National Workshop
on Highway Asset Inventory and Data Collection
Durham, North Carolina

# ***Digital Highway Measurement System***
## *In Revised Role, Vision, & Approach*

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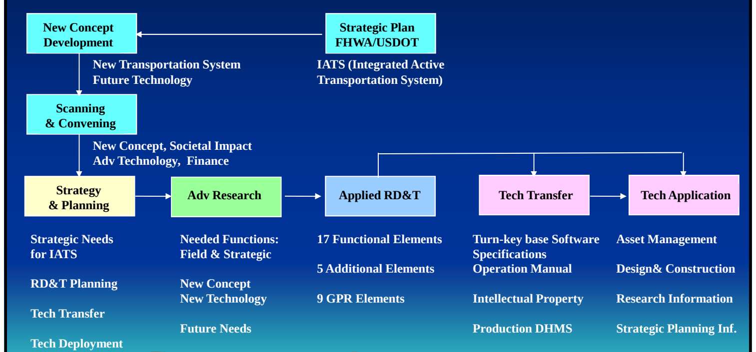
September 25, 2008

## A. Overview
## Digital Highway Measurement System Development

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## B. Digital Highway Measurement System
- Functional Elements -

- **Establishing the Reference System**
  Vehicle position established, DHM measurement relative to vehicle, Measurements transformed to ground reference frame, Control line established fixed to ground
- **Roadside Geometry**
  Horizontal and vertical alignment, cross-slope and super elevation, pavement width
- **Pavement Condition**
  Roughness, Macro-texture, Joint faults
- **Roadside Features and Inventory**
  Shoulder characters, Roadside profile, Locate and identify signs, barriers, luminaire supports, etc., vertical clearance
- **Sub-Surface Condition** (for the next conference)

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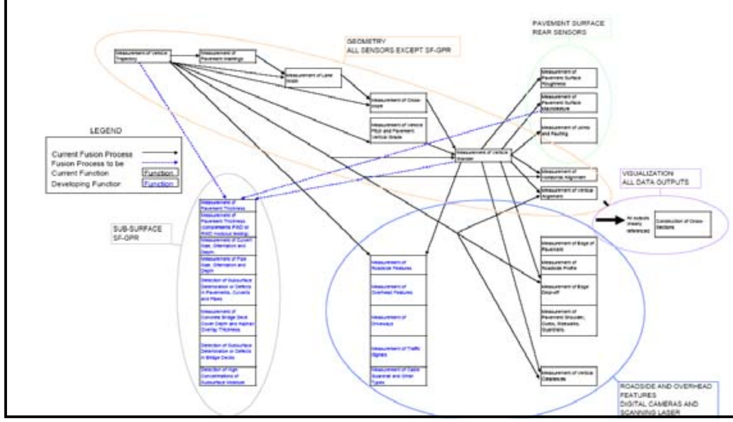
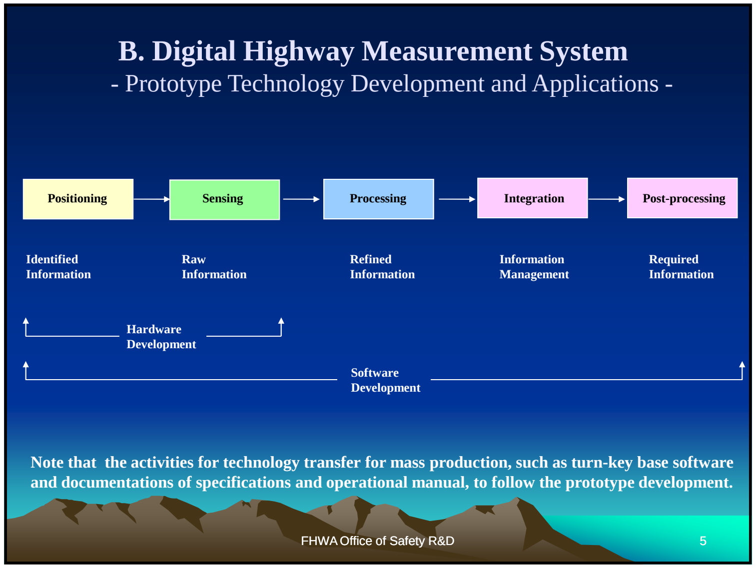
## B. Digital Highway Measurement System
- Development Process -




B. Digital Highway Measurement System
- Prototype Technology Development and Applications -
Positioning
Sensing
Processing
Integration
Post-processing
Identified Information
Raw Information
Refined Information
Information Management
Required Information
Hardware Development
Software Development
Note that the activities for technology transfer for mass production, such as turn-key base software and documentations of specifications and operational manual, to follow the prototype development.
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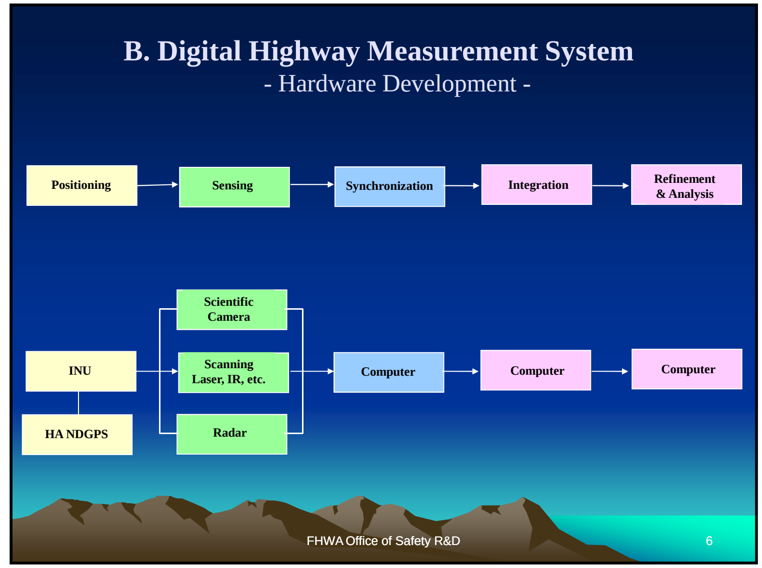
B. Digital Highway Measurement System
- Hardware Development -
Positioning
Sensing
Synchronization
Integration
Refinement & Analysis
Scientific Camera
INU
Scanning Laser, IR, etc.
Computer
Computer
Computer
HA NDGPS
Radar
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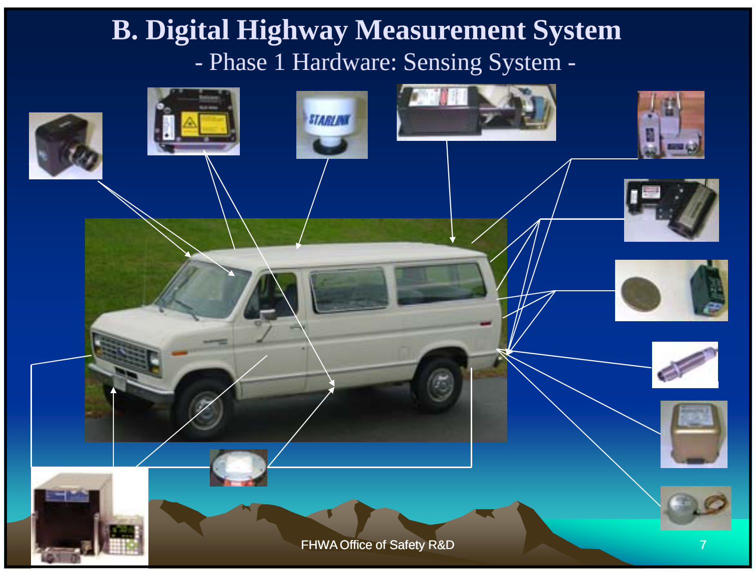
B. Digital Highway Measurement System
- Phase 1 Hardware: Sensing System -
STARLINK
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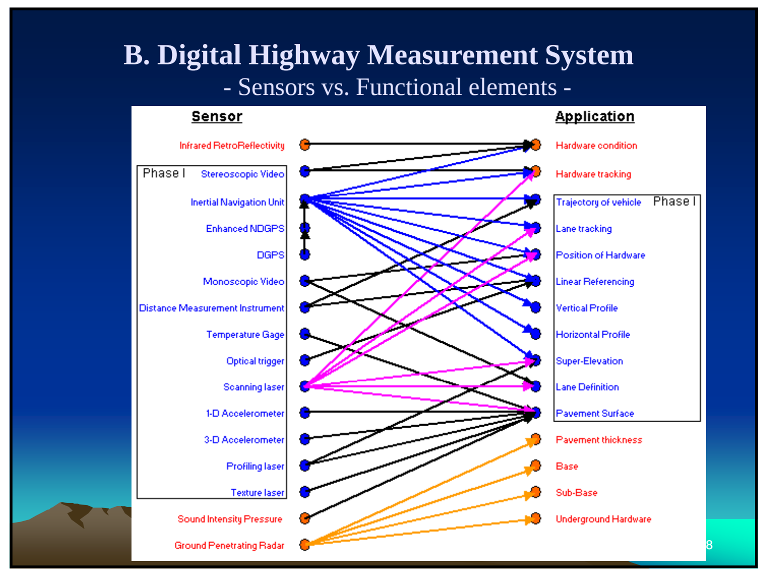
B. Digital Highway Measurement System
- Sensors vs. Functional elements -
Sensor
Application
Infrared RetroReflectivity
Phase I
Stereoscopic Video
Inertial Navigation Unit
Enhanced NDGPS
DGPS
Monoscopic Video
Distance Measurement Instrument
Temperature Gage
Optical trigger
Scanning laser
1-D Accelerometer
3-D Accelerometer
Profiling laser
Texture laser
Sound Intensity Pressure
Ground Penetrating Radar
Hardware condition
Hardware tracking
Trajectory of vehicle
Phase I
Lane tracking
Position of Hardware
Linear Referencing
Vertical Profile
Horizontal Profile
Super-Elevation
Lane Definition
Pavement Surface
Pavement thickness
Base
Sub-Base
Underground Hardware
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## B. Digital Highway Measurement System
- Technical Advantages-

- **Integrated Data Collection at Highway Speed**
  - Static Features On, Over, and Under the Ground
- **Accuracy & Reliability**
  - Positioning (without GPS), Retro-visibility, Range, etc.
- **Qualitative Features**
  - Synchronization and Fusion of sub-system outputs
  - Signal Processing and Pattern Recognition on sensor base, including image processing in stereoscopy
- **Quantitative Aspects**
  - Increased repeatability, reliability, and resolution



## B. Digital Highway Measurement System
- Technology Applications -

- **Asset Management**
  a. Build Planning: Road Geometry, Pavement, Signs, Signals, etc.
  b. Pavement Inspection and Repair: Failed Road and Prediction of Road Failure
  Pavement Life with Temperature and Sound Pressure,
  Vehicle Stability with Frictions between the road and the tire
  c. Underground Information: Pavement Thickness, Underground Hardware, etc.
- **Planning, Engineering Design, and Construction**
  Road Geometry, Pavement Life, Marking, Intersection Safety, Driver Visibility, Roadway Signs, Turn Signals, etc.
- **Research Information**
  Traffic Density, Vehicle Stability on the road, Driving Simulator, etc.
- **Strategic Planning Information**
  Road Information for Planning and Strategy of IATS



## B. Digital Highway Measurement System
- Technology Transfer -

- **Pooled Fund Research**
  a. Research Activities to improve DHM System Technology
  b. Road Data Collection & Analysis:
  1) Infrastructure Maintenance, Condition improvement, Failure prediction, and Design and Construction
  2) Optimization of Driving Conditions
- **License Agreement**
  a. Commercialization of DHM Technologies
  b. Usage of Specific Research Tools such as the GPR System
- **Joint Program Development through Contracts**
  a. Highway Safety Research
  b. Infrastructure Engineering, Design, and Build



## C. Future Digital Highway Measurement System
- Master Plan -

| | Phase 1<br>Static Features<br>09/03 ~ 05/ 06 | Phase 1.a.<br>Static Features<br>05/06 ~ 08/10 | Phase 1.b.<br>Commercialization<br>09/06 ~ 08/10 | Phase 2<br>Transient<br>01/10 ~ 1213 | Phase 3<br>Dynamic<br>01/14 ~ 12/19 |
|---|---|---|---|---|---|
| Strategy & Concept | 1. On/Over the Ground with 17 elements | 1. Add'l 5 elements<br>2. Under the Ground with 9 elements | 1. Complete Static Feature with additional elements<br>2. 3D-GPR, IR<br>3. Quality & Reliability | | |
| RD&T | 1. A Brief of Algorithm Process | 1. HW Improvement<br>2. Image Processing<br>3. Laser to LiDAR<br>4. Radar to LADAR<br>5. 3D-GPR | | | |
| Tech Transfer | | | 1. Turn-key base Software<br>- All Platforms<br>- Source Codes<br>- Algorithm Process<br>- Data Analysis<br>2. Specifications<br>3. Operation Manual<br>4. Production DHM | | |
| Tech Deploy | 1. DHM System for Road Data & its Analysis | 1. DHM System<br>2. ULIP<br>3. 3-D GPR System | 1. Rodeo – TRB<br>2. Rodeo – NC<br>3. Demo – State DOT | | |

## C. Future Digital Highway Measurement System
- Advanced Research -

- **Advancing with Current Technology:**
  1. Complete Integration of Research Algorithms
  2. to address 17 current DHM-Functions
  3. and 5 additional DHM and 9 new GPR functions
  4. including Image Processing, Software integration, etc.
- **To develop Next-Generation Technology**
  1. Basic Technology for DHMS Improvement
     Computer Storage and Processing, Sensing, Data Processing, Image Processing, Data Management, etc.
  2. New Technology from Private Institutions
  3. Technology for Future Needs (IATS Implementation)



## D. Appendix
- Detailed Functional Applications -

- **Establishing the Reference System**
  **a.** Vehicle position established in a ground ref. frame
  - HA ND GPS: Initial position
  - INU: maintain position
  b. Sensors establish the positions and orientations of the objects of interest w.r.t. the vehicle
  c. Measurements transformed to ground reference frame
  d. Pavement marking, vehicle wander, lane width, vehicle pitch, vehicle trajectory from INU and DMI data



## D. Appendix
- Detailed Functional Applications -

- **Roadside Geometry**
  - Horizontal and vertical alignment
  - Cross-slope and super elevation
  - pavement width
- **Roadside Features and Inventory**
  - Edge drop-off, roadside profile, pavement shoulder
  - Locate and identify signs, barriers, luminaire supports, etc.,
  - Vertical clearance



## D. Appendix
- Detailed Functional Applications -

- **Pavement Condition**
  1. Roughness:
     Using rear mounted profiling laser and accelerometers, an inertial profile can be computed and processed with the Internal Roughness Index (IRI) ride quality algorithm

     The highway geometry vertical profile can also serve as a profile source for the IRI algorithm
  2. Macro-texture:

## D. Appendix
- Detailed Functional Applications -

- **Pavement Condition**
  1. Roughness:
  2. Macro-texture:
     LMI Selcom 2008 macro-texture lasers compute mean profile depth (MPD) using the ASTM E1845 algorithm or the proprietary ROSAN algorithm

     Uses for texture data include aggregate segregation analysis, and noise and friction estimate
  3. Joint faults:

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## D. Appendix
- Detailed Functional Applications -

- **Pavement Condition**
  1. Roughness:
  2. Macro-texture:
  3. Joint faults:
     LMI Selcom 2008 macro-texture lasers identify and measure transverse joints and faulting at the joints. Joint width, depth, and spacing are determined from the 1mm spaced texture data.

     Faulting data can be used as one measure for pavement condition indices.

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## D. Appendix
- Detailed Functional Applications -

- **Sub-Surface Condition**
  1. Ground Penetrating Radar creates 3-D Map
     a. Sub-surface feature detection, measurement, and imaging
     - Output is a series of longitudinal sections
     - Plan views of GPR results can be generated by combining elevation plots and cross sections
  2. Technology

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## D. Appendix
- Detailed Functional Applications -

- **Sub-Surface Condition**
  1. Ground Penetrating Radar creates 3-D Map
  2. Technology
     a. Data collection
     - large antennas operate over the full bandwidth of the system, while small or medium ones over a fraction of the system bandwidth
     - use 3 or more full bandwidth antennas. Each collects depth profiles at full range of depths.

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## D. Appendix
### - Detailed Functional Applications -

- **Sub-Surface Condition**
  1. Ground Penetrating Radar creates 3-D Map
  2. Technology

     b. Data Processing

     - Detailed images of pavement materials, deterioration, and condition, including moisture gradient under pavement
     - measure pavement thickness and key features in data using 1-D layer stripping method, and refine the data using 2-D or 3-D migration methods
     - Step-Frequency Radar covers substantial bandwidth, and increases post processing efficiency
     - Specific frequencies can be notched out of emitted spectrum to avoid interference with other nearby receivers

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Thank You !

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