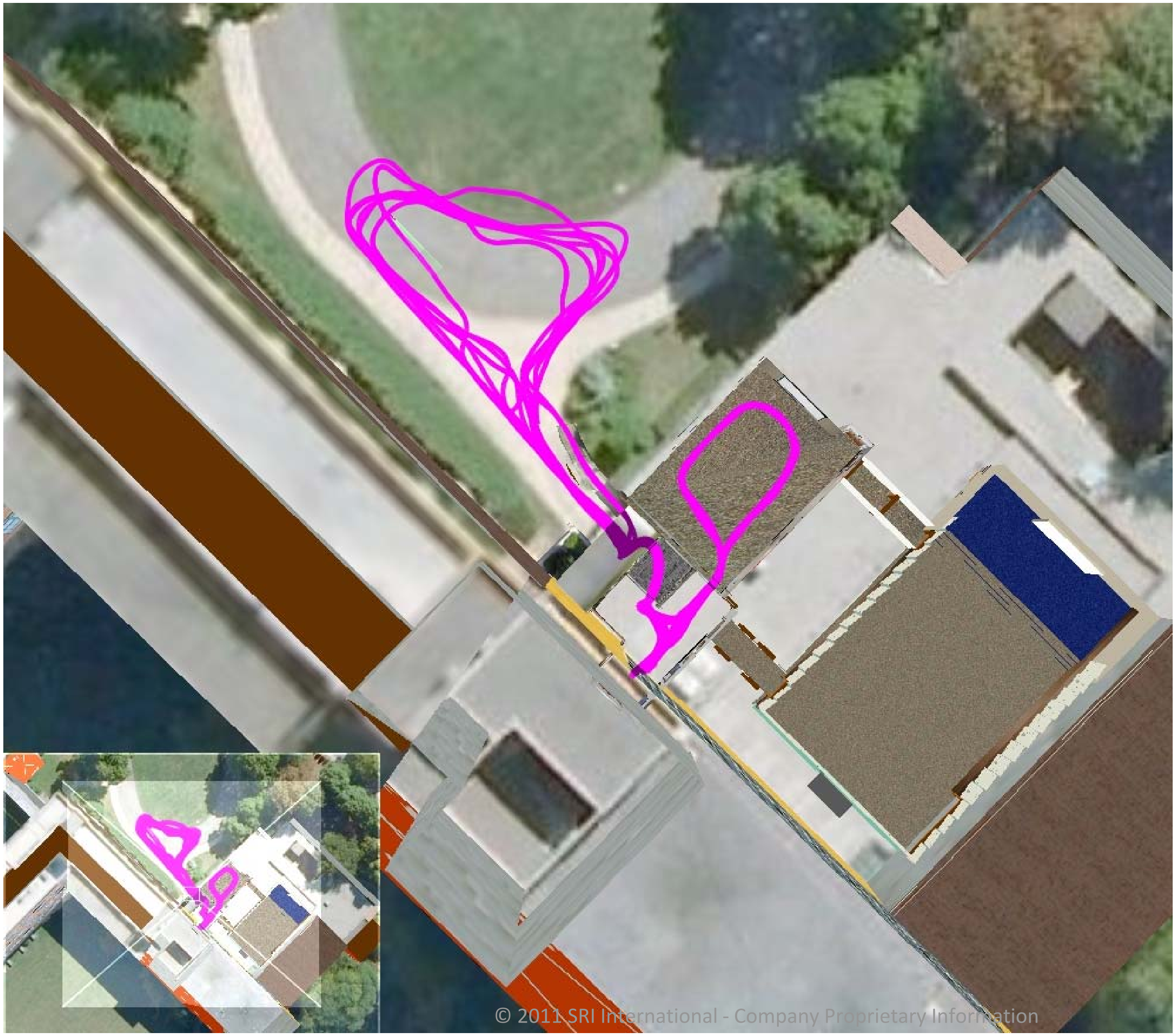
Top
View

Camera
View

# Long Sequence Results with Landmark Matching

Total Travelled Distance:
810.6 meters

Total Travelled Time:
16.46 minutes

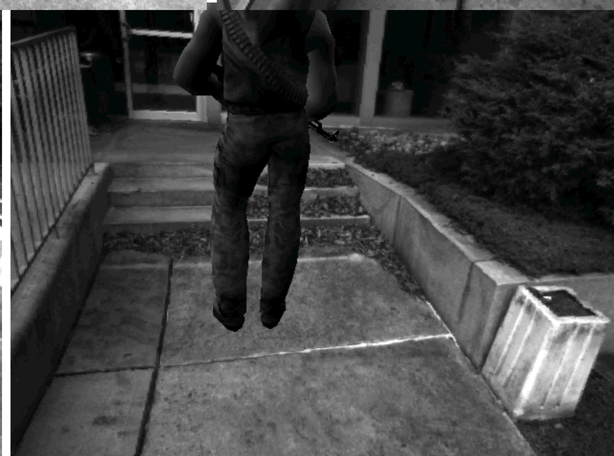


# Repeat-Visit Consistency of Insertion

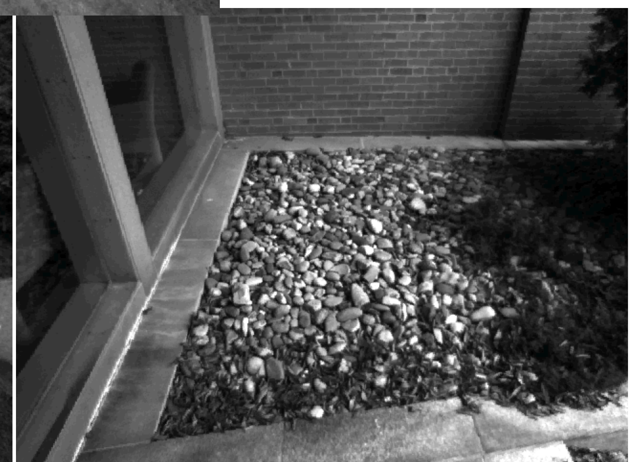
Starting Time: 10.37 min

Starting Time: 11.48 min

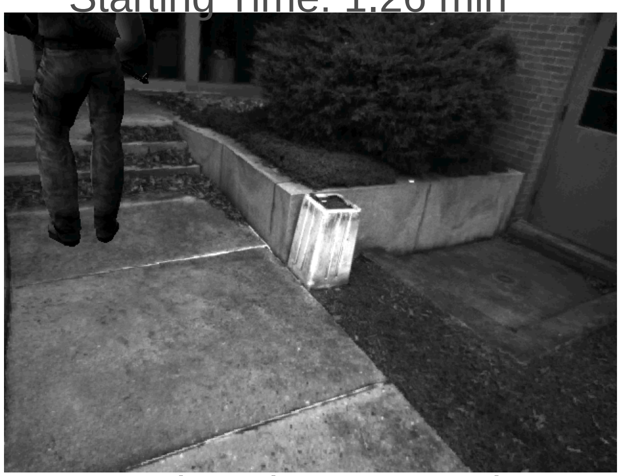
Starting Time: 1.26 min



Starting Time: 3.11 min

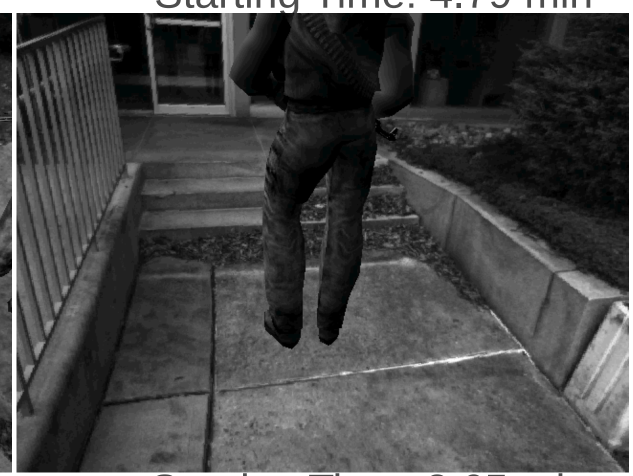


Starting Time: 4.79 min



Starting Time: 5.96 min

Starting Time: 7.51 min



Starting Time: 8.65 min

# Insertion of Avatars at the IIT, Camp Pendleton

Insertion is done using:

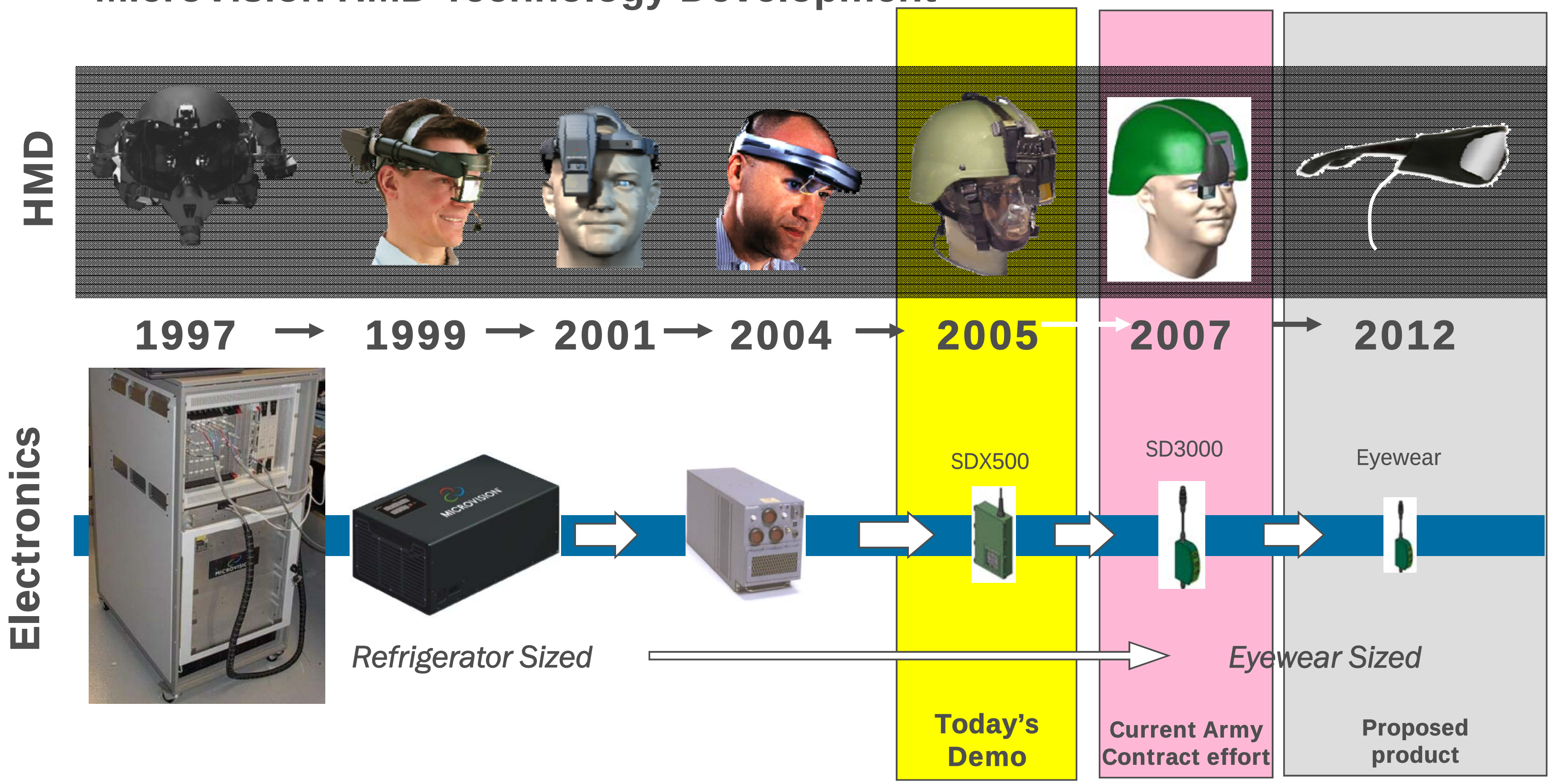
•Estimated 3D Head Pose and Location

•Depth map from stereo for occlusion culling

Video

# Head Worn Displays Product Roadmap

## MicroVision HMD Technology Development



SRI International

# Other Applications of Augmented Reality

# Augmenting Television: 2D Video Insertion

What the fans see


What the TV viewers see

PVI: Electronic insertion of advertisements in live television.


Yellow line in football

# SRI Magic Mirror: Virtual Shopper Demonstration

# Shopping: Augmented Reality Catalogs

Cisco Future Shopping Concept
http://www.youtube.com/watch?v=jDi0FNcaock

# Smartphone based Augmented Reality Games


Arhrrrr – Augmented Reality Shooter : Georgia Tech & SCAD-Atlanta
http://www.youtube.com/watch?v=cNu4CluFOcw

SRI International

# Application of Augmented Reality for Repair of Vehicles

# Augmented Reality Vocational Training

BMW Concept Advertisement
http://www.youtube.com/watch?v=P9KPJlA5yds

# Need

- There are 3 Key Customer Sets/Markets That Need New Vocational Training Options Associated with Auto Service & Repair

- Auto and Vehicle Manufacturers
  - Must Reduce Warranty Costs
  - Must Fix it Right the First Time
  - Must Fix It Fast with Minimal Touch Labor
  - All of the Above Needs Are Especially Critical for New Model Rollouts

- Military Transportation Commands - Vehicle Service Staff
  - Limited Training Prior to Deployment, Technicians Only Learn Basics
  - Impossible to Get Trained on All Vehicles/Platforms, Technicians Need Field Assist
  - Must Fix Vehicles/Platforms that Technicians Have Not Seen Before
  - Must Fix Problems or Provide Service that Technicians Have Not Performed Before
  - Must Perform Under Less Than Optimal Conditions

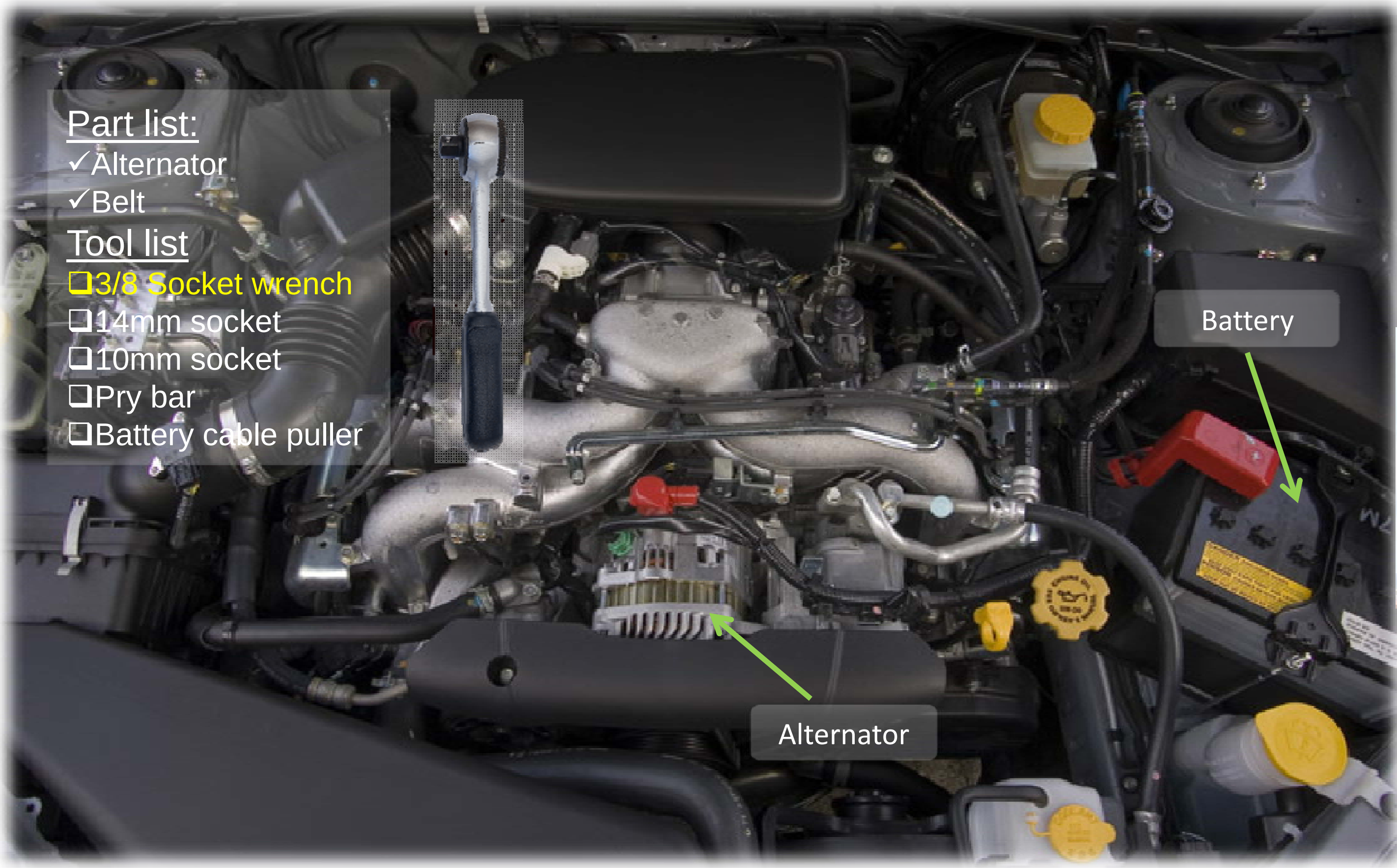
- Community College Vocational Programs
  - Due to Both of the Above, Need to Improve Training Options to Properly Prepare Graduates to Rapidly Adapt to Work Scenarios
  - Must Adapt to Remain Relevant, To Properly Serve Their Hiring Base

# Approach

- Provide AR Based Immersive Learning Demo Prototype
- Technician Wears Goggles to can See/Hear Virtual Objects with Instructions, Enables Interactive Learning and Interactive Field Work
  - Tech sees labeled vehicle parts as he scans the vehicle
  - Tech can See Virtual Parts, Assembles, Mechanisms Draped on Actual Vehicle
  - Overlaid on Real Scene: Virtual Procedures, Exploded Views, and Instructions
  - Technician View Include Fused Data from Diagnostics System
- AR Systems Monitors Technician Actions
  - Provides Step-by-Step Guidance
  - Alerts When Something is Wrong
  - Evaluates Performance and Provides After Action Reports
  - Provides Quality Control Capability in the Field

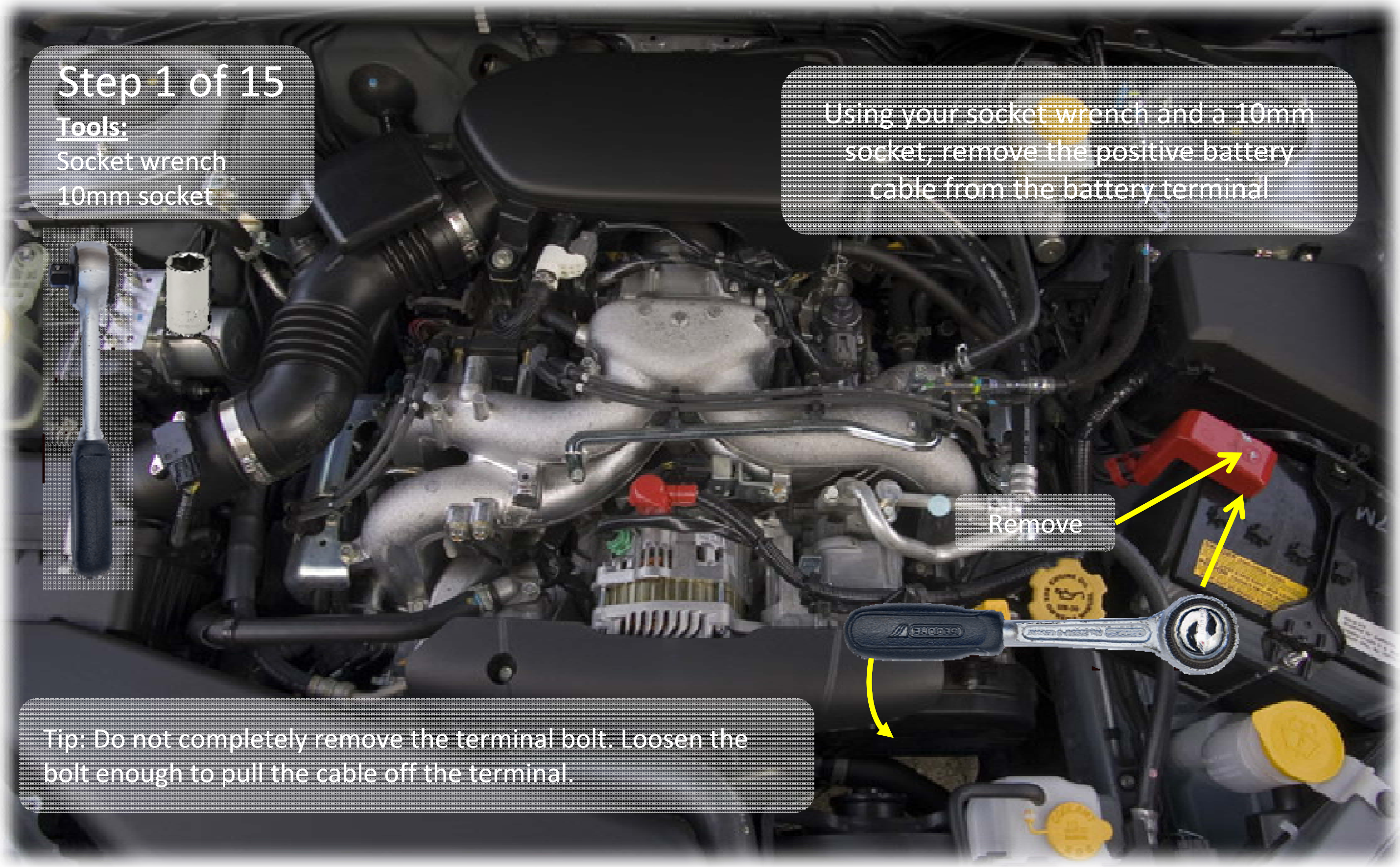
# Example: Automotive Repair

Information is overlayed on real world image. Audible commands are used for GUI navigation. In this case verbal “CHECK” required for each item in part and tool lists before proceeding to next step.



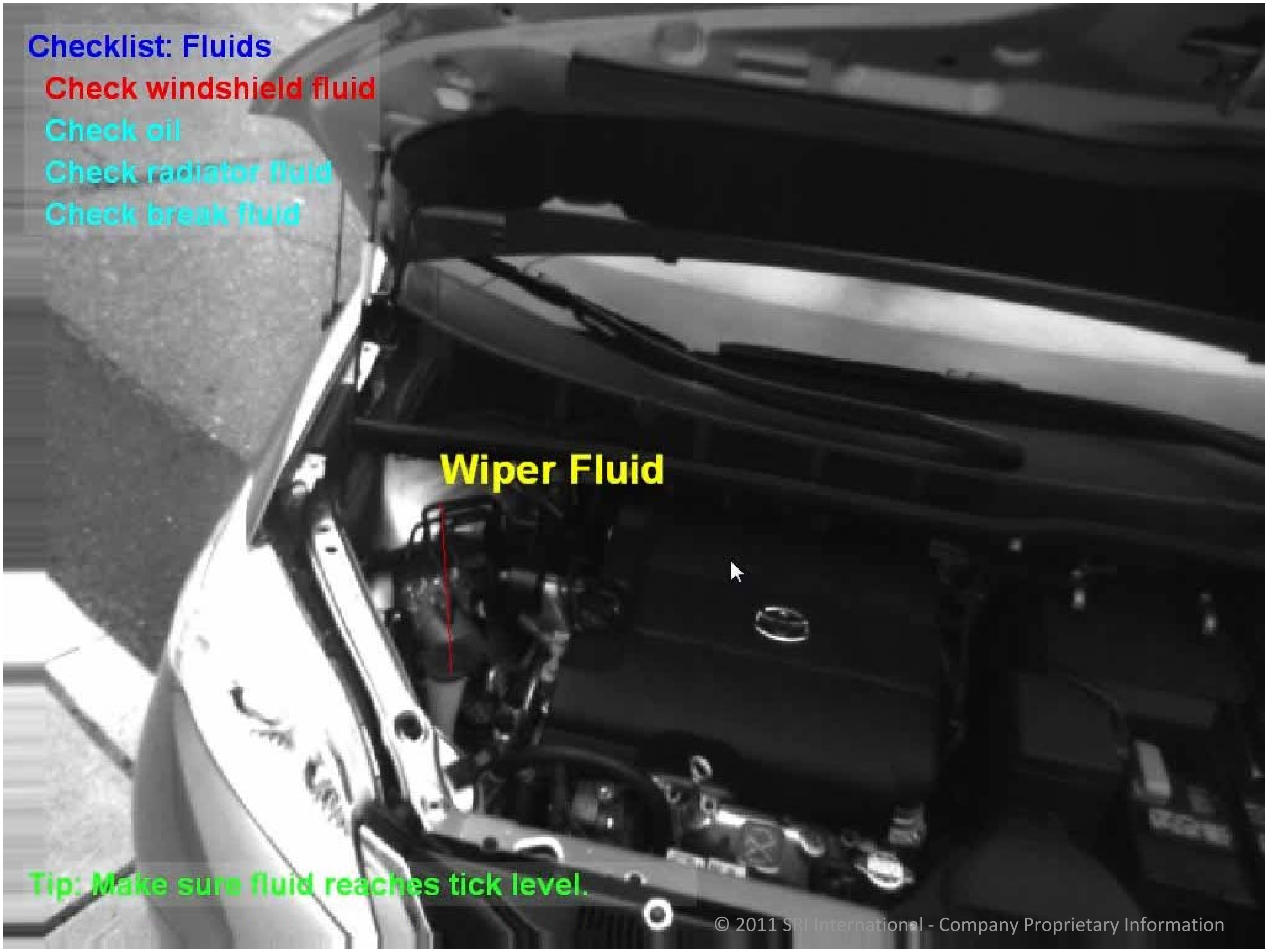

Augmented view of the world, objects are automatically recognized and labeled

# Example: Automotive Repair

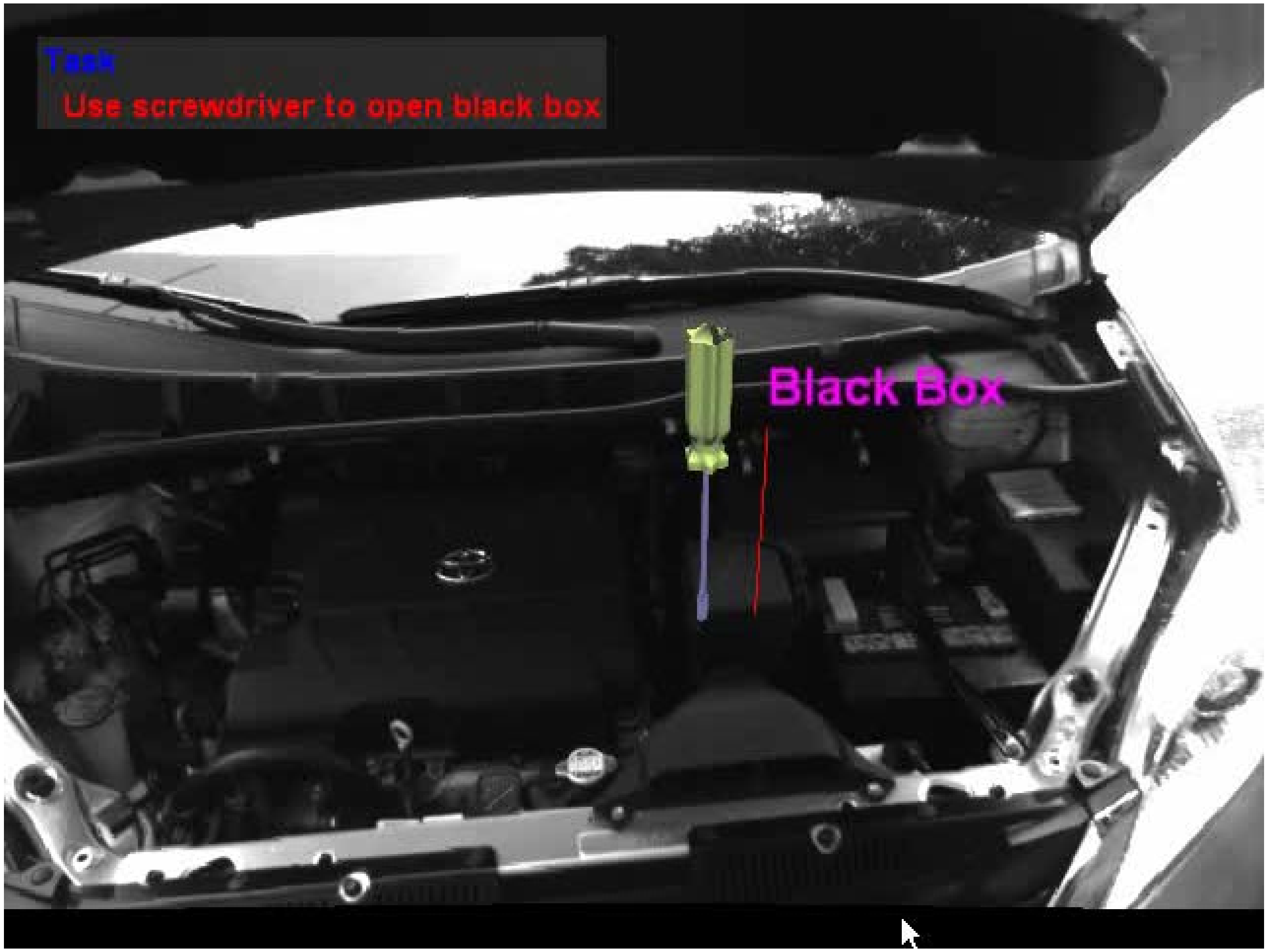



Repair steps are animated and rendered as overlays on the viewed scene to guide the user.

# Example: SRI Automotive Maintenance Guide example

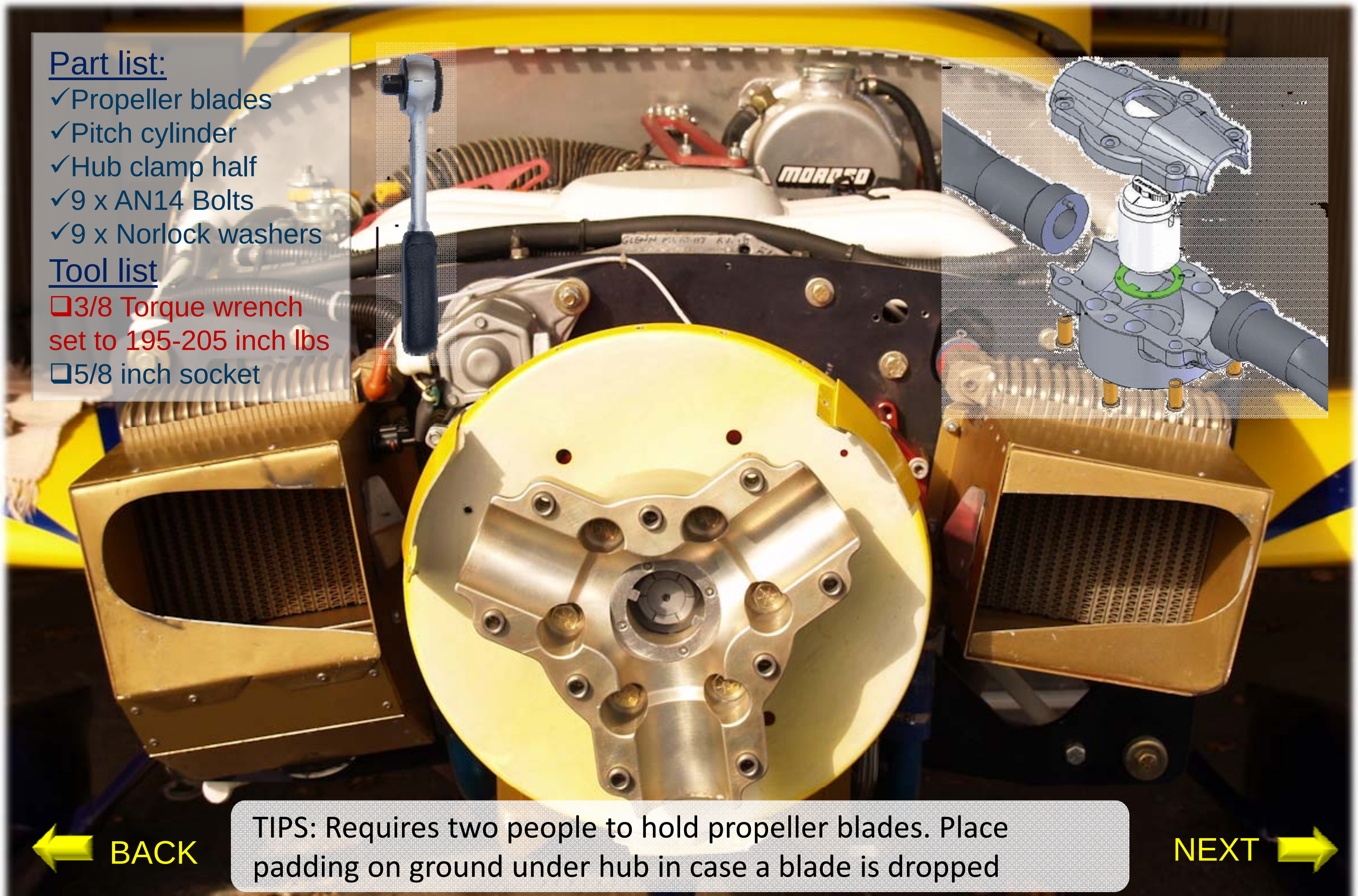


# Example: SRI Automotive Maintenance Guide

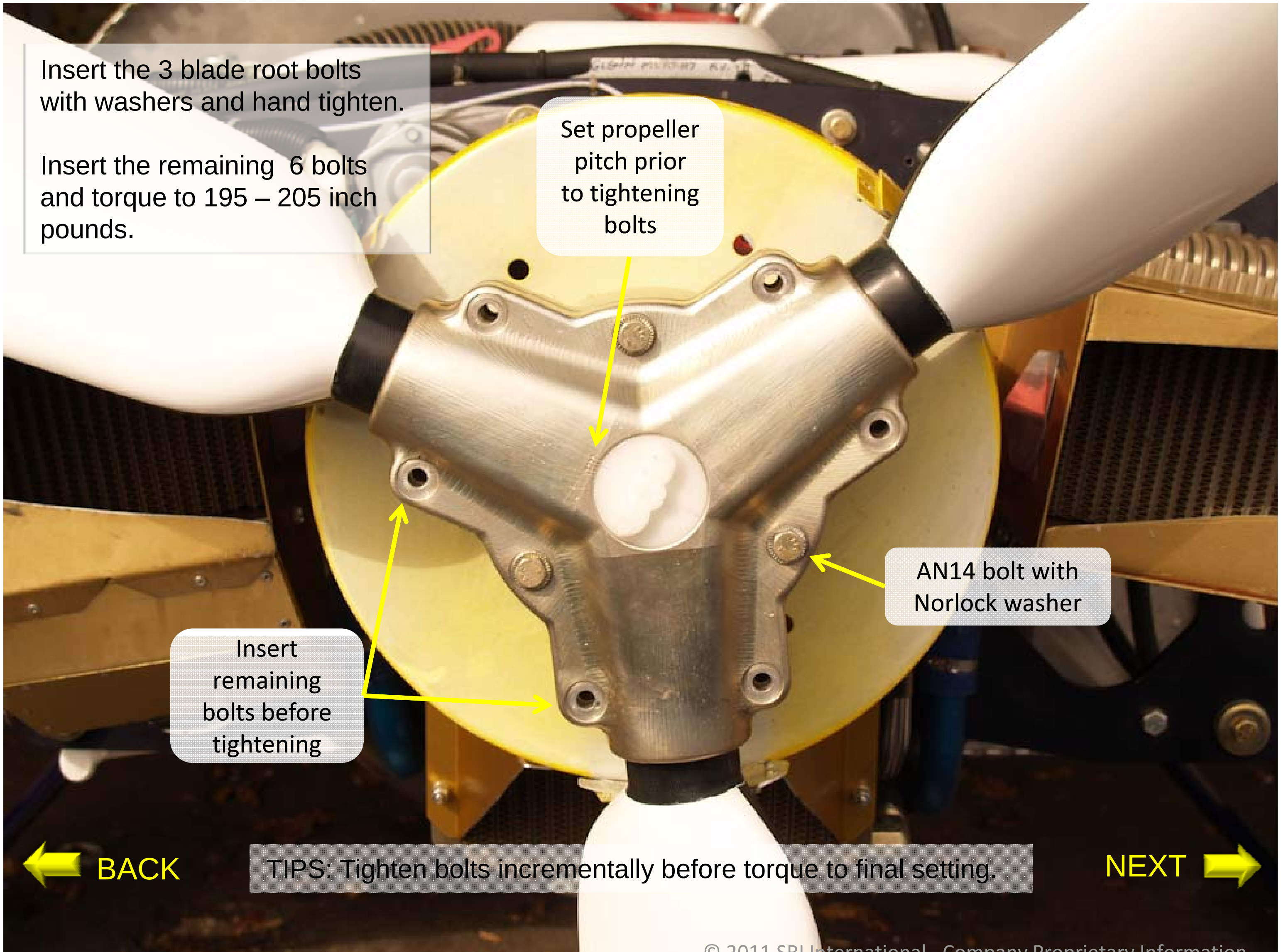


# Example: Airplane propeller installation

Check list for required parts and tools. Audible navigation.



# Example: Airplane propeller installation



# SRI key technologies for Augmented Reality Maintenance and Repair

- Augmented Reality
  - Markerless camera navigation
  - 3D reasoning and rendering of icons
  - Jitter and drift free placement of icons
- Automatic Performance Evaluation and Tutoring
  - Automatic Measurement of Performance
  - System cues trainee to correct behavior or next step to follow
  - Automatic identification of parts in vehicle with overlays
  - Sequence-by-Sequence overlay of tool use

# Columbia University: Case Study

## Augmented Reality for Maintenance Repair

LTC Steven Henderson,
Dr. Steven Feiner

Columbia Computer Graphics and User Interfaces Lab,
Columbia University, New York

http://graphics.cs.columbia.edu/projects/armar/index.htm

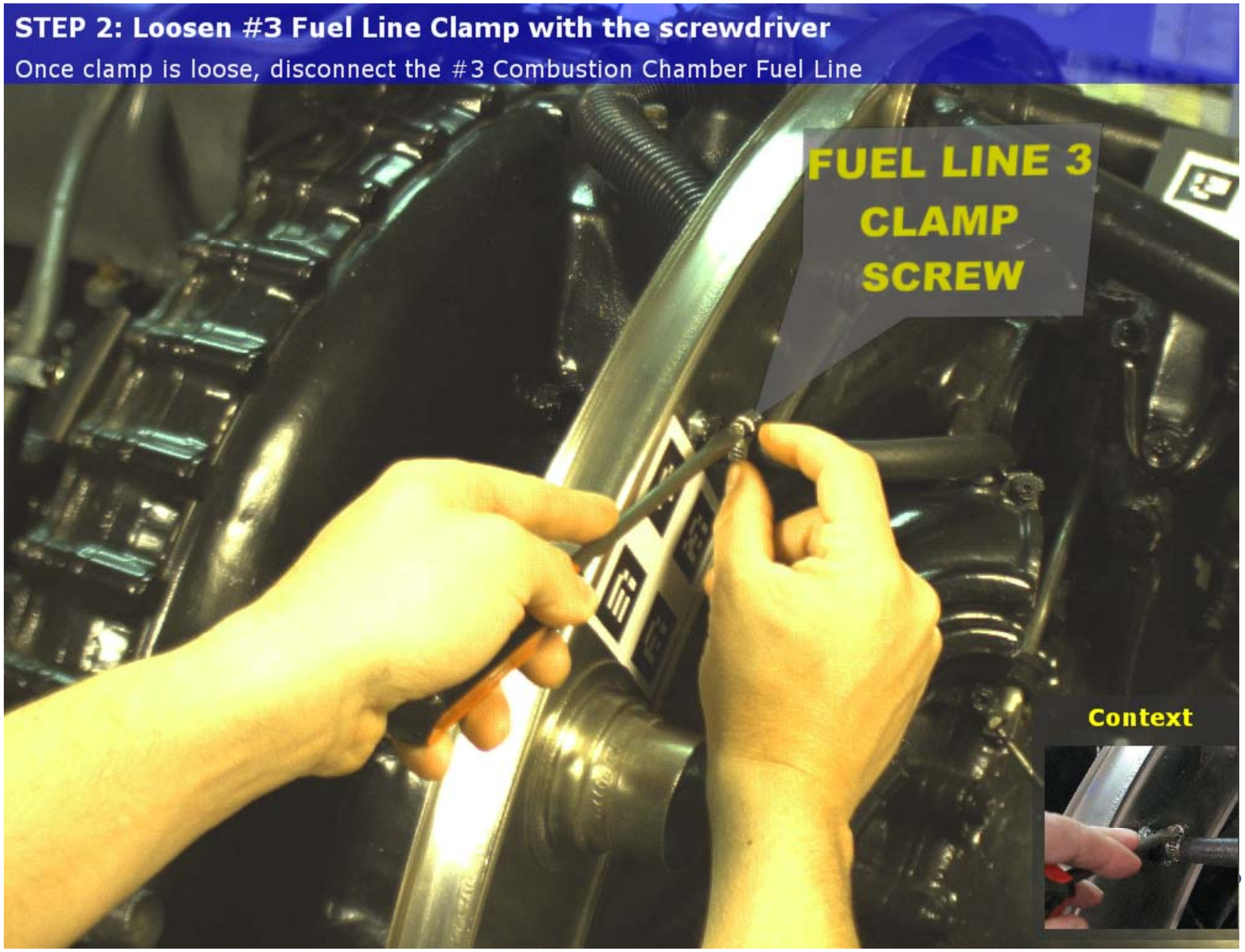
# Eyewear-Based Task Assistance

graphics.cs.columbia.edu/projects/armar

S. Henderson & S. Feiner, 2010

# Eyewear-Based Task Assistance

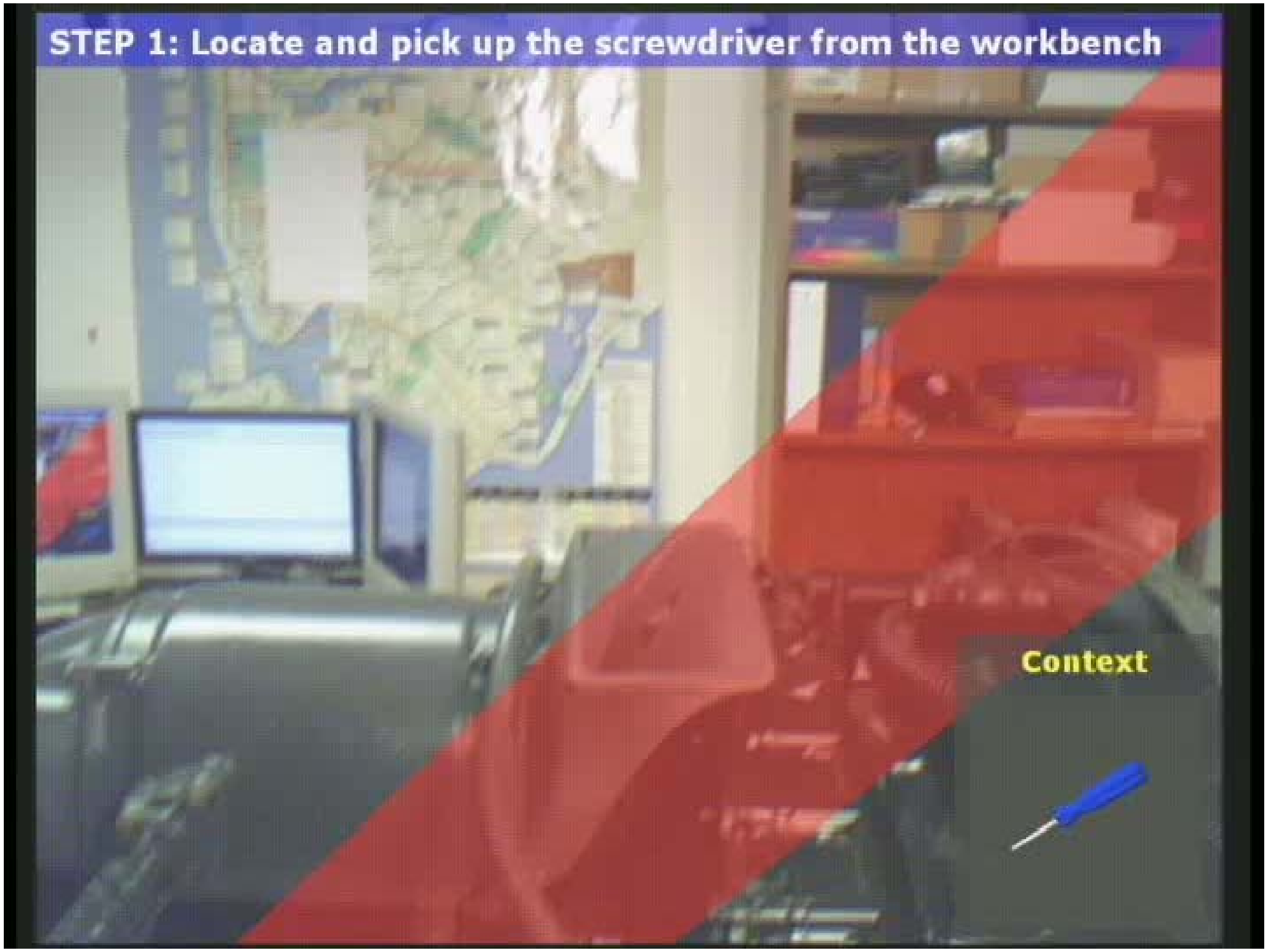
graphics.cs.columbia.edu/projects/armar




S. Henderson & S. Feiner, 2010

# Eyewear-Based Task Assistance

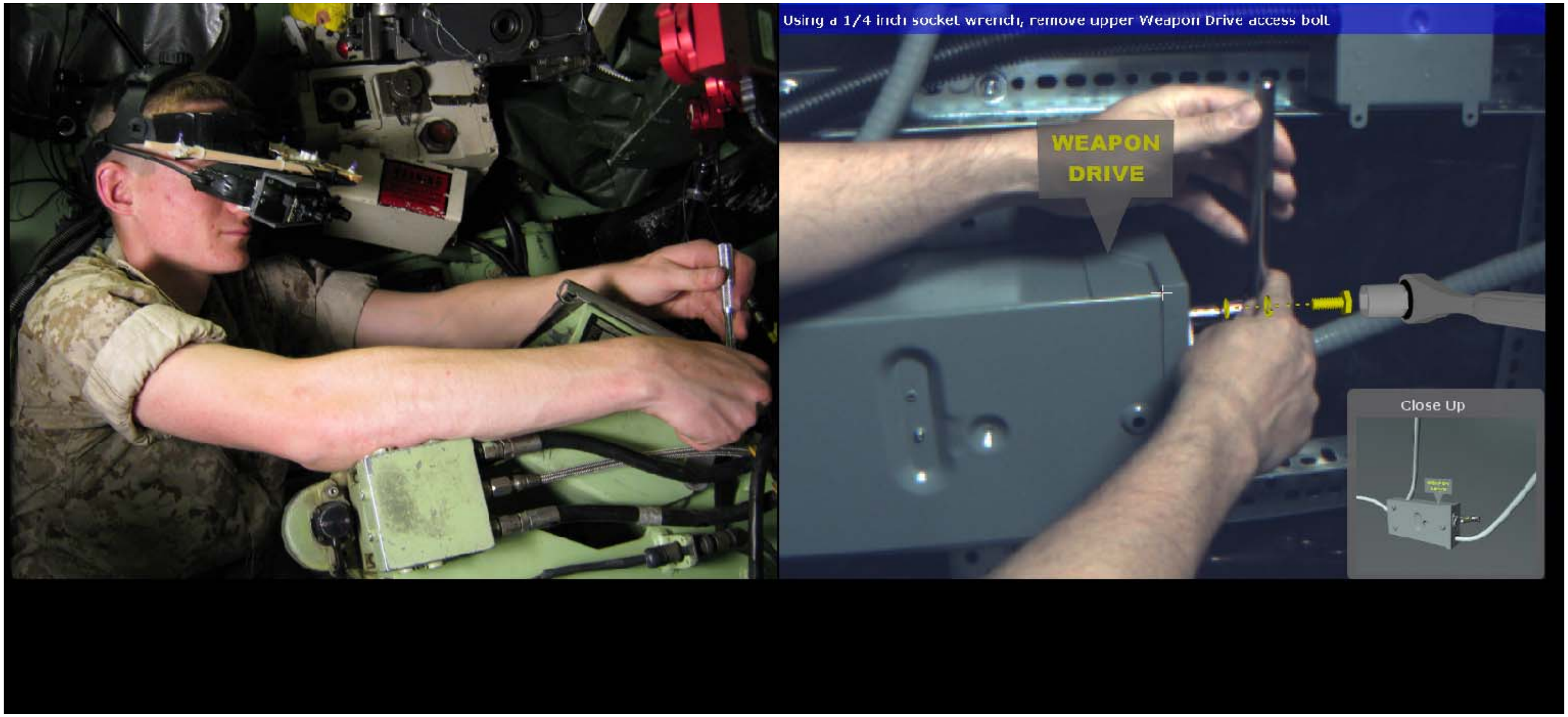
graphics.cs.columbia.edu/projects/armar




S. Henderson & S. Feiner, 2010

# ARMAR: AR for Maintenance and Repair

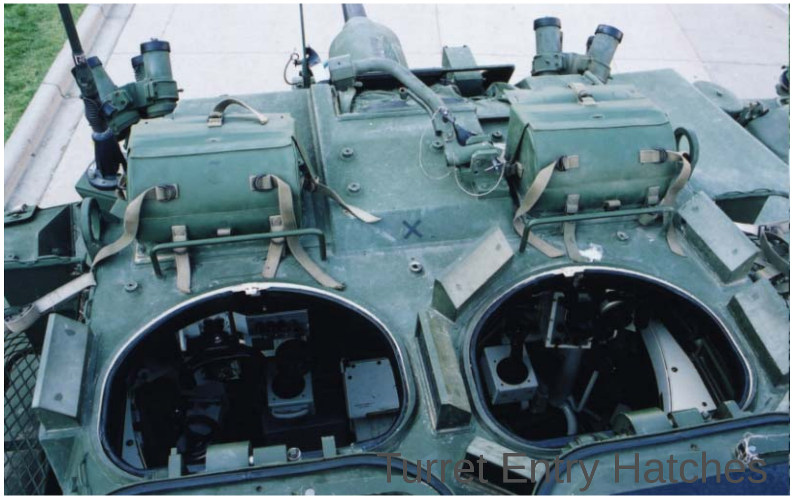
S. Henderson and S. Feiner, ISMAR 2009



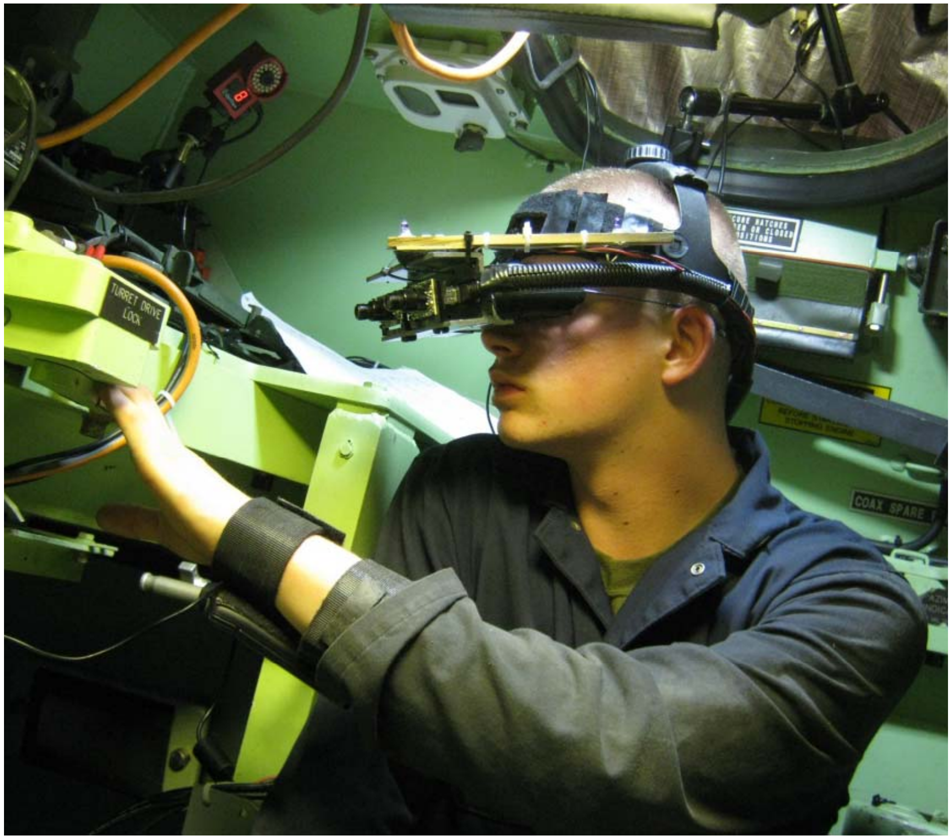

- User study of AR for task assistance

# ARMAR Domain: USMC LAV-25 A1 Armored Personnel Carrier Turret


– Funded by USMC/ONR




# ARMAR User Interface

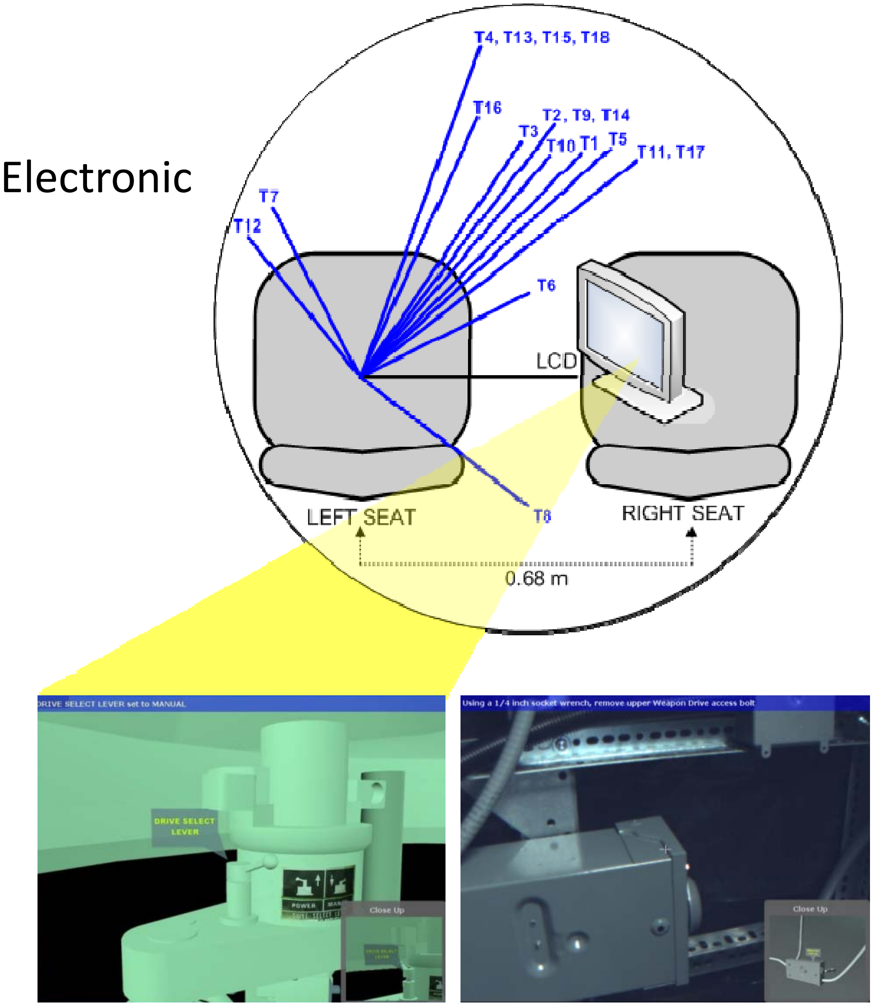



Head-worn
Head-tracked video see-though display

Wrist-worn
Android G1 controller

# ARMAR Study Tasks/Conditions

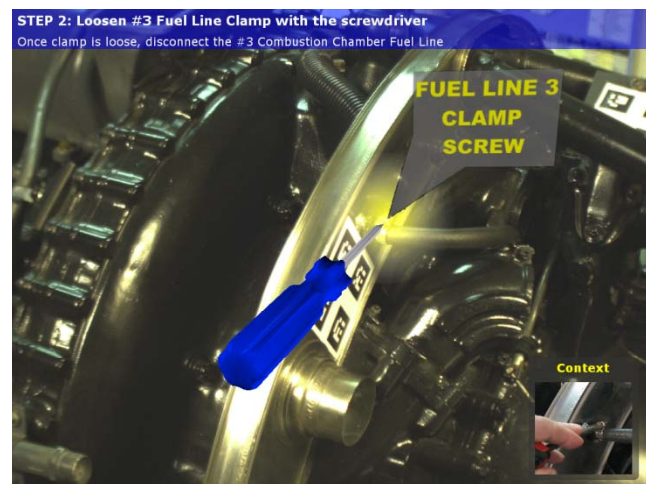
- 18 LAV-25 maintenance tasks
  - Actual tasks from IETM (Interactive Electronic Technical Manual)
  - Arbitrary ordering to mitigate familiarity/learning effects
    - Installation/removal
    - Setting switches/levers
    - Inspections
- Baseline comparison conditions
  - Fixed LCD Display (LCD)
  
    "Improved" IETM
  - Untracked HWD (HUD)




LCD Condition HUD Condition

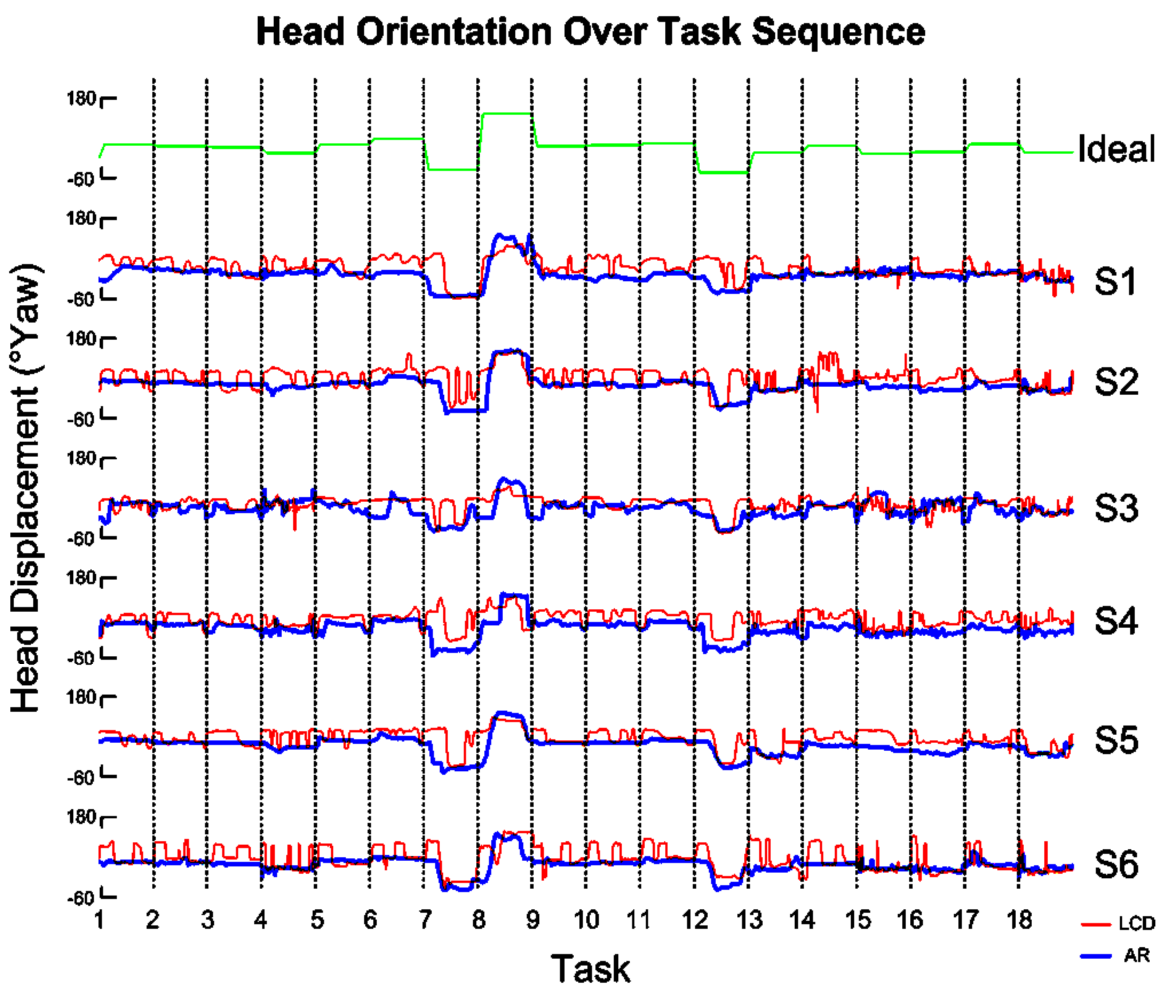
# ARMAR Study Design

- Within-subject design
- Counterbalanced start condition
- Fixed, arbitrary task sequence
- 6 participants (male, age 18–28), students in USMC LAV mechanic course at APG
  - 4 additional participants in pilot study



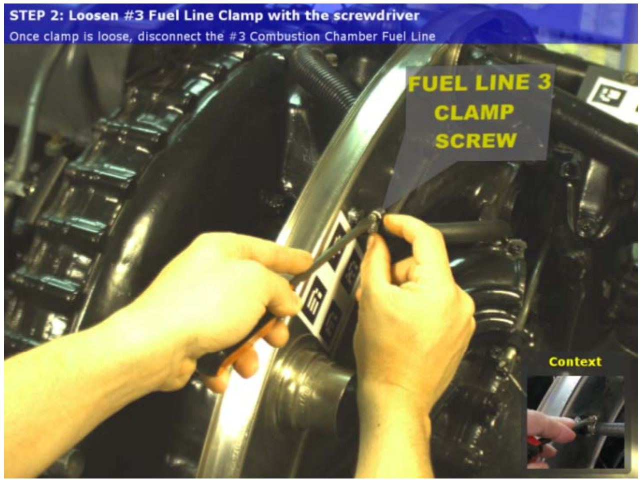
# ARMAR Study Results

- AR head orientation was closer to ideal than LCD head orientation

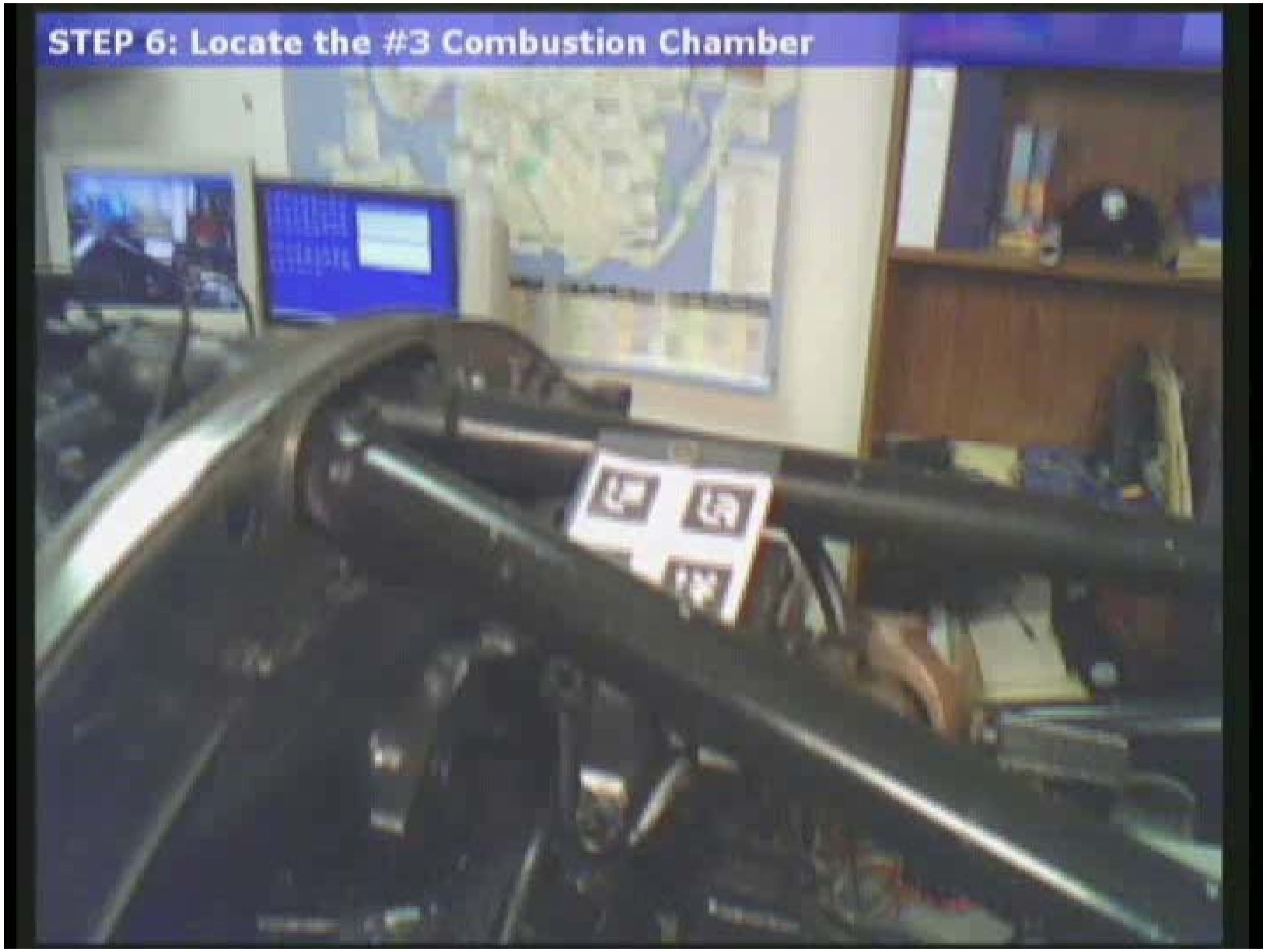


# ARMAR Study Results

- Localization of task was significantly faster in AR than in LCD or HUD
- Overall task performance was *not* faster in AR
  - Primarily due to the limited field of view HMD augmented reality eyewear used in the experiments.



# ARMAR Ongoing: Workpiece Task Assistance




S. Henderson & S. Feiner, 2010

# Augmented Reality Meets Training and Repair Needs By:

- Providing Low Cost Training Option
- Expedites Technician Service Readiness
  - Auto Industry Able to Prepare for New Products Faster
  - Military Personnel Able to Provide Field Support Faster
  - Faster Path to a Comprehensive Vocational Degree
- Improves Quality of Service (Fewer Errors) in Fields
- Can Support Rapid Prep for New Vehicle Sales and New Vehicle Deployments
- Vocational Colleges Can Leverage/Re-Use Auto/Military Modules for Students

# Augmented Reality for use in Repair and Training: Benefits to Client

- Reduces cost to repair. Step by Step Guidance. List of required tools and parts prior to starting the task.
  - Note: want to be certain an engine isn’t dismantled only to find a part is missing and now the work bay can’t be used until part is received.

- Enables client to diagnose and fix item correctly the first time.

- Provide Audit trail
  - Labor time and parts for billing
  - Record and print log book entries required for aircraft maintenance
  - Retain records for warranty coverage
  - Video recording of key steps for liability coverage
  - Retain diagnostic measurements for future repair of same vehicle –
    - Note: this is useful for items such as piston compression values –
    - Required for inspection of reciprocating aircraft engines to see if the compression has degraded over time indicating a potential engine failure.

# Conclusions

- Augmented Reality is coming into the marketplace
- First set of consumer applications will be based on Smartphones
- Ultimate Goal is to have users wear optical see through HMDs
  - Information is overlaid on the user's view-point to appear seamlessly blended with the real world scene
  - User is guided step-by-step on his tasks
- Associated technology is Personal Virtual Assistant
  - System monitors users actions
  - Suggests next set of actions.

SRI International

# End