Naturalistic Driving: Need, History and Some Early Results

Tom Dingus

Driving Transportation with Technology

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A New Method of Study: Large-Scale Naturalistic Driving

- 20 to 2500 drivers
- No instructions
- 6 mos. to 3 yrs.
- 10,000's of hours
- Many MVMT

An Historical Perspective

"During the period beginning in 1989 and extending through 2005, NHTSA and FHWA were key players in establishing the importance of studies incorporating Naturalistic Driving as a vital element of driver-based data collection. The development and application of the concept was based on the recognition that Naturalistic Driving studies were the most effective and accurate means of obtaining relevant and meaningful data directly applicable to safety issues the Agencies were attempting to address. The evolution of the "concept" paralleled a series of issues-based studies and associated analyses directed at characterizing driver behavior and performance in the "real world", and was facilitated by the increasing prevalence of in-vehicle technology and NHTSA's efforts directed at making significant improvements in techniques and technology for unobtrusively collecting data on driver behavior and performance in a naturalistic setting."

Mike Goodman, NHTSA (retired)

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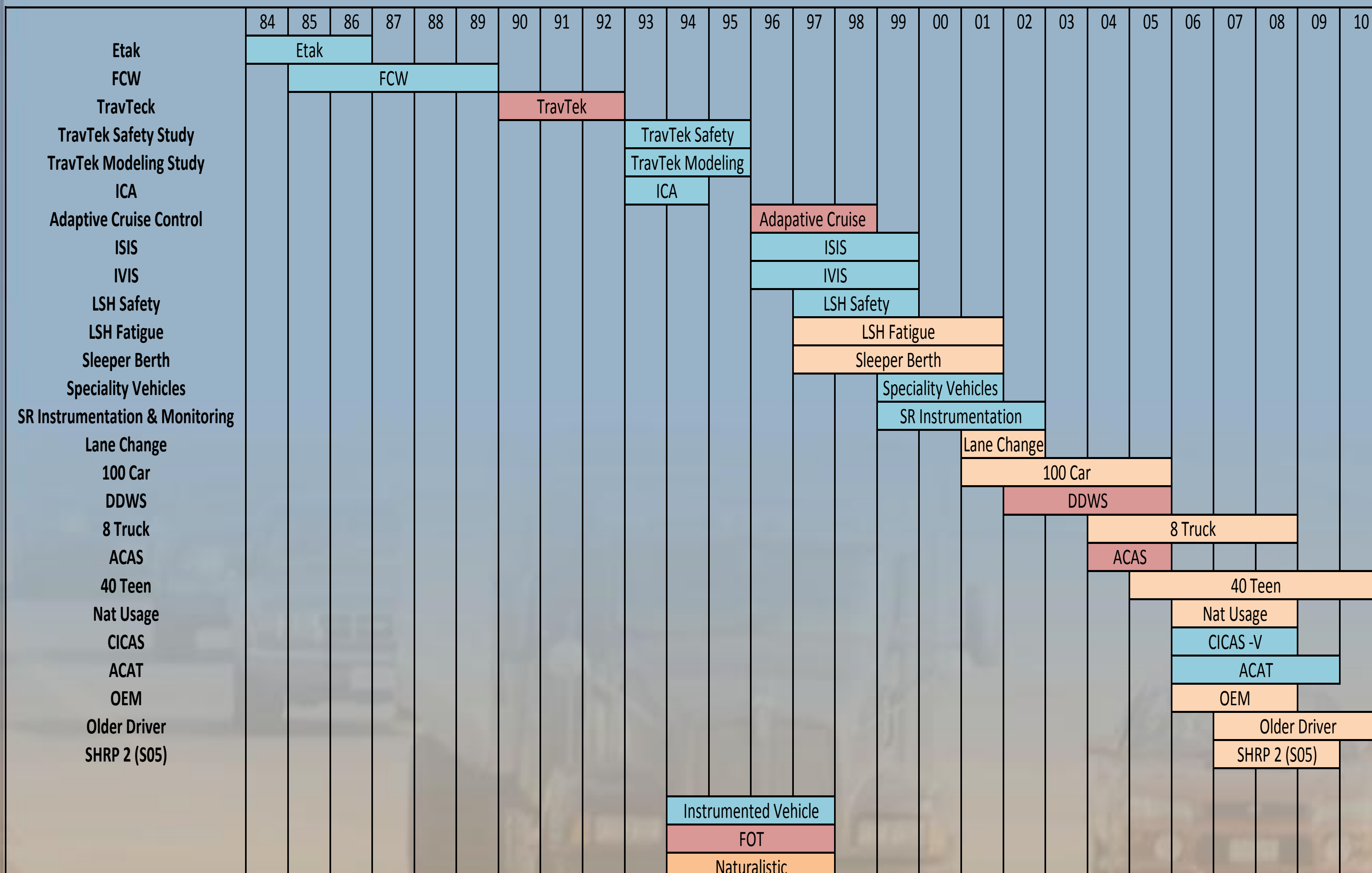
Relevant NHTSA Projects and Programs

- Inventory of Heavy Vehicle Technology
- Heavy Vehicle Driver Workload
- Preliminary Investigation of the Safety Implication of Cellular Phone Use in Vehicles
- Data Acquisition System for Crash Avoidance Research (DASCAR/Micro-DAS)
- Naturalistic Lane-Change Field Data Reduction, Analysis, and Archiving: A Comprehensive Examination of Naturalistic Lane-Changes
- Analysis of Distribution, Frequency, and Duration of Naturalistic Lane-Changes
- Proposed Operator On-Road Assessment and Comprehensive Longitudinal Evaluation (ORACLE)
- Heavy Vehicle Naturalistic Driving Study
- The 100 Car Naturalistic Driving Study
- Voice-Based Interface Characteristics, Hands-Free Issues, and Their Effects on Driver Distraction

Relevant NHTSA Projects and Programs (con'd)

- The 100 Car Naturalistic Driving Study
- Voice-Based Interface Characteristics, Hands-Free Issues, and Their Effects on Driver Distraction
- The Relationship Between On-Road Wireless Phone Use and Crashes (Unpublished)
- A Preliminary Assessment of Algorithms for Drowsy and Inattentive Driver Detection on the Road
- Wireless Phone Research: Driver Distraction and Use Effects on the Road
- NHTSA Driver Distraction Public Meeting/Internet Forum
- A System for Automated Analysis of Driver Glance Videos- Phase II

U.S. Driving Studies



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The Issues at Hand

- Human performance and behavior contribute to over 90% of vehicular crashes.

- Roughly 10% of drivers account for almost 50% of the crash risk. Why?
  - impairment (due primarily to alcohol)
  - inattention and distraction
  - drowsiness
  - judgment-related error.

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Naturalistic Data Collection Approach

Highly capable instrumentation (well beyond EDRs)

- Multiple channels of digital, compressed video
- Multiple radar sensors front, rear and/or side
- Machine vision-based lane tracker
- Many other sensors: GPS, glare, RF, acceleration, yaw rate, controls, etc.
- Cell phone, wireless internet, or hardwire download
- Ties into vehicle networks to obtain other information

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Data based upon Police Accident Reports

Well meaning, nominally trained police officers coming upon a scene is the source of much of our data

- Vehicles have often been moved
- Drivers/Passengers may be deceased or injured
- Drivers/Passengers are almost always dazed
- Pre-crash events happen so fast key elements are forgotten by driver/passenger and left out by witnesses
- Drivers sometimes purposely deceive police officers to avoid prosecution or embarrassment
- Driver/Passengers may not be looking in the correct location to see critical information (vision is not omnipresent)

Example: What are the contributing factors?

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- Precise knowledge about crash risk
- Information about important circumstances and scenarios that lead to crashes

Epidemiological Data Collection

- Reactive
- Very limited pre-crash information

Large-Scale Naturalistic Data Collection

- "Natural" driver behavior in full driving context
- Detailed pre-crash/crash info including driver performance/behavior, driver error and vehicle kinematics
- Can utilize combination of crash, near crash and other safety surrogate data

- Proactive
- Provides important ordinal crash risk info

Empirical Data Collection

- Imprecise, relies on unproven safety surrogates
- Experimental situations modify driver behavior

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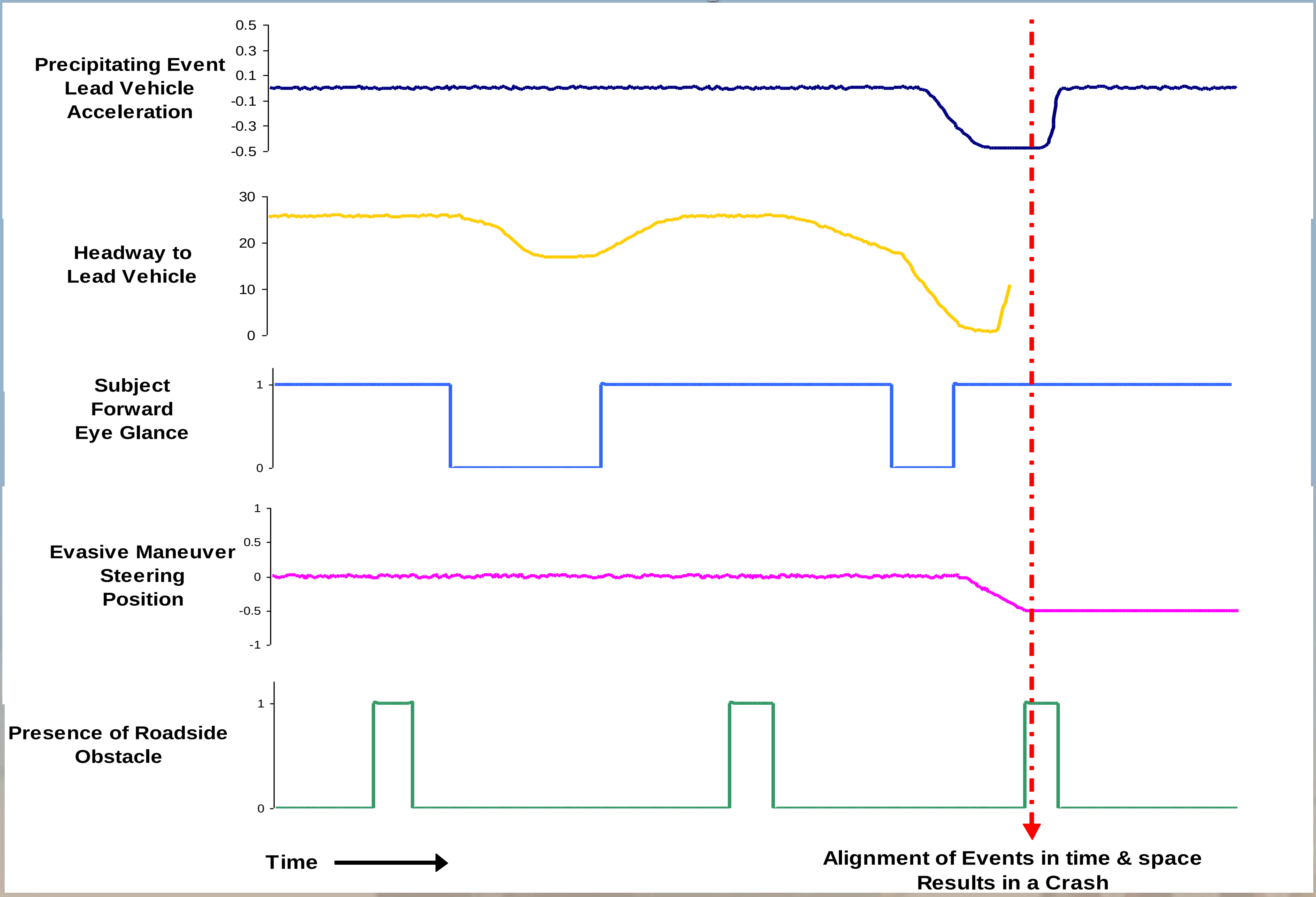
Multi-Linear Events Sequence: Pole Crash



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Lead Vehicle Conflict/Road Departure

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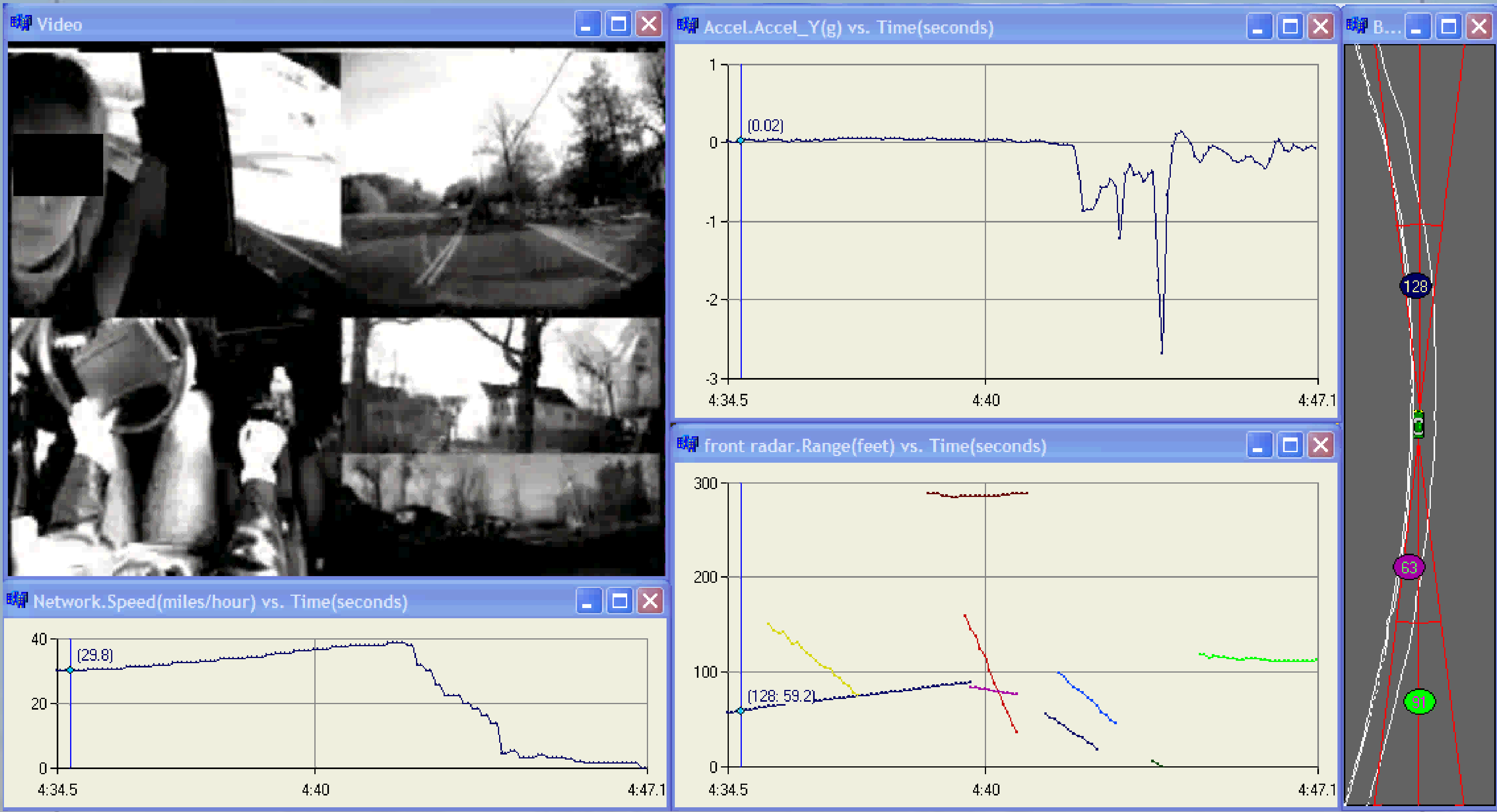

Video
Accel.Accel_Y(g) vs. Time(seconds)
B...
Network.Speed(miles/hour) vs. Time(seconds)
front radar.Range(feet) vs. Time(seconds)
(0.02)
(29.8)
(128; 59.2)
4:34.5
4:40
4:47.1
128
63
91

VTTI instrumentation history: 1984

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RESEARC
VEHICLE
MICHIGAN
611 NBE
GREAT LAKES

Instrumented Vehicles 1995-2000

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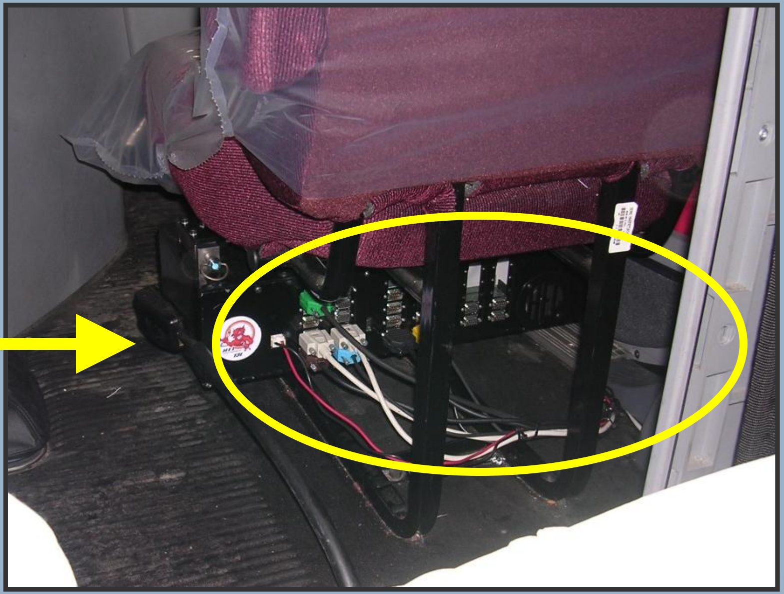
Instrumentation 2001-2007

Data collection system box

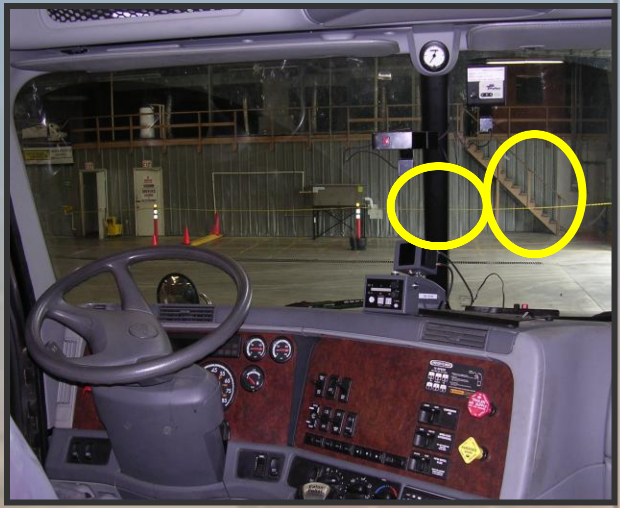
under passenger's seat



Front Radar

Rearward Camera

Face & Forward Cameras



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100 Car Instrumentation Mounted in Trunk

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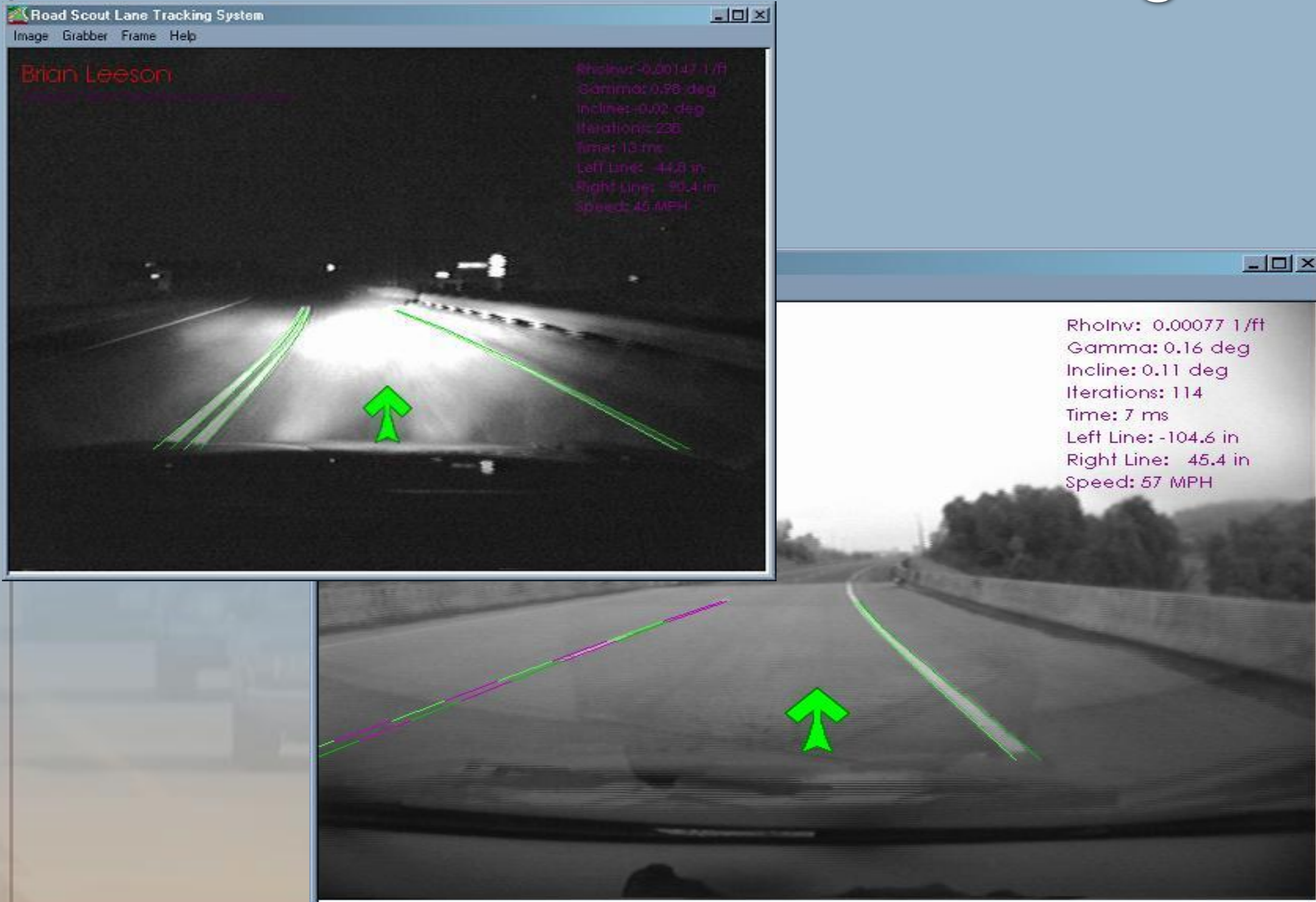
Machine Vision Lane Tracking



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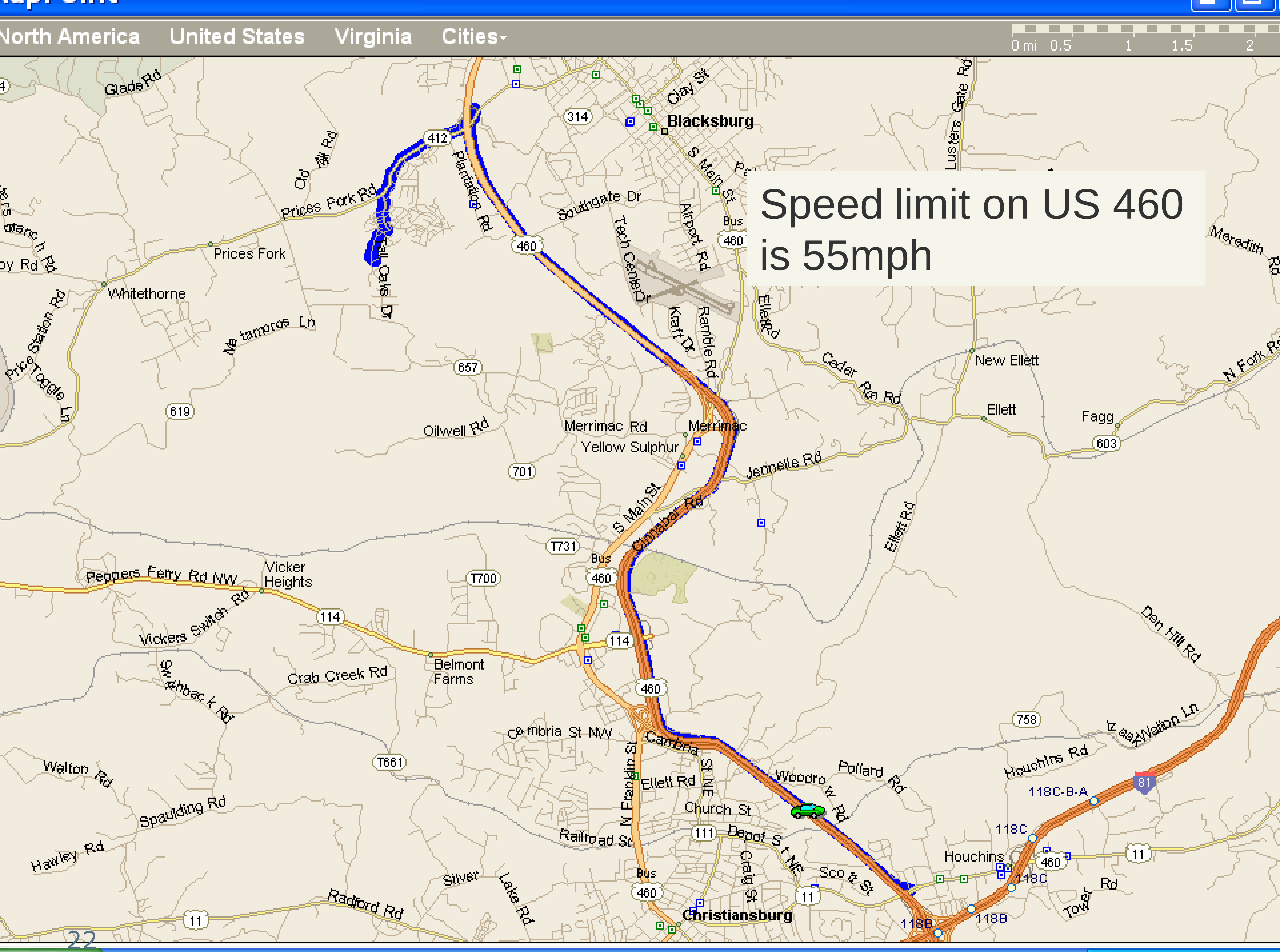
Data analysis tools: 5th generation



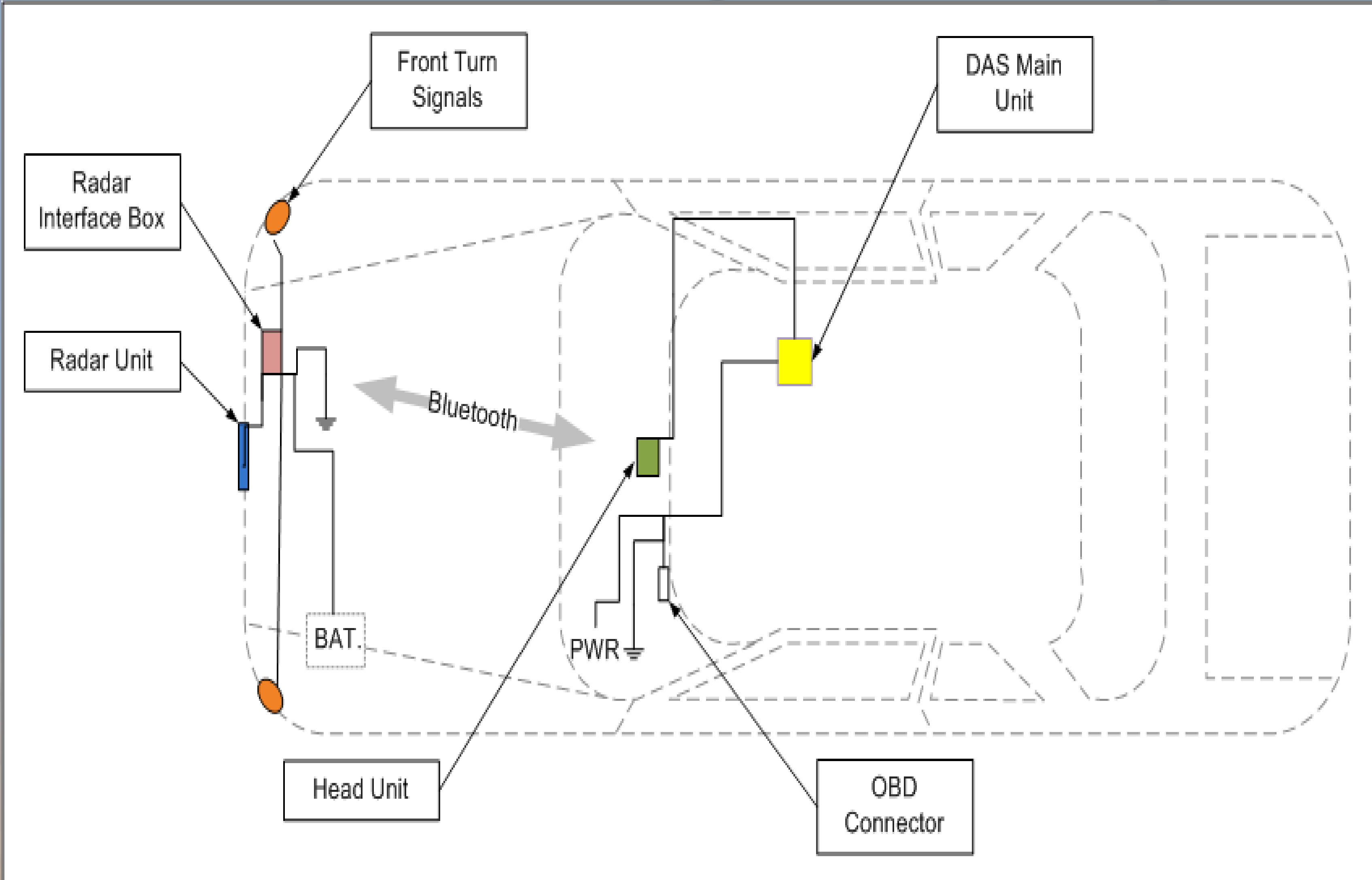
Speed limit on US 460 is 55mph

Next Generation, Large-scale Data Acquisition System

- Custom Design
  - Need minimal footprint
    - Electrically
    - Physically
  - Custom software
    - Real time system
    - Maximum data automation and checking
  - Specialized tracking information


wavecom
Model:MTSMC-G-F1
Yr2007Wk36
333

SHRP 2 DAS Component Concept



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SHRP 2 Data Acquisition System Concept

- Multiple Videos
  - Machine Vision Driver ID
  - Machine Vision Eyes Forward Monitor
  - Machine Vision Traffic Signal State Detector
  - Machine Vision Lane Tracker
- Accelerometer Data (3 axis)
  - 10Hz, and 1KHz ACN
- Rate Sensors (3 axis)
- GPS
  - Latitude, Longitude, Elevation, Time, Velocity
- Forward Radar
  - X and Y positions
  - Xdot and Ydot Velocities
- Cell Phone
  - ACN, health checks, location notification
- Wi-Fi (80211.g)
  - Health checks, remote upgrades
- Luminance sensor
- RF sensor
- Passive alcohol sensor
- Estimate of sound level
- Incident push button
- Video
- Audio (only on incident push button)
- Turn signals
- Vehicle network data

  Accelerator
  Brake pedal activation
  ABS
  Gear position
  Steering wheel angle
  Speed
  Horn
  Seat Belt Information
  Airbag deployment
  Many more variables…

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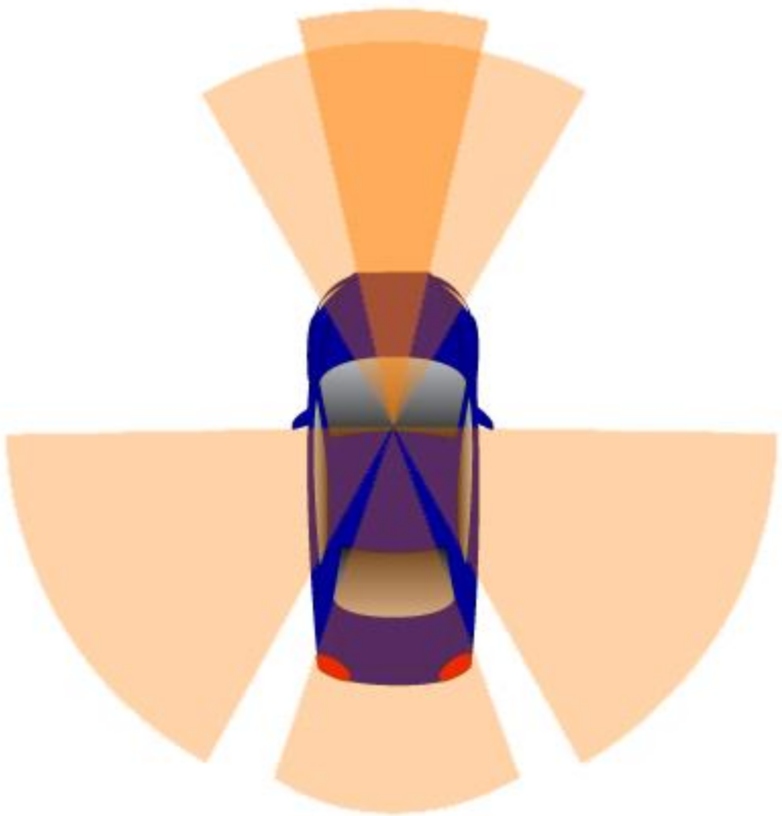

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SHRP 2 Enhanced DAS
Prototype camera under consideration

In scenes with mixed lighting, conventional CCD and CMOS cameras will show saturation and deep shadow, making safety applications ineffective.

Conventional Camera

Camera with Autobrite®

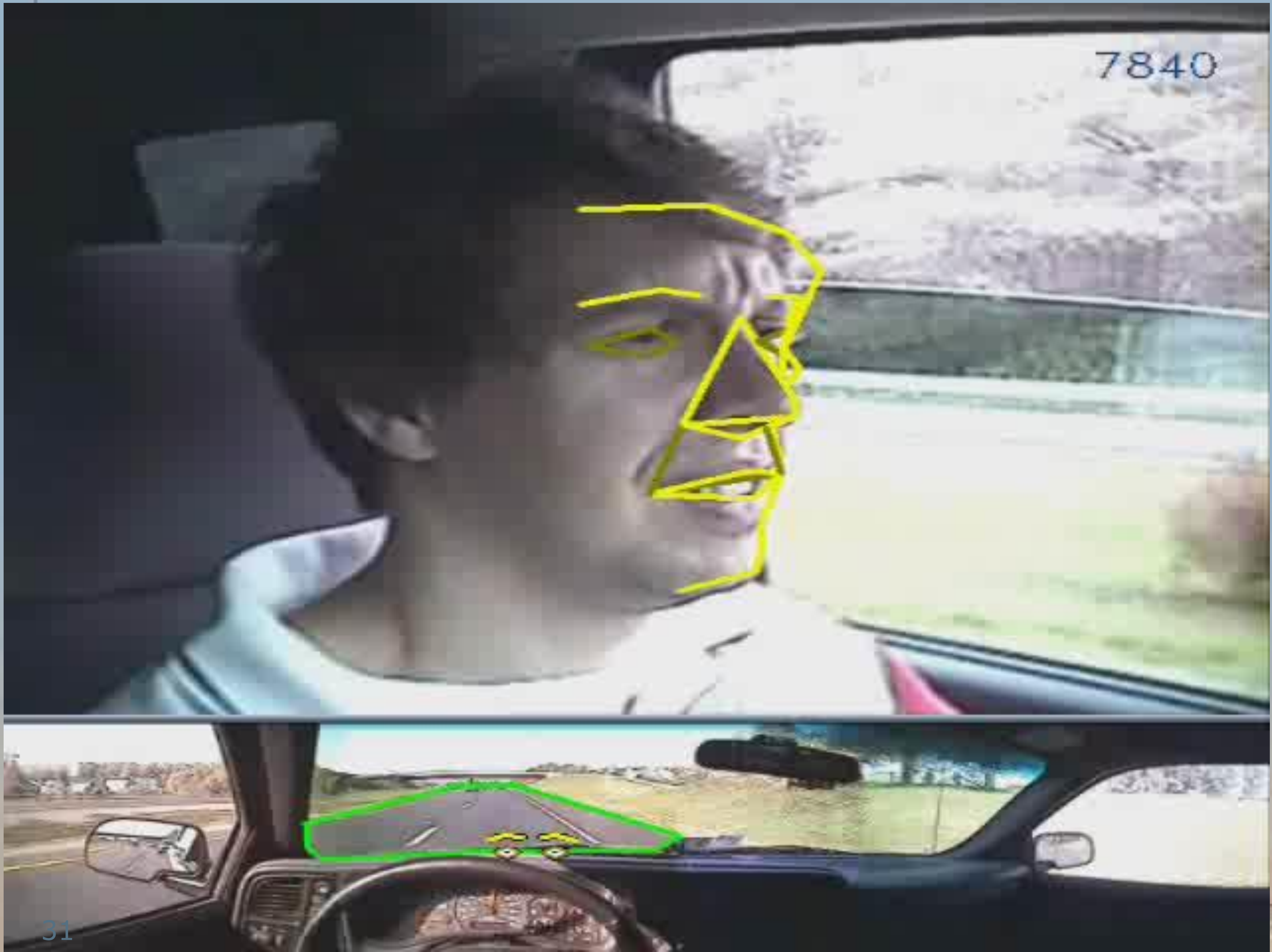
Autobrite® provides high dynamic range so that details in both bright and dim areas are clearly visible.

Video Automation

Candidate systems operating or under development

- Lane Tracker
- Eyes Forward/ Head Tracker
- Traffic Signal State Detector
- Driver ID

VTTI Prototype Machine Vision Driver Monitor



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What is the Potential of Naturalistic Driving?
Some Early Results

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Driver drowsiness is a significant factor in both light and heavy vehicle crashes.

- Drowsiness is a contributing factor in 15%-20% of crashes and other safety-related incidents for long-haul trucking, local/short-haul trucking and light vehicle driving.
- Driving while drowsy increases crash and near-crash risk 6 to 8 times that of driving while alert.
- Drowsiness occurs during all times of the day.
- Long-haul “team” truck drivers get poorer sleep quality (moving truck), however they sleep for longer periods and are generally safer than “single” drivers
- In local/short-haul trucking a major cause of drowsiness is that drivers begin the work week in a tired state.

Drowsy Truck Driver Example

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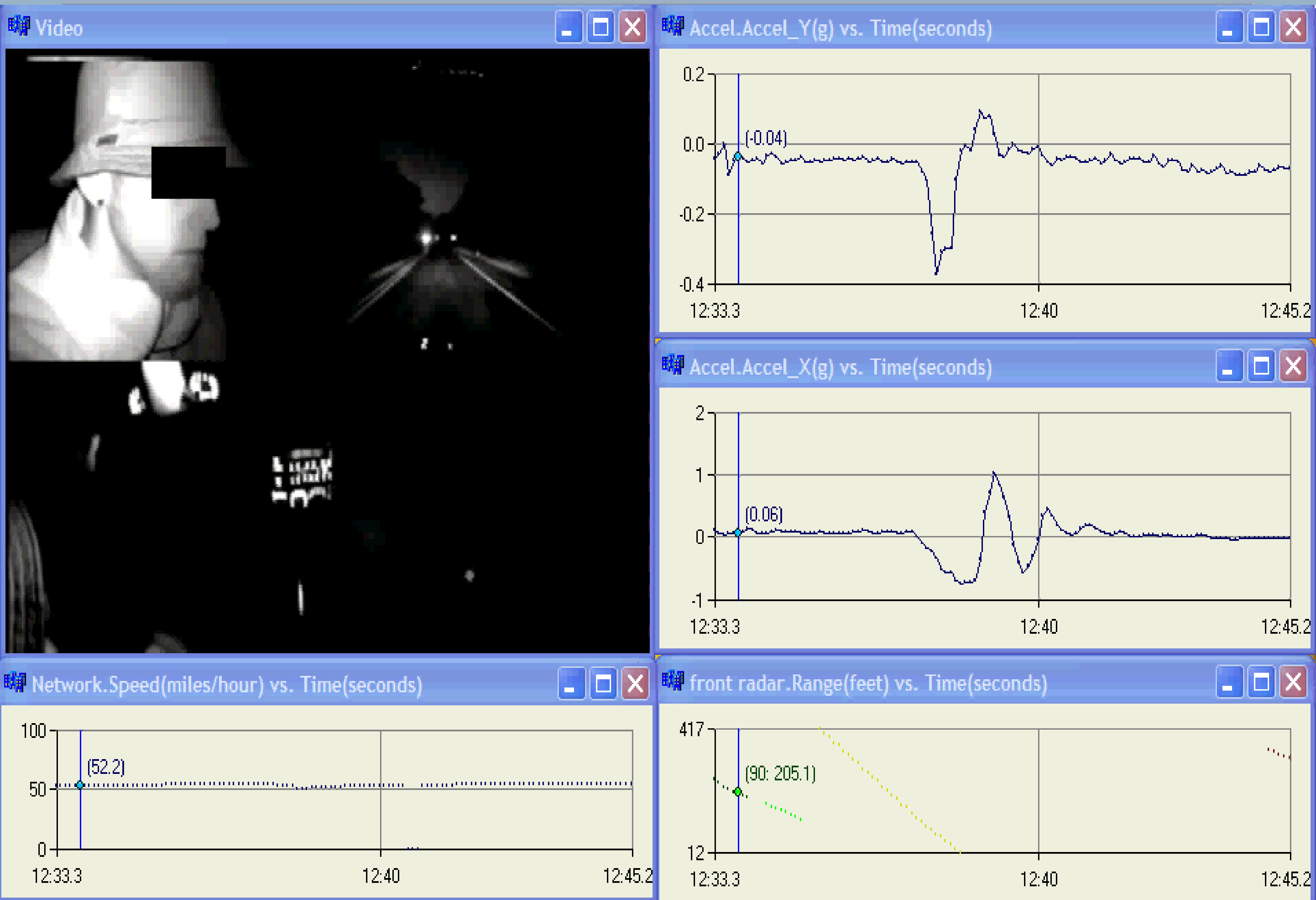
Fatigue/Impairment-Related Near Crash



Video
Accel.Accel_Y(g) vs. Time(seconds)
0.2
0.0
-0.2
-0.4
(-0.04)
12:33.3
12:40
12:45.2
Accel.Accel_X(g) vs. Time(seconds)
2
1
0
-1
(0.06)
12:33.3
12:40
12:45.2
Network.Speed(miles/hour) vs. Time(seconds)
100
50
0
(52.2)
12:33.3
12:40
12:45.2
front radar.Range(feet) vs. Time(seconds)
417
12
(90: 205.1)
12:33.3
12:40
12:45.2

Driver inattention is also a key contributing factor in crashes for both truck and light vehicles

- The largest single contributing factor is looking away from the roadway just prior to an unexpected event or condition. This accounts for somewhere between 70% and 90% of unsafe events.
- Engaging in activities that are unrelated to driving (i.e., “secondary tasks”) and external distractions account for most of the inattention-related risk.
  - High Risk: Looking away many times and/or long periods
  - Includes: Cell phone dialing, text messaging, Ipod/MP3 manipulation, and internet interaction.
  - Much less risk: Eating/drinking, talking to passengers, simple radio functions, and even talking on a cell phone.
- Teens are four times more likely to be involved in a near crash or crash while performing a secondary task than their adult counterparts.

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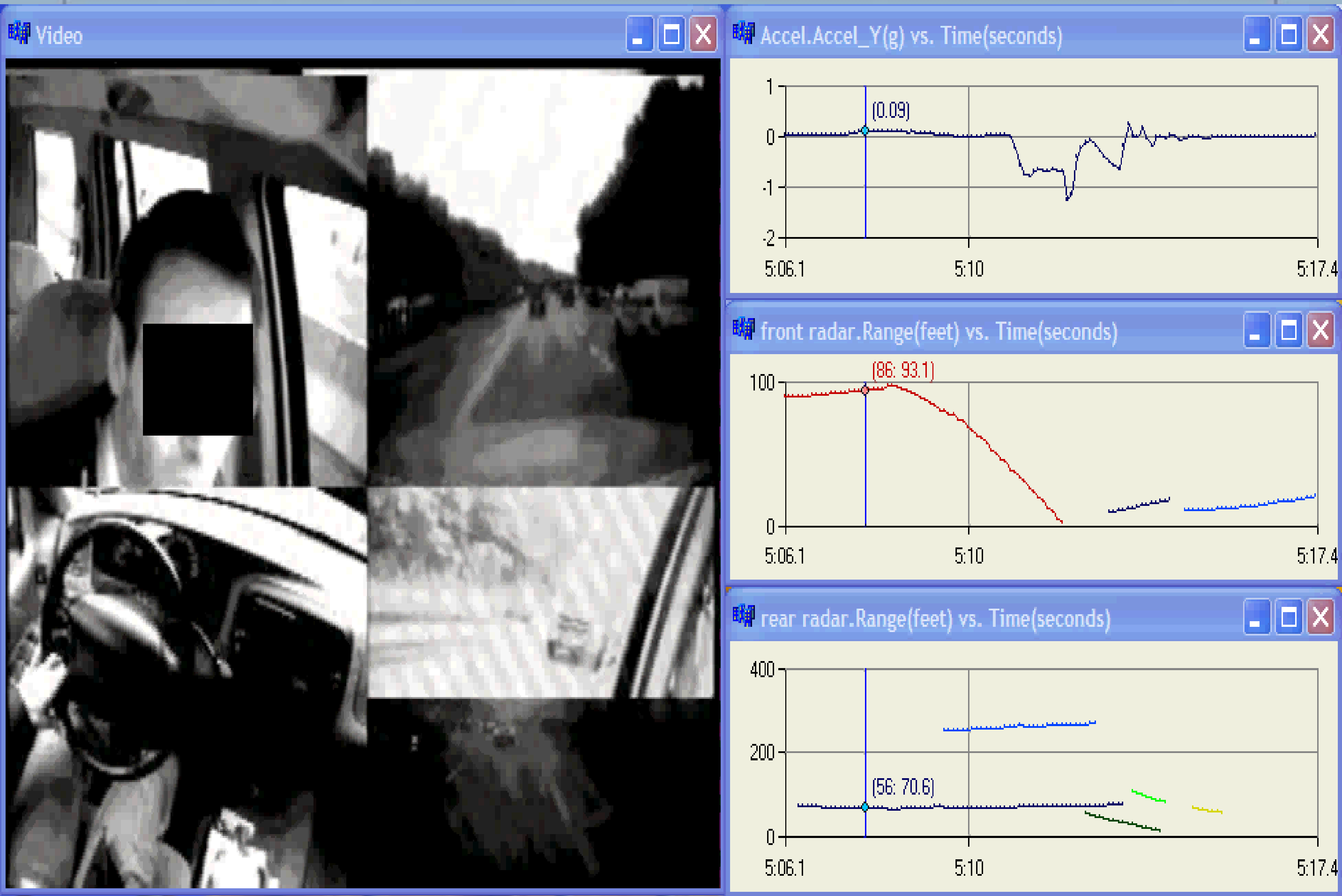
Teen Distraction Example


Video
Accel.Accel_Y(g) vs. Time(seconds)
1
0
-1
-2
(0.09)
5:06.1
5:10
5:17.4
front radar.Range(feet) vs. Time(seconds)
100
0
(86: 93.1)
5:06.1
5:10
5:17.4
rear radar.Range(feet) vs. Time(seconds)
400
200
0
(56: 70.6)
5:06.1
5:10
5:17.4

Relative Crash Risks for Types of Inattention

Type of Inattention	OR	Lower Confidence Level	Upper Confidence Level
Complex Secondary Task	**3.1**	**1.7**	**5.5**
Moderate Secondary Task	**2.1**	**1.6**	**2.7**
Simple Secondary Task	1.2	0.9	1.6
Fatigue	**6.2**	**4.6**	**8.5**
Driving-Related Inattention to the Forward Road > 2 s	**0.5**	**0.2**	**0.8**
Driving-Related Inattention to the Forward Road < 2 s	**0.2**	**0.2**	**0.3**
Reaching for moving object	**8.8**	**2.5**	**31.2**
Reading	**3.4**	**1.7**	**6.5**
Dialing Hand-held Device	**2.8**	**1.6**	**4.9**
Applying Make-up	**3.1**	**1.3**	**7.9**
Handling CD	2.3	0.3	17.0
Eating	1.6	0.9	2.7
Talking/Listening to Hand Held	1.3	0.9	1.8
Drinking	1.0	0.3	3.2
Adjusting Radio	0.6	0.1	2.2
Passenger in Adjacent Seat	**0.5**	**0.4**	**0.7**

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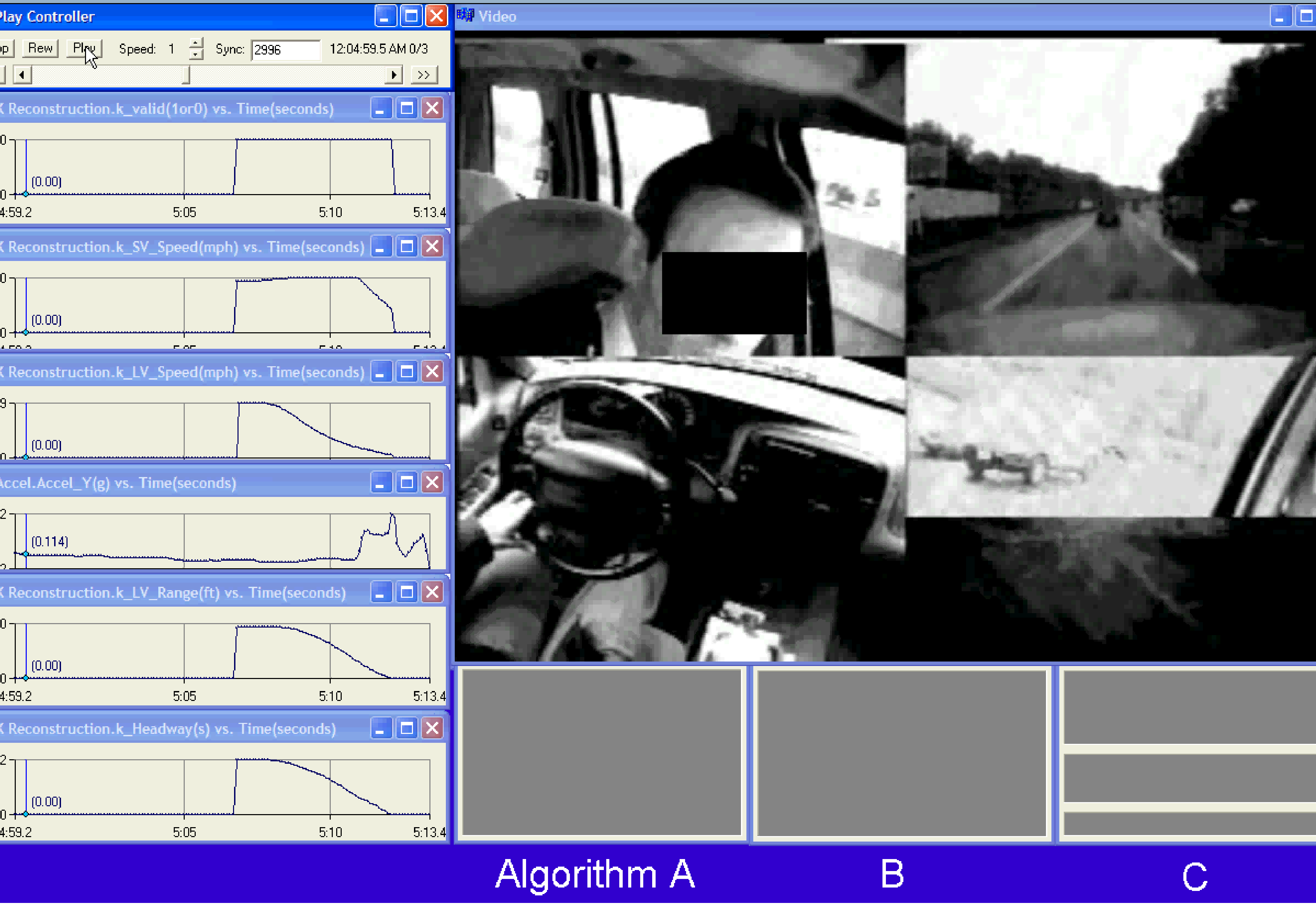
Example use of data: Algorithm development



01_08_Left_Lane_ABC

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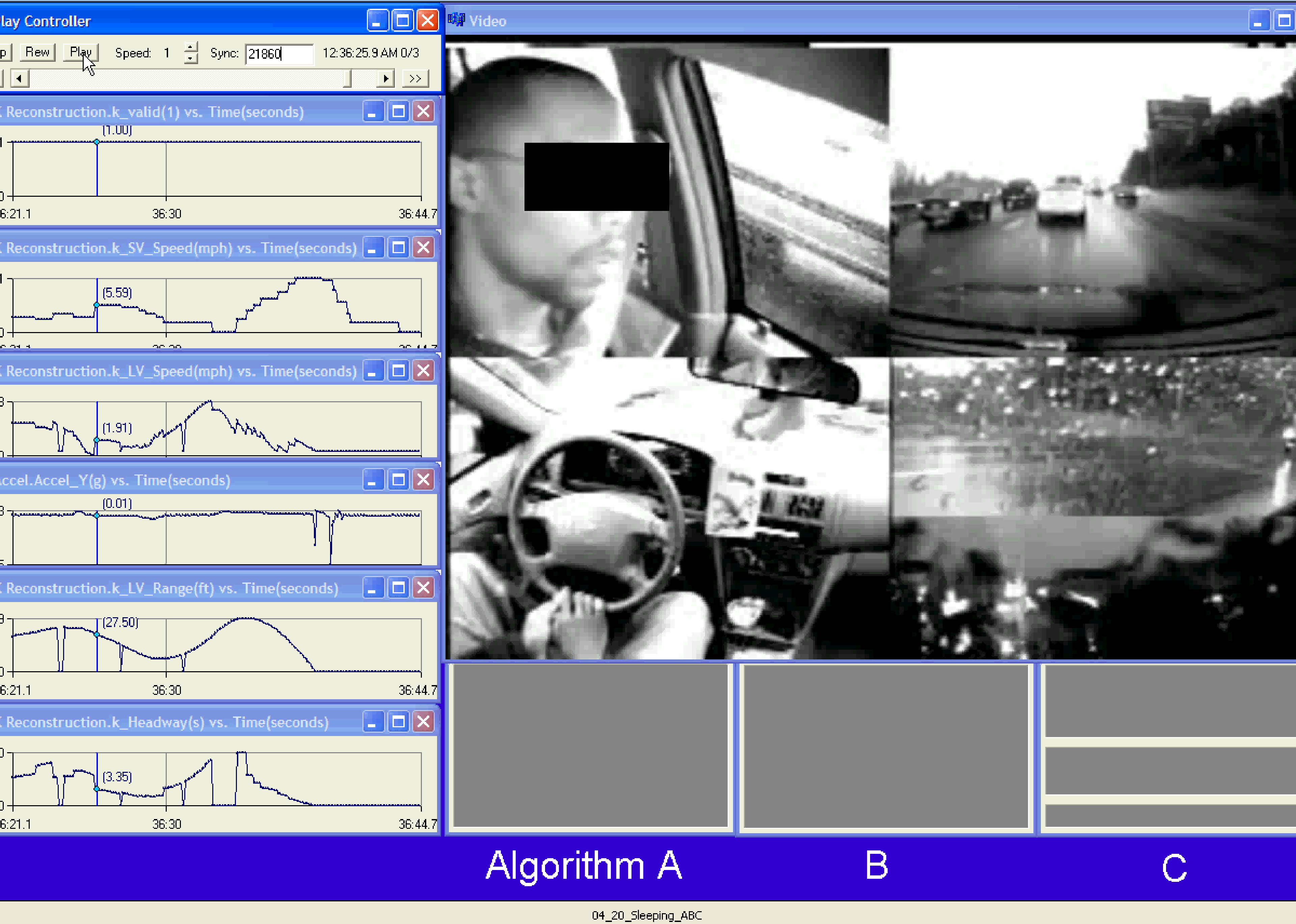
02_04 Yield_female_ABC


Play Controller
Stop
Rew
Play
Speed: 1
Sync: 2725
12:04:32.4 AM 0/3
K Reconstruction.k_valid(1or0) vs. Time(seconds)
K Reconstruction.k_SV_Speed(mph) vs. Time(seconds)
K Reconstruction.k_LV_Speed(mph) vs. Time(seconds)
Accel.Accel_Y(g) vs. Time(seconds)
K Reconstruction.k_LV_Range(ft) vs. Time(seconds)
K Reconstruction.k_Headway(s) vs. Time(seconds)
4:32
4:35
4:40
4:43.7
Video
Algorithm A
B
C
03_24_Telephone_pole_ABC


lay Controller
Rew
Play
Speed: 1
Sync: 21860
12:36:25.9 AM 0/3
Video
Reconstruction.k_valid(1) vs. Time(seconds)
(1.00)
6:21.1
36:30
36:44.7
Reconstruction.k_SV_Speed(mph) vs. Time(seconds)
(5.59)
Reconstruction.k_LV_Speed(mph) vs. Time(seconds)
(1.91)
ccel.Accel_Y(g) vs. Time(seconds)
(0.01)
Reconstruction.k_LV_Range(ft) vs. Time(seconds)
(27.50)
6:21.1
36:30
36:44.7
Reconstruction.k_Headway(s) vs. Time(seconds)
(3.35)
6:21.1
36:30
36:44.7
Algorithm A
B
C
04_20_Sleeping_ABC

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Naturalistic Driving

- Discussion . . . .
- Questions?
- Thanks!

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