Evaluation Parameters for 360-Degree Situational Awareness Systems on Military Ground Vehicles

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Introduction

• 360-Degree Situational Awareness (360 SA) Systems Offer Great Capabilities to Warfighters in the Field
  – Increase Combat Effectiveness
  – Increase Warfighter Safety
Introduction

• To Transition 360 SA Systems to the Field, Operationally Relevant Requirements Must Be Developed

• 360 SA Requirements Must Be Based Upon a Relevant Set of Evaluation Parameters in the Following Areas:
  – Vehicle-Mounted Visual Sensors
  – Data Transmission Systems
  – In-Vehicle Displays
  – Intelligent Cuing Technologies
  – Human Factors Considerations
Previous Work

• In 2008, CERDEC NVESD Worked with Industry to Build 360 (H) x 90 (V) Distributed Aperture System (DAS)
  – 33 Sensors: De-Warped, Stitched, and Fused in Real-Time
  – Color Day, Image Intensified, and Uncooled Infrared Imagers

• Integrated Onto the M2 Bradley Fighting Vehicle
  – Increased Soldier SA When Compared to Baseline Vehicle
  – Important Limitations:
    • Required Substantial Computational Capabilities
    • Cost-Prohibitive in Production
Previous Work

- IMOPAT ATO\(^1\) Established to Develop Cost-Effective 360 SA System for Ground Combat Vehicle (GCV)
  - **Objective:** Limit Per-Unit Cost to Ease Transition into the Field
  - **Included Capabilities:**
    - High-Resolution Sensors and Displays
    - Advanced Warfighter-Machine Interfaces (WMI)
    - Automated Control and Threat Cuing Algorithms
    - Occupant Workload Management Systems

\(^1\) Improved Mobility and Operational Performance through Autonomous Technologies Army Technology Objective
Vehicle-Mounted Visual Sensors

- Visual Sensors Are Fundamental Components of 360 SA
  - Detect, Recognize, and Identify Threats from Safe Distance
  - Used to Augment Other Sensors Upon Vehicle

- A Single Sensor Cannot Tend to Sometimes-Conflicting Requirements of Complete 360 SA System
  - Thus, Vehicle-Mounted 360 SA Systems Are Designed in Layers to Account for Conflicting Requirements
• **Detection Layer**
  – Set of Fixed, Wide FOV Sensors That Offer Simultaneous 360-Degree Coverage of Surrounding Environment

• **Interrogation Layer**
  – Set of High-Resolution, Narrow FOV Sensors That Interrogate Threats Discovered in Detection Layer

• **Broad-Area SA Layer**
  – Video Communication with Unmanned Aerial Systems (UASs), Unmanned Ground Vehicles (UGVs), and Other Assets
Vehicle-Mounted Visual Sensors

[Evaluation Parameters]

- **Simultaneous Field of View:** The FOV that a 360 SA System Concurrently Obtains Across All Sensors Upon Vehicle

- **Sensor Field of View:** FOV of Single Sensor in 360 SA System
  - Fundamental Trade-Off Between Sensor FOV and Range Performance

- **Range Performance:** The Maximum Distance of a Target from Imager At Which an Observer Can Conduct Discrimination Task

- **Ground Intercept:** The Nearest Intercept of a Sensor’s Cone of Vision with the Ground
Data Transmission Systems

- Data Transmission Systems Transfer Information from One Component of 360 SA System to Another
  - Example: Visual Sensor to In-Vehicle Display

- Analog Systems Provide Acceptable Reliability, Ease of Integration, and Latency
  - Drawbacks: Limited Resolution & Video Processing Capabilities
Data Transmission Systems

• 360 SA Systems Aim to Adopt Digital Video Architectures
  – New Limitations: Greater Bandwidth and Latency Constraints

• Despite Limitations, Digital Video Offers Opportunities to Provide Advanced Capabilities:
  – Discriminate Threats via Intelligent Cuing Technologies
  – Identify Potential Improvised Explosive Devices
  – Record Visual Sensor Information for Future Analysis
  – Share Video Information with Other Battlefield Resources
### Data Transmission Systems

#### [Evaluation Parameters]

- **Bandwidth**: The Amount of Information That Can Flow Between Components of a Given 360 SA System

- **Latency**: Delay from the Moment Event Is Captured by a Sensor to the Moment It Appears on an In-Vehicle Display
  - Should Be Below *80 Milliseconds*

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In-Vehicle Displays

- **In-Vehicle Displays Are Vital Components of 360 SA**
  - Display Warfighter-Machine Interface to Vehicle Occupants
  - Provide Interface to 360 SA Video Sensor Imagery
  - Provide Interface to Vehicle Diagnostic and Management Functions

- **Display Resolution Must Match or Exceed Sensor Resolutions**
  - Advanced Sensors Cannot Be Fully Utilized Without Adequate Displays
In-Vehicle Displays
[Evaluation Parameters]

- **Screen Size**: The Physical Dimensions of the In-Vehicle Display
  - Constrains the Capabilities of the Warfighter-Machine Interface

- **Screen Resolution**: The Number of Pixels within the Vertical and Horizontal Components of the In-Vehicle Display
  - Must At Least Match the Resolution of Vehicle-Mounted Sensors

- **Brightness and Contrast**: Must Be Chosen to Maximize Warfighter Ability to Visualize Sensor Imagery
  - Brightness: The Maximum Luminance of In-Vehicle Display
  - Contrast: The Ratio of Brightest to Darkest Color That Display May Produce
Intelligent Cuing Technologies Aim to Minimize Cognitive Load Upon Warfighters:
- Draw Warfighters’ Attention to Potential Enemy Combatants, Improvised Explosive Devices, and Other Battlefield Threats
- Classify the Threat Level of Detected Objects
- Identify Road Edges or Traversable Off-Road Terrains
Intelligent Cuing Technologies

• Intelligent Technologies Are Often Unreliable
  – Inherently Based Upon Statistical Methods
  – Rely Upon Noisy Sensors in Unstructured Environments

• Intelligent Systems Require High Computational Capabilities
  – Directly Impacts Latency Requirements
Intelligent Cuing Technologies

[Evaluation Parameters]

• **Probability of Correct Detection**: The Probability That a System Correctly Detects the Event for Which It Was Designed
  – *Perfect Detection Unrealistic*
  – Yet, Cannot Be So Low As to Render System **Ineffective**

• **False Alarm Rate**: The Rate at Which a System Misrepresents a Non-Event as an Event for Which It Was Designed
  – *Perfect False Alarm Rate Unrealistic*
  – Yet, Cannot Be So High As to Render System **Unreliable**

• **Computational Load**: The Computational Capabilities Required to Drive Intelligent Cuing Algorithm
  – Must Minimize Burden on *Support Systems* and Maintain *Latency Requirements*
Human Factors Considerations

- Cognitive Load Must Be Minimized through Effective WMIs
  - WMIs Provide Access to 360 SA Capabilities
  - Must Be Simple to Use

- Human Factors Research Has Brought About Development of Standard Metrics to Assess WMI Effectiveness
  - Helps to Ascertain the Ease and Quickness with Which the Warfighter Interacts with 360 SA System
Human Factors Considerations
[Evaluation Parameters]

- **Probability of Correct Identification**: Represent the User’s Ability to Correctly Identify a Target in a Given Environment
  - Constraints: Environmental Stressors, Visual Display Characteristics, Decision Aids, and User Training Modules

- **Glance Time**: The Time a User Needs to Visually Sample a Scene through the WMI

- **Movement Time**: The Time a User Needs to Manipulate a Control Within the WMI

- **Reaction Time**: The Time Elapsed Between the Onset of Warfighter Stimulus and His Response
Goals

Develop *Indirect Vision* and *Drive by Wire* Systems that Provide Electro-Optic Indirect Vision Based **Local Situational Awareness** and **Mobility Capabilities** At or Above the Performance Levels of Direct Vision Mechanical Drive Systems and to Enhance High-Definition Cognition Technologies to Dynamically Manage Workload to Increase Operational Performance on Future Platforms.

Objective

TARDEC-Led IMOPAT ATO Contains CERDEC-NVESD, ARL-HRED, and NSRDEC as Joint Partners to Mature **Visual Sensor Suites**, **Human Integration**, and **Assisted Mobility Technologies** in Three Phases of Evolution:

- **Baseline:** Establish Initial *Indirect Vision Driving (IVD)* and *360-Degree Local Situational Awareness (LSA)* Capabilities.

- **Enhanced:** Increase IVD and LSA Capabilities.

- **Advanced:** Integrated State-of-the-Art IVD and LSA System that Provides “Secure Mobility Capability”.
• 360 SA Systems Upon Other Vehicle Platforms Have Similar Designs, Characteristics, and Requirements
  – Yet Generally, Development Efforts Are Largely Independent

• Years of Trial and Experimentation Have Promoted Standard 360 SA Design Practices
  – Increased Collaboration Between Technical and Military Operational Experts Now Required to Develop Standard Requirements
Questions?

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