JPL D-l 3459

Variable Dynamic Testbed Vehicle (VDTV)

Functional Requirements

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Jet Propulsion Laboratory
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ABBREVIATIONS

ABS	Automatic Braking System
AHS	Automated Highway System
BBW	Brake by Wire
FMVSS	Federal Motor Vehicle Safety Standards
HSCE	Hydraulic system cleaning equipment
IS0	International Standards Organization
JPL	Jet Propulsion Laboratory
KM/H	Kilometers per hour
NADS	National Advanced Driving Simulator
NHTSA	National Highway Traffic Safety Administration
OCAR	Office of Crash Avoidance Research (sponsor)
PVT	Performance Verification Test
S/S	Subsystem
SAE	Society of Automotive Engineers
SCI	Safety Critical Item
USEIF	User-Supplied Equipment Interface
VDA	Vehicle Dynamics Area. Paved area approximately 500 meters x 600 meters at VRTC
VDTV	Variable Dynamic Testbed Vehicle. When used alone, refers to the vehicle itself; the total system is called the VDTV system.
VRTC	Vehicle Research and Test Center, East Liberty, Ohio. NHTSA's primary vehicle test center

DEFINITIONS

Representative vehicle- A five passenger, four door sedan manufactured by a firm headquartered in the US and typical of mid-size sedans of the US vehicle fleet.

Base vehicle- Essentially, a platform for the dynamic subsystems and on-board electronics. Includes human factors characteristics (such as interior and exterior appearance). Developed from a modified production car, a custom car, or a hybrid of these two approaches.

Donor vehicle- A vehicle used to supply components which will be used in the base vehicle. Molds used to fabricate special body parts might also be taken from a donor vehicle.

Output devices- Generic callout for on-board devices which receive data from the Control S/S. Although dynamic subsystems (especially their actuators) are the dominant function for dynamic performance, data displays and other on-board functions are also included.

Large flat paved surface Generic definition of an area used for vehicle dynamics tests. An example is the Vehicle Dynamics Area (VDA) located at VRTC in East Liberty, Ohio. The VDA is an asphalt surface approximately 500 m by 600 m, so provides a large area for vehicle maneuvers which involve simultaneous lateral and longitudinal accelerations. Other surfaces with minimum slopes for water drainage, such as those at an airport, are within this definition.

Approved Road- Any road whose adjacent property (such as shoulders, drainage ditches, etc.) gradually slopes to permit a vehicle to run off without impinging into the ground and is free from obstructions (such as sign post bases) or other conditions which could cause high deceleration. Many airport runways are within this definition. Also includes highways with concrete barriers designed to constrain vehicles to the normal road surface in case of an impact with the barrier.

VARIABLE DYNAMIC TESTBED VEHICLE (VDTV)

FUNCTIONAL REQUIREMENTS

SECTION 1. OVERVIEW

1.1 SYSTEM OBJECTIVE

The Variable Dynamic Testbed Vehicle (VDTV) system's objective is to support the National Highway Traffic Safety Administration's (NHTSA's) crash avoidance research. NHTSA's Office of Crash Avoidance Research (OCAR) is the sponsor of this effort. To accomplish this, the vehicle must have two possibly divergent capabilities: (1) dynamic performance which ranges, when compared to performance of production vehicle, from low to high, and (2) characteristics of a production car. To permit research to investigate bounds of dynamic performance, the VDTV's dynamic performance must exceed that of normal production vehicles. To permit investigation of human factors on crash avoidance maneuvers and technology, the VDTV must offer an environment similar to that of production vehicles.

1.2 VDTV SYSTEM DESCRIPTION

1.2.1 BASE VEHICLE

The VDTV may use either a production vehicle, a custom vehicle, or a hybrid of both as its base. Each approach has significant advantages and disadvantages, with the choice probably dependent on the Contractor's capabilities. Essentially, the base vehicle must provide acceptable human factors characteristics, and a platform to which dynamic subsystems and electronics are attached.

1.2.2 VDTV DYNAMIC SYSTEMS

The VDTV's total dynamic performance is provided by its inherent dynamic characteristics with inactive dynamic subsystems, and nine variable dynamic subsystems:

- Front steer, brake, and throttle by wire.
- Direct driver feedback ("feel") for these three subsystems.
- Rear steer.
- Semi-active suspension.
- High performance automatic braking system at each wheel.

Each subsystem will have performance greater than those found in production vehicles. Performance of each subsystem can be varied from its maximum capability to lower levels via laptop computer commands and other methods, thus emulating performance of faster and slower dynamic motions.

1.2.3 VDTV SYSTEM FUNCTIONS

The VDTV system includes seven functions which, when combined, will support NHTSA's crash avoidance research:

- <u>VDTV Vehicle.</u> The term "VDTV" will refer to the vehicle itself, not the system, in this specification.

- Safety. Safety is the most important function; an unsafe VDTV cannot be used to conduct research activities.

- Interface With User Supplied Equipment. The VDTV must support research activities for a period of at least five years. During this period, technology will provide sensors and equipment which must be integrated into the research activities. The VDTV will provide interfaces which will support this equipment.

- Off-Board Data Processing. The VDTV system will include an off-board data processing capability.

- Maintenance. The VDTV system will include maintenance support for the vehicle.

- Operations Documentation. Operations will be conducted by NHTSA, but the VDTV system will include documentation which assists these operations, particularly from the safety viewpoint.

- Configuration Control Documentation. The VDTV system will include documentation which outlines configuration control during the VDTV's life.

1.3 DOCUMENT CONTENT

This specification contains the following sections:

Section 2	Applicable documents.
Section 3	System-level performance and requirements. High-level user requirements, safety, and dynamic performance at the vehicle level.
Section 4	Subsystem description and requirements.
Section 5	Performance verification. Tests which verify that the required performance has been met.
Section 6	Deliverable data.
Section 7	Costed Options. Requirements for costed options are defined.

Notes are included throughout the document. These notes, which are defined by the word Note in italics (*Note:*), are intended only for examples or clarification and are not to be taken as requirements.

Certain summary comments concern important concepts. These comments are included in boxes to emphasize their importance.

SECTION 2. APPLICABLE DOCUMENTS

2.1 REFERENCE DOCUMENTS

2.1.1 TEXT REFERENCES

1. 1992 SAE Handbook: Volume 4 on "On-highway vehicles and off-highway machinery." Vehicle Dynamics Terminology, SAE J670e.
2. Lee, A.Y., "Emulating the lateral dynamic of a range of vehicles using a four-wheel-steering vehicle," SAE 950304. See also SP-1074, "New Development in Vehicles Dynamics, Simulation, and Suspension Systems," pp. 11-22,1995.
3. Riley, B.S., and Robinson, B.J., "Handling Test on Four-wheel-drive Multi-purpose Vehicles," Research Report 330, Transportation and Road Research Laboratory, UK., 1991.
4. Variable Dynamic Testbed Vehicle Study Final Report, JPL D11266 (3 volumes), Jet Propulsion Laboratory, August 30, 1994.
5. Marriott, Alan T, The Variable Dynamic Testbed Vehicle, SAE 950032, International Congress Exposition, February 27- March 2,1995.
6. Lee, A. Y., Vehicle Stability Augmentation Systems Designs for Four Wheel Steering Vehicles, Journal of Dynamic Systems, Measurements, and Control, Volume 112, Number 3, September 1990.
7. Automated Highway System (AHS), System Objectives and Characteristics, National Automated Highway System Consortium, November 3, 1995.

2.1.2 SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE Handbook

2.1.3 INTERNATIONAL STANDARDS ORGANIZATION (ISO)

IS0 3833	Road vehicles – Types – Terms and definitions
IS0 3888	Road vehicles – Test procedure for a severe lane-change maneuver
IS0 4138	Road vehicles – Steady-state circular test procedure
IS0 5128	Road Vehicles - Measurement of noise inside motor vehicles
IS0 7401	Road vehicles – Lateral transient response test methods
IS0 7975	Road vehicles – Braking in a turn – Open loop test procedure
IS0 8725	Road vehicles – Transient open-loop response test method with one period of sinusoidal input
IS0 8726	Road vehicles – Transient open-loop response test method with pseudo-random steering input
IS0 8555	Road vehicles – Vehicle dynamics and road-holding ability – Vocabulary

IS0 9816 Passenger cars – Power-off reactions of a vehicle in a turn – Open-loop test method

2.1.4 FEDERAL MOTOR VEHICLE SAFETY STANDARDS (FMVSS);

The intent of the FMVSS shall be met with the following exceptions:

203 Impact protection for the driver from the steering control system

205 Glazing materials

208 Occupant crash protection

2.2 DOCUMENT SOURCES

Society of Automotive Engineers

SAE, Inc., 400 Commonwealth Dr., Warrendale, PA 15096-0001

IS0 documents are available from:

Document Engineering Co., Inc.

15210 Stagg Street

Van Nuys, CA 91405

Federal Motor Vehicle Safety Standards are in the Code of Federal Regulations, Title 49, Part 571. Available from:

Government Printing Office

Superintendent of Documents

Washington, DC 20402-9328

SECTION 3. VDTV SYSTEM REQUIREMENTS

3.1 INTRODUCTION

Section 3 is concerned with the overall system, while Section 4 deals with subsystem requirements. Paragraph 3.2 describes the VDTV system, its boundary, and interfaces. User requirements define the VDTV system, so are discussed in paragraph 3.3 starting at the highest level. Since the vehicle cannot perform its intended use unless it is safe, the dominant user requirement is safety. System-level safety requirements are contained in paragraph 3.4. Paragraph 3.5 then contains system performance requirements.

3.2 SYSTEM DESCRIPTION

3.2.1 OVERVIEW

The VDTV's ability to support a broad range of crash avoidance tests is based on four capabilities:

- A base vehicle which provides the structure for occupant safety and a platform for the other three capabilities.
- Nine independently controlled dynamic subsystems, each with performance greater than a production vehicle, with a laptop computer interface to an observer or driver.
- A comprehensive data acquisition capability which will provide data from vehicle sensors for control algorithms and also transmit this data to an off-board data processing system.
- An interface to user-supplied equipment which permits new technology, available during the VDTV's life, to be integrated into the VDTV system. This interface will provide access to the VDTV's measurements and dynamic subsystems.

Since the dynamic subsystems can be controlled by commands from a laptop computer, the VDTV can quickly change configuration to emulate the dynamic performance of a range of vehicles. This range is shown by Figure 3-1, which contains only generic subjective information so is included as a guide:

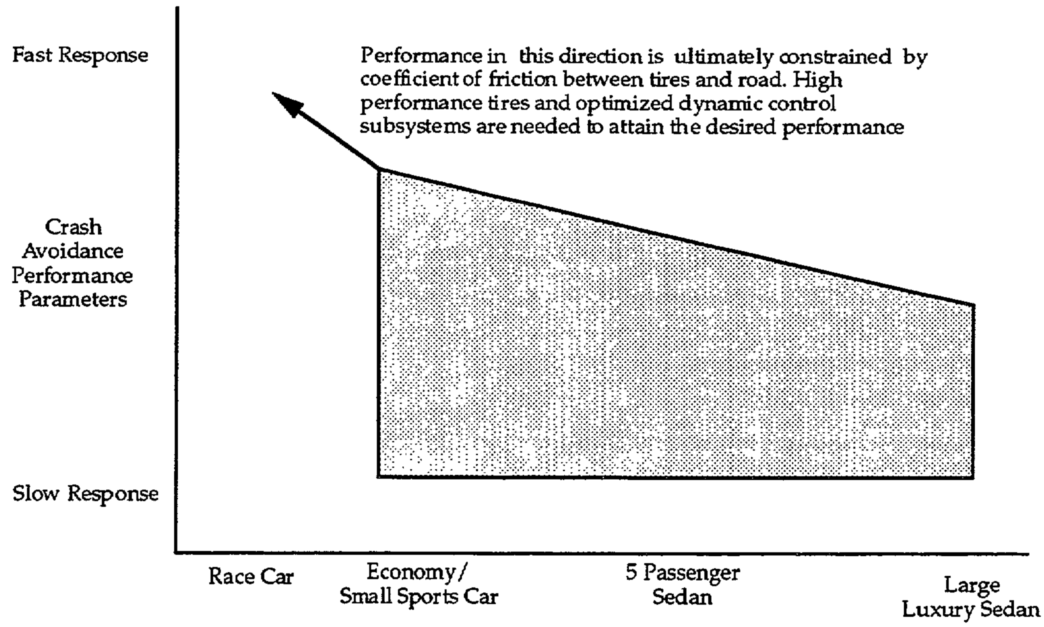

Figure 3-1. VDTV Emulation Range

This specification divides the generic crash avoidance parameter of fast response and slow response (the vertical axis of Figure 3-1) into objective performance requirements during specific maneuvers (such as a J-turn) in ¶ 3.5.2. The range of vehicles covers those of the US's vehicle fleet.

The exterior, front seat, and view from the driver's position will have characteristics of a production vehicle, permitting drivers from the general population to conduct tests in a familiar environment. Research tests can thus investigate interactions between various dynamic subsystems and drivers. A comprehensive measurement set will provide data defining the total vehicle environment.

Operation at limit performance conditions will be an important part of research tests. Such tests will be conducted on a large, flat surface. Depending on the test, drivers will vary from professional test drivers to persons from the general public.

During the five-year VDTV life, a wide variety of new crash avoidance technologies will appear. The VDTV will support tests using these technologies by providing interfaces for customer-supplied equipment. The interfaces will provide data transfer, integrated with other VDTV data, and commands to the equipment.

Since the vehicle cannot be used unless it is safe, safety will be the most important factor throughout the design.

3.2.2 SYSTEM FUNCTIONS

The VDTV system includes seven functions. Tests are conducted with the vehicle, the major deliverable, and its on-board subsystems. The next three are safety, the interface to customer-supplied equipment, and an off-board data processing capability. The last three concern maintenance, operations, and configuration control documentation and equipment for the vehicle's operations which will be conducted by NHTSA.

The interface to customer-supplied equipment is treated as an on-board subsystem in this specification.

3.2.2.1 VDTV System Boundary

The VDTV system boundary is outlined in Figure 3-2. System functions, and major capabilities within each function, are shown. Capabilities outside this boundary are beyond the VDTV system scope.

VEHICLE
Functions
Subsystems

SAFETY
Qualitative analysis
Qualitative definition of operational categories
Written operations recommendations
Objective analysis of rollover on a flat, large area
Recommended safety-critical software change control

MAINTENANCE
Custom spare parts
Long-delivery time parts
Basic maintenance documentation
special tools

INTERFACES FOR CUSTOMER-SUPPLIED SENSORS
Mechanical at front, rear, and sides
Electrical power supply at front, rear, and sides
Sensor input to VDTV computer bus
Video sync input to VDTV computer bus
Grounding EMI/RFI instructions

DATA PROCESSING
Off-board computer hardware (PC class)
Data transfer to off-board computer
Data transfer from vehicle via disk

OPERATIONS
Recommended safety-oriented operations constraints
Automated Performance Verification Test (PVT)
Operation in moderate environment

CONFIGURATION MANAGEMENT
Summary of basic approach

Figure 3-2. VDTV System Boundary

3.2.2.2 VDTV System Interfaces

Interfaces between the VDTV system and users are shown in Figure 3-3. NHTSA will conduct all operations after receiving delivery of the VDTV from JPL, so interfaces between the VDTV system and operations will consist of documentation and training.

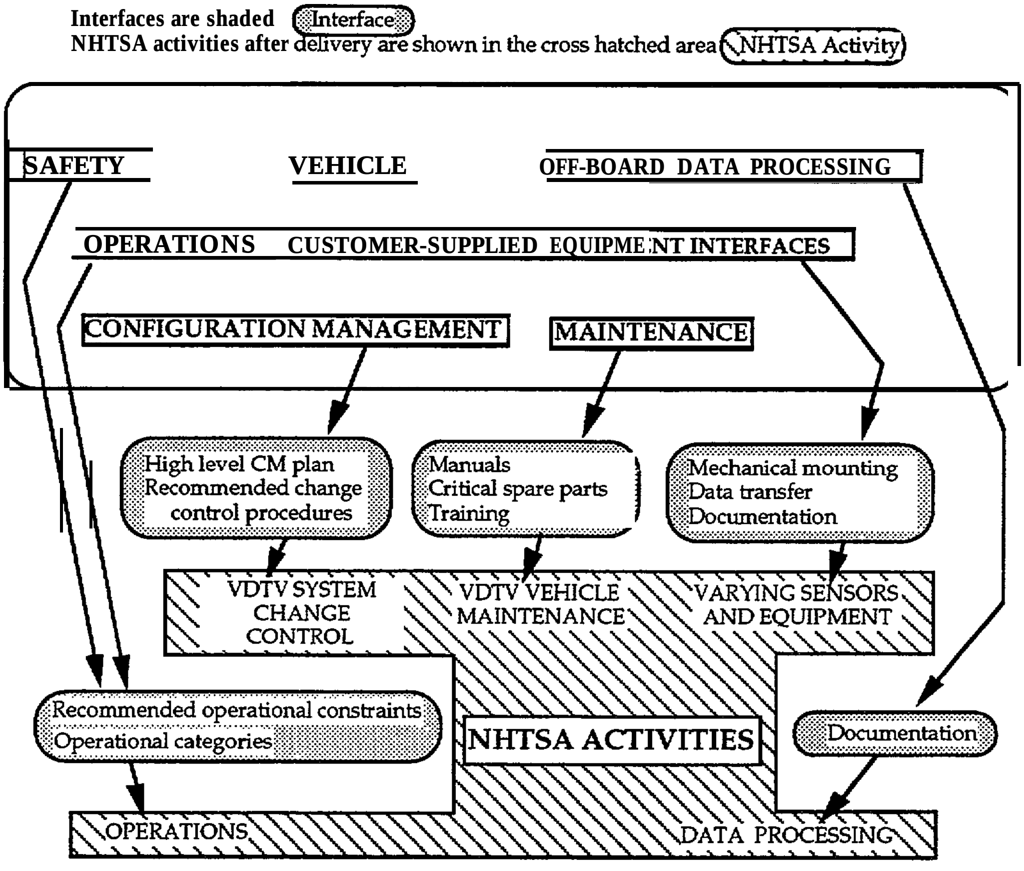

Figure 3-3. VDTV System Interfaces

3.2.2.3 VDTV Vehicle

The VDTV consists of a base vehicle which is essentially a driveable car. This base vehicle provides the functionality necessary to support human factors research (such as appearance and the driver's perception of a normal car), adequate performance from the viewpoint of normal passenger cars, and capability to operate in most weather conditions. The base vehicle includes the mechanical subsystem. The on-board subsystems (dynamic subsystems, control, measurement, customer-supplied equipment, and electrical power) are integrated with this base vehicle. VDTV subsystems are shown in Figure 3-4.

DYNAMIC SUBSYSTEMS

Steer-by-wire front wheel steer
Front steer feel
Brake-by-wire
Brake feel
Throttle-by-wire
Throtlle feel
Steer-by-wire rear wheel steer
Semi-active suspension
Anti-lock braking system

CONTROL SUBSYSTEM

Sensors
Sensor signal conditioning digitization
Measurement subsystem data transfer
Computer platform
Control algorithms
Output signals to dynamic subsystems
Actuators
Safety capability

POWER SUBSYSTEM

High-output alternator
Additional batteries
Regulated DC power

MEASUREMENT SUBSYSTEM

Sensors
Sensor signal conditioning digitization
Computer platform
Data formatting
Control subsystem data transfer
Data storage
Data transfer to off-board data processing

MECHANICAL SUBSYSTEM

Frame/body
Engine
Suspension
Wheels and tires
Drive train
Variable mass (a)

Figure 3-4. VDTV Subsystems

3.2.2.4 Safety

From the vehicle viewpoint, safety is concerned with three VDTV capabilities:

- Occupant safety devices such as air bags, seat belts, and a rollover bar/cage.
- Vehicle structural integrity which considers the VDTV's intended use: frequent operation in limit performance maneuvers.
- Automated internal status checks to detect a failure in a dynamic subsystem or electronic equipment.

In addition to the VDTV vehicle, system safety considers the other factors which enter into operational safety:

- Roads: From a large, flat paved surface to public roads.

Note: Although operation on public roads was part of early system safety analysis, the VDTV will not be operated on public roads.

- Drivers: From professional to segments of the general population.
- Maneuvers: From normal driving to limit performance.
- Operational experience: Adds to knowledge of the VDTV's reliability.

3.2.2.5 Data Processing

An off-board data processing capability will be provided. Data from all on-board measurements will be transmitted to this off-board capability.

3.2.2.6 Maintenance

Maintenance support adequate for operation at sites within the US for periods of several months will be provided. This includes software, custom parts, long-delivery parts, and special tools. Training for maintenance personnel will also be provided.

3.2.2.7 Operations

Operational support will largely consist of documentation which recommends operating practices which promote safe operation.

3.2.2.8 Configuration Control

Configuration control will consist of a summary of recommended configuration control practices to maintain records of test configurations.

3.3 HIGH-LEVEL USER REQUIREMENTS

User requirements are based on the Phase 1 final report[1], discussions with users identified by NHTSA, reports from these users, and contractual documents. Also, VDTV operational sites are treated as users in a generic sense to include operational requirements during the VDTV's five-year life.

High-level user requirements in this section lead to lower-level requirements throughout the document. Most lower-level requirements are contained in sections dealing with subsystems, permitting these requirements to be defined in the subsystem responsible for implementation.

3.3.1 OFFICE OF CRASH AVOIDANCE RESEARCH (OCAR)

OCAR's research will use the VDTV to investigate driver/vehicle interactions and new technologies. OCAR's research is thus concerned with dynamic performance which varies from low to well beyond that of the US's passenger car fleet. Performance must be quickly variable via commands from a laptop computer. Also, research of human interactions with these levels of dynamic performance is essential. An example is driver reactions to simultaneous dynamic motions (such as body roll and deceleration during a brake and turn maneuver to avoid a crash) .

> This leads to a VDTV which includes several dynamic subsystems rather than separate vehicles, each providing only one dynamic mode.

OCAR's use thus defines many of the upper bound requirements of all VDTV users; high dynamic performance simultaneous with human factors performance. OCAR's research program can use the VDTV for testing activities for at least five years. All VDTV use must be under safe conditions. OCAR thus has five high-level requirements:

a. The VDTV's dynamic performance shall emulate performance of a range of vehicles from a small economy car to a large luxury sedan.

b. The VDTV's dynamic performance shall be greater than that of production vehicles to permit research at boundary conditions.

c. The VDTV shall permit drivers from segments of the Nation's population to act as if driving a production vehicle.

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[1]Variable Dynamic Testbed Vehicle Study Final Report, August 30,1994: Jet Propulsion Laboratory document D-11266; three volumes

d. The VDTV's life shall be at least five years.

e. Limit performance dynamic data shall be acquired on a large, flat surface, qualified proving ground road, or other road which meets operational safety criteria.

3.3.2 AUTOMATED HIGHWAY SYSTEM (AHS)

The AHS must be compatible with the dynamic performance of conventional passenger cars. During the AHS development, fleets of vehicles (on the order of several tens) will conduct tests to validate models and operational scenarios. This fleet will have dynamic performance similar to that of the Us's passenger car fleet. However, cost constraints dictate that very high dynamic performance cannot be included in these vehicles. The VDTV's excellent dynamic performance, and comprehensive data recording of this performance, will support the AHS program by defining bounds of attainable performance. The VDTV must also support very fine longitudinal speed and lateral position control for platoon and lane following research. Some measurements defined for the AHS vehicle fleet, such as sensing of normal vehicle parameters (fuel level, turn signal state, etc.) are in addition to those of other users but will result in small changes to the VDTV design. Integration of the VDTV into AHS tests, which may be conducted in several locations throughout the Nation, is thus essential. This leads to four requirements above those imposed by OCAR:

a. The VDTV's capabilities shall permit its operation to be used with the AHS vehicle fleet.

b. The VDTV shall be operated on roads dedicated to AHS tests anywhere within the US.

c. The VDTV system shall provide a maintenance capability to support AHS operations at any AHS test site for periods of at least several months.

d. The VDTV's dynamic control subsystems shall support AHS's platooning and lane following research activities.

3.3.3 NATIONAL ADVANCED DRIVING SIMULATOR (NADS)

Use of the VDTV to validate NADS concerns both dynamic performance and human factors tests. The latter, concerned with any differences between human capabilities and perceptions in actual road conditions and the simulator environment, is very important. In addition, the VDTV can conduct maneuvers at sustained high-g levels impractical for a simulator to augment NADS results. Any NADS need for limit performance dynamic maneuvers must be consistent with the VDTV's safety constraints.

NAD's dynamic performance and human factors requirements are similar to those of OCAR, but may require somewhat different operating conditions. AHS's location requirements, and support at these locations, are expected to meet NADS requirements. A possible limitation is the VDTV's restriction not to operate on public roads.

3.3.4 HUMAN FACTORS

Viable human factors results are essential to OCAR, NADS, and evaluation of different technologies that will be evaluated during the VDTV's five-year life. It is thus essential that the VDTV be perceived to be representative of a conventional passenger car to provide viable human factors research results. The "perception" is different than being similar to, or exactly the same as, a conventional passenger car. Since human factors research will be concentrated on driver reactions, parts of the VDTV not visible to the driver have no constraints from the human factors viewpoint. Examples are content of the trunk, hood, and under the back seat. Exterior appearance of a generic vehicle, not a specific model, is required. Some characteristics, such as interior noise and vibration, are important.

Human factors research imposes measurement requirements in addition to those of other users. Multiple channel video data of the driver's motions and his field of vision are expected to be recorded on video tape, but the tape must be correlated with other vehicle data. Additional human factors requirements are:

a. Physiological data from a driver shall be integrated with other test data.

b. Video data shall be time correlated with all other data.

Note: Customer-supplied equipment, outside the VDTV system scope, will include: (1) physiological sensors and signal conditioning, and (2) video cameras and tape recorders.

3.3.5 TECHNOLOGY ASSESSMENT

New technologies which enable advanced crash avoidance and highway systems will appear constantly during the VDTV's life. These technologies will have unknown capabilities, data outputs, and support requirements. These technologies will be supported with interfaces which support user-supplied equipment. Technology assessment thus enhances research for all users, with a requirement of:

- The VDTV shall provide interfaces which support customer-supplied equipment.

3.3.6 OPERATIONS

VDTV operations will be performed by NHTSA after delivery of the VDTV system. Since operations requirements apply to every user, they are included here. To provide efficient operations, the VDTV system must satisfy three requirements:

a. Safe operations, addressed in paragraph 3.4.

b. Maintenance, addressed in 3.5.10.

c. Availability, addressed in paragraph 3.6.2.

d. Cost effective operations, addressed in many paragraphs.

The primary location will be VRTC, although the VDTV must be capable of sustained operations in other locations throughout the US.

3.4 SAFETY

The VDTV system safety represents one system function, but is separated from other functions because of its importance: if the VDTV system is not safe, it cannot be used.

Safety requirements were developed at the start of the task, starting with a single high-level requirement which led to lower-level functional requirements. These requirements, contained in Appendix A, were guides for JPL's internal activities leading to this functional requirements document.

> The safety requirements contained in Appendix A are at a functional level, not the detailed level appropriate for design and acceptance testing. The requirements of Appendix A are to be used to develop lower level requirements which will guide design, fabrication, and test activities.

3.4.1 GENERAL SAFETY REQUIREMENTS

General safety requirements for this task are:

a. Safety requirements in Appendix A shall be used as the base for development of lower-level safety requirements.

b. All design, fabrication, and test activities shall comply with the lower-level safety requirements of (a) above.

c. Safety activities shall start at the inception of the Contractor's work and shall be an integral part of all decision, analysis, design, and test activities.

3.4.2 SPECIFIC SYSTEM-LEVEL SAFETY ACTIVITIES

a. Early analysis, base vehicle selection, and all Task 1 activities defined in the Statement of Work shall show that VDTV will not rollover under the following conditions:

    i. Vehicle configuration with the highest performance tires used for any part of the Acceptance Test.

    ii. Operation on a large, flat, paved surface including:

    (a) Any turn and brake maneuver, both at limit performance.

    (b) The Performance Verification Test of ¶3.5.1.1, the J turn maneuver of ¶3.5.2.2, and the obstacle avoidance maneuver of ¶3.5.2.3.

b. Early analysis and all Task 1 activities defined in the Statement of Work shall objectively define road requirements for the Performance Verification Test (PVT) (cf. ¶3.5.1.1):

    i. For a full PVT conducted on a large, flat, paved surface:

        (a) Physical size of a large, flat, paved area for the full PVT.

        (b) Flatness parameters if undulations greater than those of normal pavement are important.

        (c) Dry coefficient of friction and its test conditions if those are different than normal asphalt or concrete pavement are important.

    ii. For a limited PVT conducted on a two or four lane road, the same parameters of (i) above assuming that only the VDTV occupies the road.

3.5 SYSTEM FUNCTIONAL REQUIREMENTS

3.5.1 VEHICLE

3.5.1.1 <u>Performance Verification Test</u>

A Performance Verification Test (PVT) will be included to significantly improve operational efficiency. Major objectives are: the VDTV can be expected to provide safe operations, assurance that the VDTV (particularly its dynamic subsystems) are performing as intended, and components common to data channels (such as power supply and digitization) are functioning properly. Conduct of a PVT before and after each test is intended to provide real-time assurance that reliable research data was obtained, and to accomplish this with essentially no labor. Failures during a PVT can lead to rapid problem correction and, to a large extent, avoid wasted resources resulting from tests conducted with faulty equipment.

a. The VDTV shall perform a PVT with these characteristics:

   i. PVT maneuvers shall be controlled by on-board software with the only human input of laptop commands to start the PVT start.

   ii. The PVT shall cause all dynamic subsystems with safety implications to perform their functions.

   iii. The PVT shall cause the dynamic subsystems of (ii) above to perform their functions within 90% of limit performance conditions:

      (a) Variable dynamic subsystem parameters shall be set for optimum performance for the PVT.

      (b) Maneuvers beyond limit performance, such as spins, locking wheels during braking (beyond ABS functions), or slipping tires during acceleration shall be avoided.

   iv. The PVT shall cause variable parameters to operate at their extreme dynamic conditions, such as bandwidth or slew rate.

   v. The PVT shall be conducted with the highest performance configuration permitted with the mechanical and dynamic subsystem configuration.

   Note: Emulation of lesser performance configurations, such as a heavy vehicle, does not need to be included.

b. The PVT shall include road characteristics in determination of the PVT to be conducted.

   i. Road size shall define the surface on which the PVT is to be conducted.

   Note: A large, flat paved surface capable of accommodating the base PVT is the safest condition. However, if only limited road width is available, a PVT suitable for these road conditions must be conducted. A PVT designed for the large, flat surface but conducted on a limited road width would create a significant safety hazard.

Definition and confirmation of the road is thus a critical safety item prior to conducting a PVT.

ii. Road characteristics shall be defined by laptop computer commands prior to conducting the PVT.

Note: A dry surface is assumed. Other parameters that may affect the PVT, such as coefficient of friction, should be included.

iii. Software shall require that the road characteristics are entered, then confirmed prior to starting the PVT.

c. Actual performance during each PVT shall be automatically compared to parameters which:

i. Consider the VDTV's PVT's test conditions:

(a) Configuration characteristics which affect the dynamic performance.

Note: The primary example is tires; others are mechanical changes such as anti-roll bars and tread width.

(b) The road characteristics of (b) above.

ii. Include the most important dynamic performance variables which define satisfactory performance.

iii. Include upper and lower tolerances for (i) and (ii) which define bounds of acceptable performance during the PVT.

iv. Provides an acceptable or unacceptable output, available to an occupant.

v. Provides the output of (iv) above within 30 seconds.

d. The PVT shall include a minimum of two maneuvers:

i. An initial precursor maneuver which limits longitudinal and lateral accelerations to 0.5 g maximum to assess the VDTV's capability to conduct the actual PVT.

ii The actual PVT which extends longitudinal and lateral accelerations near the limit performance.

e. The actual PVT shall not be enabled until the precursor maneuver is completed successfully.

f. PVT maneuvers shall include, subject to the limitations of (a)(iii)((b)) above:

i. Full acceleration from a standing start.

ii. Near limit performance right and left turns.

iii. Near limit performance combined brake and turn during right and left turns.

iv. Near limit performance deceleration near the end of the PVT.

v. A gradual deceleration to a complete stop at the end of the PVT.

g. Subject to the limitation of (a)(iii)((b)) above, all VDTV dynamic subsystems, with the exception of the three feel subsystems, shall be exercised at their maximum requirement during the PVT.

h. The three feel subsystems shall be exercised to the extent necessary to show basic functional performance.

Note: Driver participation, such as placing hands on the steering wheel and feet on the brake or accelerator pedals, may be a part of (i) above.

3.5.1.2 Space Allocation

a. Space for four video recorders shall be provided so video tapes can be inserted and removed easily when the trunk is opened.

b. The volume for the four video recorders is 40 cm wide x 25 cm deep x 20 cm high when viewed from the open trunk. An additional depth of 10 cm is required for input/output cables.

c. Weight of the items of (b) above will be less than 10 kg.

d. The Measurement S/S shall be located so the disk which provides transfer to off-board data processing can be inserted and removed easily when the trunk is opened.

e. The Measurement S/S volume is 50 cm wide x 40 cm deep x 25 an high when viewed from the open trunk.

f. Weight of the items of (e) above will be less than 34 kg.

g. No lead-acid batteries or other devices which contain hazardous materials shall be located in the passenger compartment.

Note: Small encased batteries, such as lithium, are excluded.

3.5.1.3 Mechanical Mounting

Mounting of all components must permit removal for repair and modification, yet withstand forces which may encountered in an accident.

a. All electronic components shall be mounted so they can be removed by technicians familiar with auto research activities within 15 minutes.

b. All components shall be mounted to withstand forces that may be encountered in an accident, including rollover, without breaking loose from the mounting.

3.5.2 DYNAMIC PERFORMANCE

The VDTV shall provide the dynamic performance defined in this paragraph according to the following conditions:

a. The VDTV's dynamic performance shall be controllable throughout the ranges specified in ¶3.5.2 via commands from a laptop computer.

b. The dynamic performance specified in ¶3.5.2 shall be obtained with a single mechanical configuration.

3.5.2.1 Understeer Coefficient

The VDTV's understeer coefficient is defined in Section 9.4.7 of Reference 1 (cf. ¶2.2.1).

a. At a specified level of lateral acceleration, the VDTV shall be programmable to achieve an understeer coefficient that falls between the upper and lower bounds depicted in Figure 3-5.

b. Approximate values of the understeer coefficients at 0.15g for both the upper and lower bounds are also given in Figure 3-5.

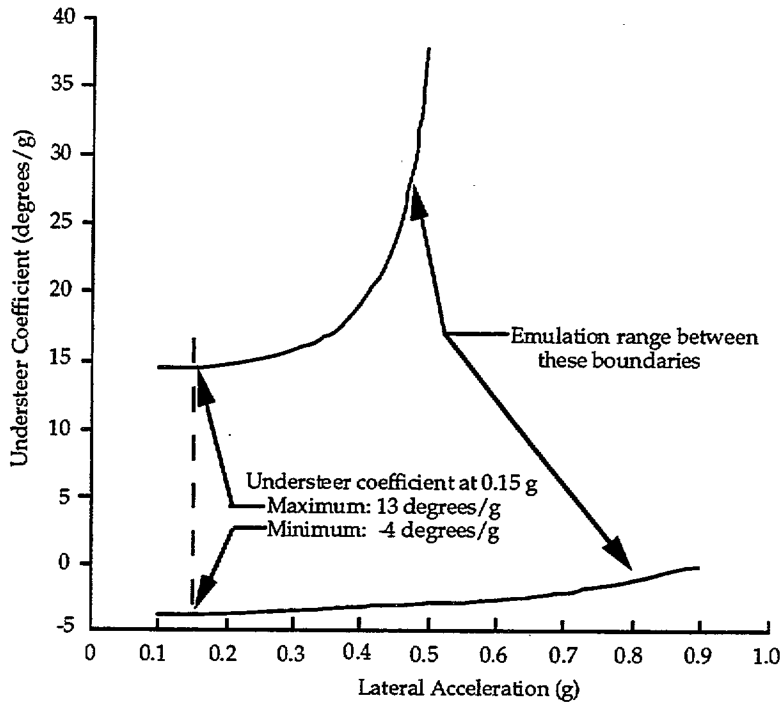


Figure 3-5. Understeer Coefficient Emulation

3.5.2.2 J-Turn Maneuver

A "J-turn maneuver" at a forward speed of 80 km/h is that achieved using a "pseudo" step steering wheel command input. The steering wheel is ramped linearly to its steady-state magnitude at a rate of 360 deg/sec. The magnitude of the steady-state steering wheel command determines the level of vehicle's lateral acceleration achieved.

a. For the above defined J-turn maneuver, the 90% rise time of the VDTV's lateral acceleration is defined as the time it takes the lateral acceleration to reach 90% of its steady-state value, as measured from the time the steering wheel command reaches 50% of its steady-state value.

b. After the 90% rise time, the magnitude of the lateral acceleration shall stay above 90% of its steady-state value. See Reference 2 (cf. Section 2.1.1) for further details.

c. At a specified level of lateral acceleration, the VDTV shall be programmable to achieve a 90% rise time that falls between the upper and lower bounds depicted in Figure 3-6.

d. Approximate values of the 90% acceleration rise time for both the upper and lower bounds at 0.15g are also given in Figure 3-6.

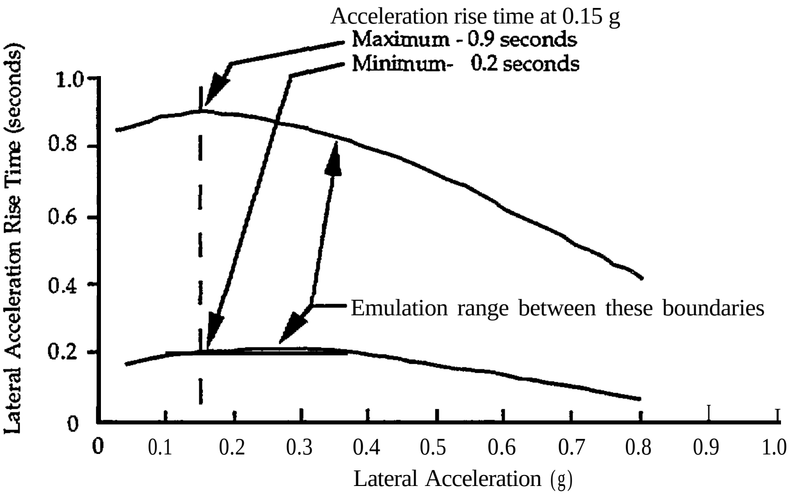


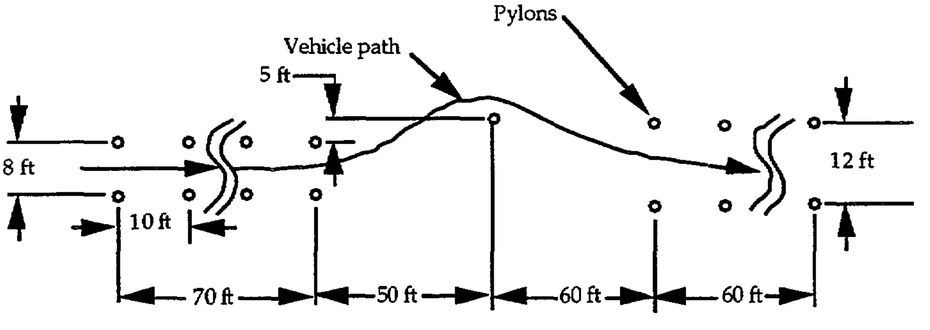
Figure 3-6. J Turn Lateral Acceleration Rise Time

3.5.2.3 Consumer Union-Defined Obstacle Avoidance Maneuver

An obstacle avoidance course depicted in Figure 3-7 is used by Consumer Union as a means to objectively evaluate the handling quality of passenger vehicles during emergency obstacle avoidance maneuvers. A detailed description of this obstacle avoidance course and other test conditions are given in Reference 3.

a. With a given mechanical configuration (cf. Section 4.5.2.2), the VDTV shall be able to successfully negotiate the Consumer Union obstacle avoidance course at all speeds below 55 km/h.

b. The maneuver shall be conducted with a fixed accelerator pedal position and no braking from the time the VDTV enters the course.



Note: not to scale

Figure 3-7. Consumers Union Obstacle Avoidance Maneuver

3.5.2.4 Steady State Lateral Acceleration

- The VDTV shall attain a steady state lateral acceleration of at least 0.95g under conditions of:

  i. A 30 meter circle.

ii. Tires and roads used for other dynamic performance tests.

3.5.3 GENERAL PERFORMANCE CHARACTERISTICS

- The VDTV shall have the following performance:

3.5.3.1 Acceleration

a. From 0 to 100 km/h in less than 9 seconds, with a starting condition of the engine idling.

b. From 70 to 105 km/h in less than 5.5 seconds.

3.5.3.2 Deceleration

a. From 100 km/h to 0 in less than 40 m.

b. From 130 km/h to 0 in less than 70 m.

C. Ten successive 0.5 g stops from 100 km/h with increase in pedal force from the first stop to the tenth stop not greater than 50% of the first stop, under conditions of:

i. Full acceleration between stops, excluding turns between runs in different directions.

ii. Acceleration immediately after a complete stop.

3.5.3.3 Maximum Speed

The VDTV shall attain a maximum speed of 200 km/h under conditions of:

a. Ambient temperature from 1O^{0}C to 300C.

b. Wind less than 5 km/h from any direction.

C. A maximum acceleration distance of 0.8 km.

3.5.4 HUMAN FACTORS CHARACTERISTICS

The VDTV shall have the following characteristics which may affect drivers from the general public:

3.5.4.1 Appearance

The VDTV's appearance shall be governed by:

a. The VDTV shall have the general exterior appearance of a representative vehicle when viewed from a distance of 10 meters by a typical person from the US public.

Note: For a VDTV based on a specific production vehicle, body panels to accommodate wider tires are acceptable. For a base vehicle based on a custom approach, body panels fabricated to appear to be those of a standard production vehicle (with modifications to accommodate other VDTV requirements such as tire clearance), are acceptable given that typical grille, trim, windows, and other appearance characteristics are executed in a quality manner.

b. The VDTV's front seat, and interior forward of the back of the front seat, shall have the appearance of a representative vehicle when viewed from the driver's position by a typical person from the US public.

Note: This includes, but is not limited to, these examples:

- Steering wheel and dash.
- Carpets, floor covering, door panels, and interior trim.
- Instrument panel and instruments.
- Roof covering.

C. The VDTV's hood and all exterior parts within a +/- 120^{o} field of view, with Oo taken as straight ahead, shall have the appearance of a representative vehicle when viewed from the driver's position by a typical person from the US public.

3.5.4.2 Front Seats

The VDTV's front seats, and mounting from the front seat to the body or frame structure, shall:

a. Provide room ranging from a 5 percentile female to a 95 percentile male.

b. Be adjustable as defined in (c) below via controls taken from the same US production vehicle as (a) above.

C. Include independent adjustments of: (1) vertical and horizontal seat adjustments, and (2) angle of the seat back.

Note: Electrically adjustable seats are preferred.

3.5.4.3 Interior Noise

The VDTV's interior noise shall be:

a. Measured according to IS0 Standard 5128 except for:

i. Tires shall be those of the type, size, and manufacturer used for the dynamic performance tests.

Note: Mileage of the tires should generally conform to the IS0 standard, but greater mileage is permitted.

ii. The vehicle load shall include all equipment used for the dynamic performance tests.

b. Not greater than:

i. 46 dB at idle.

ii. 70 dB at a steady speed of 80 km/h.

iii. 74 dB at a steady speed of 110 km/h.

iv. 76 dB at full throttle acceleration.

3.5.4.4 Heating and Cooling

The VDTV shall provide interior air heating and cooling:

a. Heating capacity shall be adequate for the interior to be maintained at 250C , or warmer, under conditions of:

i. Ambient temperature of -200C.

ii. Initial VDTV temperature of 1O^{o}C.

Note: Initial temperature will be that of a garage with some heating. These conditions are typical of winter operations in mid-Ohio at the VRTC.

b. Heated air from the interior shall be forced into the trunk compartment with a switch to turn the blower on and off.

c. Cooling capacity shall be adequate for:

  i. The interior to be maintained at 20°C, or cooler, under conditions of:
    (a) Ambient temperature of 40°C.
    (b) Full sun load.
    (c) Initial VDTV temperature of 40°C.
    (d) Fifteen minutes cool down from the initial temperature.
    (e) Two occupants in the vehicle after cool down.
    (f) 200 watt electrical power dissipation in the rear passenger compartment during cool down.

  ii. The trunk to be maintained at 32°C, or cooler, under conditions of:
    (a) Ambient temperature of 40°C.
    (b) Full sun load.
    (c) Initial VDTV temperature of 40°C.
    (d Fifteen minutes cool down from the initial temperature.
    (e) 300 watts electrical power dissipation in the trunk during cooldown.

3.5.5 ROAD OPERATIONS CHARACTERISTICS

The VDTV shall be capable of operation on roads approved for VDTV operations, which excludes public roads, in the environment specified in ¶3.5.7 as defined in Table 3-1.

3.5.6 INTERFACES FOR USER-SUPPLIED EQUIPMENT

The VDTV will interface with user-supplied equipment (lane detectors, forward/backward looking sensors, video cameras, physiological sensors, etc.). If user-supplied equipment is provided with its own data storage (for example video tape), the VDTV shall provide synchronization signals for proper time tagging.

a. Interfaces located on the exterior of the VDTV shall include:
  i. A standard protocol (SCSI, FDDI, etc.).
  ii. A bi-directional data bus connected to the Control S/S computer platform.
  ii. Data acquisition capability which provides data to the Control S/S.

b. Two interfaces located on the interior of the VDTV connected to the Measurement S/S for video and physiological data.

Note: More detailed requirements are contained in ¶4.8.

Table 3-1. Federal Motor Vehicle Safety Standards for VDTV

FMVSS STD	DESCRIPTION	VDTV APPLICABILITY Rev (a)	Req'd (b)	Intent (c)
101	Controls and displays		x	
102	Transmission shift level, etc.		x	
103	Windshield defrosting		x	
104	Windshield wiping		x	
105	Hydraulic brake systems			x
106	Brake hoses		x	
107	Reflecting surfaces		x	
108	Lamps		x	
109	New pneumatic tires			x
110	Tire selection and rims			x
111	Rearview mirrors		x	
112	Headlight concealment		x	
113	Hood latch systems		x	
114	Theft protection			x
115	Vehicle ID number			x
116	Brake fluids		x	
118	Power windows		x	
124	Accelerator control system			x
201	Occupant protection in interior impact			x
202	Head restraints			
203	Impact protection- steering column			
204	Steering control rearward displacement			x
205	Glazing materials			x
206	Door locks and door retention			x
207	Seating systems			x
208	Occupant crash protection			
209	Seat belt assemblies			x
210	Seat belt anchorages			x
211	Wheel nuts, wheel discs and hub caps		x	
212	Windshield mounting			x
214	Side impact protection			
216	Roof crush resistance			x
301	Fuel system integrity			x
302	Flammability of interior		x	

Notes

(a) Rev: The contractor shall review the particular standard for its impact on the VDTV design and functionality; the decision to satisfy the standard shall be made by the contractor.

(b) Req'd: This standard is required.

(c) Intent: The intent of this standard shall be met, but not necessarily the exact details of the standard itself.

3.5.7 ENVIRONMENT

a. The VDTV shall be capable of meeting all requirements when operating in the following environment:

i. Ambient temperature from -200C to 380C.

ii. Sun load typical of the Southern US at the higher temperature.

iii. Warm-up or cooldown times of 15 minutes when parked in an unprotected outside area.

iv. Wet roads from natural rain or snowfall excepting all requirements which depends on tire/road friction coefficient.

b. The VDTV shall not be operated on any road treated with salt or other chemical when the effects of such treatment remain on a wet road surface.

3.5.8 OPERATIONS

a. The VDTV shall be operable with a driver alone, or with a driver and observer.

b. At least one on-board person shall be fully qualified to operate the VDTV.

C. The VDTV shall continuously monitor critical operational parameters and notify the driver/observer within one second of detection of a problem.

d. The VDTV shall provide a capability for occupant(s) to notify the test site's central control area of a possible operational problem within one minute of the automated problem detection.

3.5.9 OFF-BOARD DATA PROCESSING CAPABILITY

The Off-Board Data Processing capability will support VDTV operations by providing a computer platform and interface with the VDTV. This interface will receive data from the VDTV, and transmit configuration commands to the VDTV. The latter is essential to meet the VDTV's availability requirement because preparation of configuration commands for a specific test may occupy considerable time. It is highly desirable that the VDTV is not taken from its testing activities during configuration preparation.

3.5.9.1 <u>On-Board Data to Off-Board Data Transfer</u>

a. The Off-Board Data Processing capability shall accept media which transfer data from the Measurement S/S.

b. The Off-Board Data Processing capability shall transfer data from the media of (a) above to the Off-Board Data Processing hard disk via menu-driven commands.

C. The Off-Board Data Processing capability shall verify satisfactory transfer of the data file:

i. Using check data stored by the Measurement S/S.

ii. Comparing pre- and post-test headers to verify that they have the same content.

iii. Provide visual indication that the transfer was successful.

iv. Provide retry and recovery capability in case of an unsuccessful transfer.

d. The Off-Board Data Processing capability shall be provided with a detailed description of the data file format resulting from (b) above.

Note: This description must permit various users to write utilities which reformat the VDTV's file structure into the format required by their analysis programs.

3.5.9.2 Off-Board to On-Board VDTV Configuration Transfer

VDTV configuration changes, such as defining performance of various subsystems and on-board laptop commands to vary this performance, will be developed by user-supplied software. Results will be transferred to the VDTV via the laptop computer's floppy disk.

- The Off-Board Data Processing capability shall provide a software interface between user-supplied software which generates configuration commands and a floppy disk.

3.5.9.3 Off-Board Data Processing Equipment

Off-board data processing equipment shall be of the personal computer class, selected for high performance within this class.

3.5.10 MAINTENANCE

Note: The VDTV system may include maintenance support for the first year of operation, a costed option as discussed in ¶7.3.1.

3.5.10.1 General

- The deliverable VDTV system shall include the maintenance. resources defined in ¶s 3.5.10.2 through 3.5.10.5.

3.5.10.2 Documentation

a. Documentation which describes maintenance procedures for subsystems, devices, and components shall be included. Documentation shall include mechanical hardware, electrical/electronic hardware, and software.

Note: Documentation may be in the form of written manuals, videotapes, CD ROMS, or other media.

b. Documentation shall be suitable for the skills levels of personnel at VRTC.

3.5.10.3 Spare Parts

a. Spare parts which may require replacement during the VDTV's five year life shall be provided.

i. Every purchased component which has a delivery time greater than two months.

ii. Every specially fabricated component.

b. The need for replacement during the VDTV's five year life shall be:

i. Determined during the VDTV's analysis, design, and fabrication tasks.

ii. Supported by objective information provided prior to acceptance tests.

3.5.10.4 Supplies

- Maintenance supplies for a period of one year shall be provided and delivered with the VDTV.

3.5.10.5 Special Tools

- Special tools shall be provided and delivered with the VDTV:

    i. Needed to assemble, check, remove, or otherwise maintain special components.

    ii. Needed to maintain or modify the VDTV because of limited access.

3.5.10.5 Training

a. Training for VRTC personnel shall be provided:

    i. At VRTC.

    ii. For a period of one week.

b. Mechanical training shall include:

    i. Every part of the maintenance documentation.

    ii. All special components and tools.

c. Electronic/electric training shall include:

    i. Physical arrangement of sensors, cables, and connectors.

    ii. Physical arrangement of all electronic/electric hardware modules including card replacement, module replacement, and connector removal, and procedures to protect hardware and personnel from accidental hazards.

    iii. Debugging and check procedures, location of test points, and software commands to assist debugging.

d. Software training shall include:

    i. Changing control algorithms with different algorithms linked to the Data Access and Data Output Utilities.

    ii. Using software debugging programs to assist solution of problems in data channels.

    iii. Loading different configuration modules into the VDTV via the floppy disk.

3.5.11 CHANGE CONTROL

Since the VDTV incorporates both mechanical and software variability, its exact configuration for each test must be defined. This configuration must be included in the data file which is transferred to the off-board data processing capability so all data reduction can proceed with this single file.

Change control of SCIs is a critical function.

- The deliverable VDTV system shall include the change control resources defined in ¶s 3.5.11.1 through 3.5.11.3.

3.5.11-l **Safety**

- Every SCI shall be identified as a change control item.

3.5.11.2 **Mechanical Configuration**

a. All planned mechanical changes shall be identified as change control items.

b. All planned mechanical changes shall contain detailed information identifying their characteristics.

Note: Examples are tires (manufacturer, wheel diameter, aspect ratio, and nominal pressure), wheels (diameter, width, tread offset), anti-roll bars (diameter for both front and rear), tread offset devices, additional mass (vertical, horizontal, and lateral location; and weight).

c. Software for data file header information shall include provision for all planned mechanical changes.

3.5.11.2 **Electronic/Electrical Configuration**

- The electrical configuration shall be identified in the same manner as the mechanical configuration.

3.5.11.3 **Sensor Configuration**

- All sensors shall be identified:

a. With detailed information, including manufacturer, model, serial number, last calibration date, next calibration date, and sensed parameter.

b. The information of (i) shall be included in a single sensor code which identifies these sensor characteristics.

c. The sensor code shall be included in the header information.

3.5.11.4 SCI identification shall be provided in both written and floppy disk formats.

3.6 QUALITY ASSURANCE

3.6.1 RELIABILITY

As discussed in Exhibit I, ¶9.1, operational availability is used as the primary quality assurance criteria. The "ility" requirements are thus included in availability requirements.

3.6.2 OPERATIONAL AVAILABILITY

3.6.2.1 **Definition**

a. Operational availability shall be defined as the time that the VDTV is available to perform tests:

    i. Limited to deliverables under the contract.

    ii. Excluding constraints outside the scope of the VDTV system defined in Figure 3-2.

    iii. The VDTV is fully operational.

b. Constraints of (a)(ii) above shall include:

    i. Times that NHTSA requires the VDTV for publicity and related activities.

    ii. Times that NHTSA requires to modify the VDTV.

    iii. Weather at the test site.

    iv. Transportation to and from various test sites.

    v. Holidays.

    vi. Test area availability.

    Note: a test area may not be available for VDTV tests because other tests are scheduled.

    vii. Scheduled maintenance defined in contractual deliverables.

3.6.2.2 Requirements

The VDTV shall be available for tests an average of four days per five day work week as measured by:

a. The work week shall be five eight hour days.

b. The average availability shall be over four consecutive weeks.

Note: Averaging permits lengthy maintenance tasks to be performed over a period of greater than one day while maintaining the average availability.

c. All normally scheduled maintenance shall be performed according to procedures defined in the Contractor's maintenance documentation.

d. All unscheduled maintenance and repairs shall be determined to be completed under conditions of:

    i. At the completion of any unscheduled maintenance or repair activity, the VDTV shall perform a Performance Verification Test (PVT).

    ii. Upon successful completion of the PVT, the VDTV shall be deemed available.

    iii. The time that the VDTV is available shall be when it returns to the garage and shall be calculated on the basis of the nearest hour.

e. Activities defined by NHTSA shall not be included as unavailable time:

    i. Modifications from the as-delivered state, defined in the Contractor's documentation and change control documents after the as-delivered state. Upon completion of any modification, the VDTV shall conduct a PVT test to verify the VDTV's operational readiness. After successful completion of the PVT, the VDTV will be deemed ready to perform tests and returned to the available status.

    ii. Time when configuration changes defined by floppy disk inputs are being input to the VDTV and are being verified (including PVT after such configuration changes).

    Note: NHTSA will develop different configurations on the Off-Board Data Processing capability while the VDTV is available for tests.

iii. Time between tests when NHTSA reviews test data to determine data quality and test results before committing to the next test.

iv. Time for demonstrations and other public relations activities.

v. Time for NHTSA-defined activities shall be calculated on the basis of the nearest hour.

3.6.3 ELECTRICAL INTERFERENCES

As discussed in Exhibit I, ¶9.2, the critical characteristics are the VDTVs safety and operational availability. Both require freedom from all electrical interference. This leads to two requirements for electrical interference:

a. The VDTV shall meet all performance requirements with no effects of electrical interference.

b. The VDTV shall operate anywhere in the US with no constraints caused by electrical interference.

SECTION 4. VDTV-SUBSYSTEM REQUIREMENTS

4.1 INTRODUCTION

The VDTV consists of 6 subsystems:

- Dynamic Subsvstems- This one subsystem includes nine dynamic subsystems which provide specific dynamic variability.
- Control Subsystem- Sensors required for dynamic subsystems, storage of digital data for these sensors, computational capability shared by all dynamic subsystems, and control signals compatible with all dynamic subsystem actuators.
- Mechanical Subsvstem- Frame/body, propulsive power train, suspension, and any shared hydraulic power for the dynamic subsystems.
- Electrical Power Subsvstem- Electrical power for the vehicle, including any shared electrical power for the dynamic subsystems.
- Measurement Subsvstem- Sensors through on-board data storage not required by the Control Subsystem, and on-board to off-board data transfer.
- User Supplied Equipment Interface Subsvstem- Mechanical, electrical power, and bi-directional data interfaces to equipment which will be incorporated into tests during the VDTV's lifetime.

Overall characteristics of each subsystem are in paragraph 4.2. All dynamic subsystems are in ¶ 4.2.1; other subsystems follow. Subsystem functional requirements are contained in ¶ 4.3 in the same sequence.

4.2 SUBSYSTEM DESCRIPTIONS

4.2.1 DYNAMIC SUBSYSTEMS

Dynamic subsystems are defined from the viewpoint of performance functionality; front wheel steering, semi-active suspension, etc. Dynamic subsystems, and the paragraphs where their requirements are contained, are:

¶	Subsystem
4.3.1	Front wheel steer by wire.
4.3.2	Front wheel steer feel.
4.3.3	Brake by wire.
4.3.4	Brake feel.
4.3.5	Throttle by wire.
4.3.6	Throttle feel.
4.3.7	Rear wheel steer.
4.3.8	Semi-active suspension.
4.3.9	Automatic braking system.

Several dynamic subsystems may share a common resource such as hydraulic power, electrical power, and computational capability. These common resources are allocated to different subsystems. Using the above case as an example,

- Hydraulic Power: Mechanical Subsystem
- Electrical Power: Electrical Power Subsystem
- Computational Capability: Control Subsystem

Resource requirements for each dynamic subsystem are thus allocated to other subsystems.

4.2.2 MECHANICAL SUBSYSTEM

The mechanical subsystem includes the frame/body, where this description recognizes that the base vehicle may be derived from either a custom or production car approach. In the former case, the frame might be a welded tubular structure to which the power train, body panels, and interior components were attached. In the latter case, a unitized body and power train of a conventional production car would be used. In either case, the mechanical subsystem provides the platform onto which the other subsystems are attached.

Conventional parts of the braking and suspension functions are included. Examples are: (1) brake disks, calipers and possibly wheel cylinders, and (2) suspension springs, A-arms or equivalent, wheel hubs, and conventional anti-roll bars. In general, the Mechanical Subsystem includes components which are not variable via commands from the Control Subsystem; components needed to provide variable dynamic functions are allocated to the dynamic subsystems. Brake disks and calipers may need greater capacity to assure excellent brake performance with the combination of added weight and high performance tires which are expected to result from overall VDTV requirements.

The power train (engine, transmission, and coupling to the drive wheels) is included in the mechanical subsystem. It is expected that the power train will generally consist of conventional parts used in a representative vehicle. A possible significant exception is the engine power, which may have to be increased to provide acceleration performance equivalent to representative vehicles, compensating for the additional weight of the VDTV's dynamic subsytems and other modifications.

Tire/road adhesion will be the dominant factor in the VDTV' s dynamic performance. Tires and wheels will thus be a variable, changed during vehicle modification activities. Wheel wells must accommodate different wheel/tire volumes than a standard production car while maintaining the turning radius and vertical wheel travel. Given that appearance requirements are met, fender panels may be modified to provide the necessary functionality.

The Mechanical Subsystem includes shared resources needed by the Dynamic Subsystems. An example is the core portion of a hydraulic system; pump, main accumulator, reservoir, pressure control valves, filters, and lines to points which connect to any dynamic subsystem which requires hydraulic power. Local accumulators, valves, or other components specifically needed for a dynamic subsystem are allocated to this dynamic subsystem.

The Mechanical Subsystem's most critical requirement may be provision of a rigid structure which: (1) supports forces imposed by high performance dynamic subsystems, and (2) provides the integrity essential for the VDTV's life, which will include extensive operation in the limit performance regime.

4.2.3 CONTROL SUBSYSTEM

The Control Subsystem consists of the sensors, and computer hardware and software necessary to control the dynamic subsystems. In addition, a laptop computer is included to act as the primary interface between the driver/observer and the VDTV.

It is expected that the Control and Measurement Subsystems will have separate computer platforms (of the same hardware manufacturer) to facilitate development, maintenance, and modification activities. Software is also expected to have maximum commonalty between the two subsystems.

Measured data required by the control algorithms is included in the Control Subsystem. The complete data channel from sensors to stored digital data is included.

Control algorithms for the VDTV's Dynamic Subsystems reside in the Control Subsystem. Software interfaces permit control algorithms, developed throughout the VDTV's life, to access measured data and transmit control data to the Dynamic Subsystems. Conversion of digital signals into the form required by dynamic subsystem actuators is also included in the Control Subsystem.

Data flows through the Control, User-Supplied Equipment, Measurement, and Off-Board processing subsystems. A straw man functional description of tasks and data flows is shown in Figure 4-l.

This straw man is intended only for information, and is not a required implementation.

4.2.4 INTERFACES FOR USER-SUPPLIED EQUIPMENT

The VDTV includes interfaces for equipment which will evolve during the VDTV's life. Examples are lane detectors and forward/backward looking sensors. These exterior interfaces will provide mechanical mounting, power, and bi-directional data communications with the measurement and control subsystems. Interior interfaces for video and physiological data will also be provided. Data from these interfaces will be received by the Control S/S.

4.2.5 ELECTRICAL POWER SUBSYSTEM

The Electrical Power Subsystem provides electrical power for all other VDTV subsytems. A high output alternator, any additional batteries, control of discharge from the vehicle battery and any auxiliary batteries, regulators, noise filters, and power distribution to all elements requiring electrical power are included.

4.2.6 MEASUREMENT SUBSYSTEM

The Measurement Subsystem provides all functions from sensors to digital data not included in the Control Subsystem.

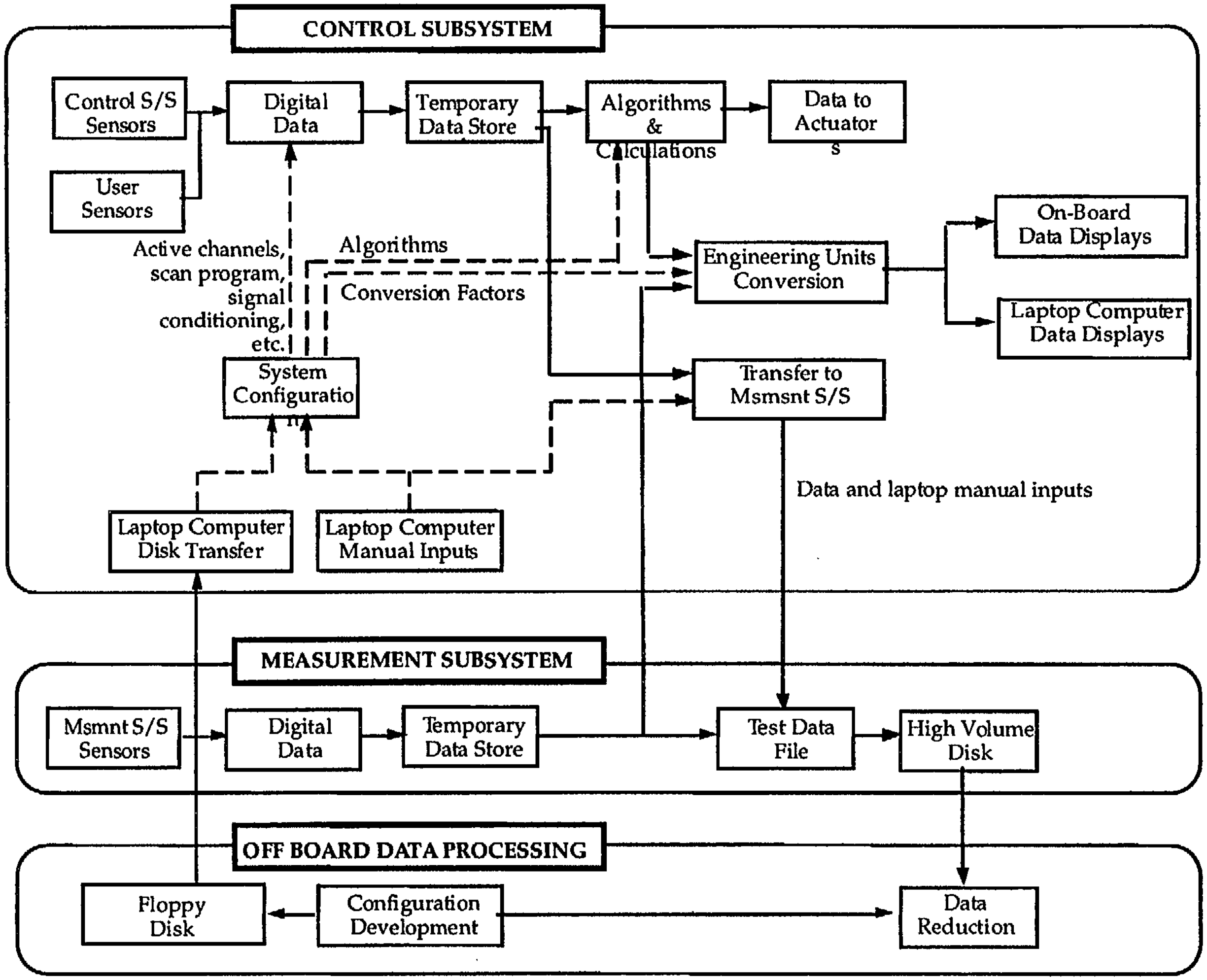


Figure 4-1. VDTV System Data Flow

4.3 DYNAMIC SUBSYSTEM FUNCTIONAL REQUIREMENTS

Note: For purposes of this document, acceptance tests which use electronic signals to actuators are assumed for some requirements. Different input and measurement techniques, based on those described in SAE and IS0 standards and papers, may be substituted to verify these requirements if equivalent data is provided. Sinusoidal inputs are assumed to verify bandwidth performance; others, such as step or pulse inputs with accompanying data reduction, are acceptable.

4.3.1 FRONT WHEEL STEER-BY-WIRE

4.3.1.1 Condition 3

a. Components from the first component (such as a connector) to receive an electronic input signal to wheel motions shall be included.

b. Tires shall be the highest performance tires used for dynamic performance tests.

c. Initial speed shall be 80 km/h with accelerator pedal position held constant throughout the tests.

d. Input signals shall be from an electronic source to the normal input to the front wheel steering subsystem.

   i. The fidelity of the signal source shall be a minimum of ten times that of the item being tested.

   Note: This generally refers to smoothness of a sine wave generated by software resident in the Control S/S.

   ii. The Control S/S may generate the necessary signals.

e. Measurements shall be made at the wheel pivot with sensor with at least 0.020 overall accuracy including characteristics of the sensor-to-mechanism attachment.

4.3.1.2 Full Scale Rotation

Center to full scale rotation shall be 36^{o}.

4.3.1.3 Bandwidth

The -3dB bandwidth shall be greater than 20 Hz, measured by:

a. Sinusoidal sweep input starting from 5 Hz, increasing until amplitude has decreased to at least -6 dB.

b. Input amplitude to attain a wheel motion of at least +/- 2^{o}.

4.3.1.4 Transient Response

a. On-center to full lock shall be 0.5 seconds maximum.

b. On-center to lo rotation:

   i. 90% rise time: 0.1 sec.

   ii. Maximum overshoot: 5%.

iii. Settling time to 2% of steady state value: 0.35 sec.

c. Center to 3^o rotation:

i. 90% rise time: 0.15 sec.

ii. Maximum overshoot: 5%.

iii. Settling time to 2% of steady state value: 0.45 sec.

4.3.1.5 Accuracy

- 0.1^o or 0.4% of the commanded angle, whichever is greater.

4.3.1.6 On-Center Resolution and Hysteresis

a. Input signals shall be:

i. Sinusoidal or triangular waves centered at the on-center wheel position.

ii. Between 0.2 and 0.5 Hz.

iii. Amplitude to attain a maximum lateral acceleration between 0.1g to 0.15 g.

b. Resolution shall be 0.050 or better.

c. Hysteresis shall be 0.150 or less.

4.3.2 FRONT WHEEL STEERING FEEL

Notes: Steering feel will be an important parameter for human factors research. Since the by-wire implementation of the front wheel steering disconnects all energy normally transmitted via mechanical connections from the road/tire interface to the steering wheel, the steering feel subsystem must emulate the basic characteristics of a representative vehicle.

It is recognized that steering feel of production car is a highly developed characteristic which involves many components. Tire/road interactions, particularly the restoring torque, provide complex signals to a driver. Detailed emulation of a specific vehicle is thus not required.

Vibration from the vehicle body/frame may be transmitted to the steering column, adding some feel to a production car. The VDTV's base vehicle may have significantly greater vibration because of dynamic performance/vibration tradeoffs. Isolation of the steering feel subsystem can permit the steering feel servo to emulate a range of road vibration.

4.3.2.1 Torque/Rotation Emulation

The torque/angular rotation emulation shall include the range shown in Figure-4-2.

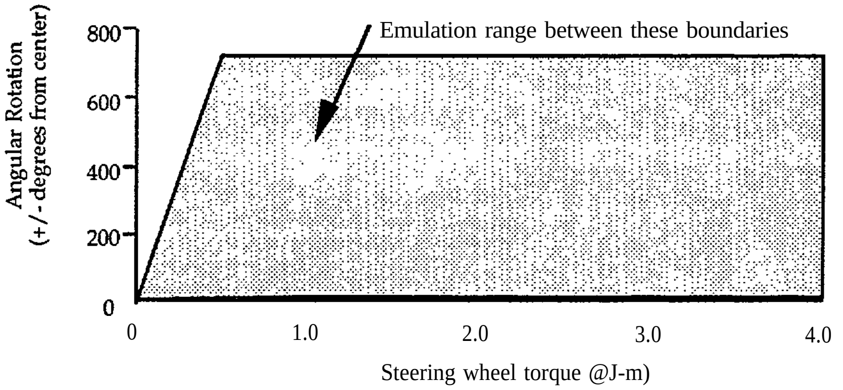


Figure 4-2. Steering Wheel Torque/Angular Rotation Emulation

4.3.2.2 Steering Ratio Variability

The steering ratio, in terms of steering wheel angle/front wheel angle, shall be continuously variable via laptop computer commands in a range from the full torque/no angular rotation mode to 20:1.

Note: Mechanical compliance of the steering mechanism is not included.

4.3.2.3 Steering Power Assist

The power assist shall be variable within the emulation range shown in Figure 4-3:

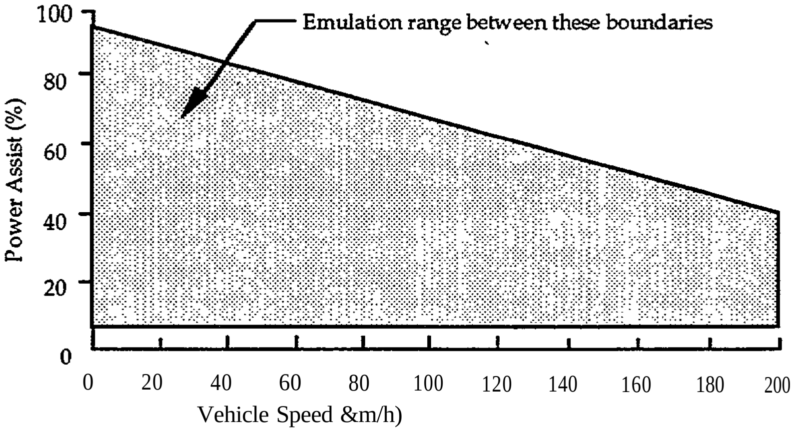


Figure 4-3. Power Assist Emulation Range

a. Laptop computer commands shall provide selection of different power assist algorithms.

b. The power assist of (i) above shall be a function of any sensor data available via the Data Access Utility of ¶4.4.3.

4.3.2.4 Restoring Torque

Emulation of tire/road restoring torque, as measured at the steering wheel, shall be continuously variable via laptop computer commands from zero to at least 1-1/2 times the tire/road restoring torque of a representative vehicle.

4.3.2.5 Road Vibration

Emulation of road vibration, as measured at the steering wheel, shall be:

a. Continuously variable via laptop computer commands from zero (subject to the minimum vibration provided by ¶4.3.2.6 below) to at least 1-1/2 times the road vibration of a representative vehicle.

b. A random input:

   i. Not necessarily related to actual structural or road vibrations.

   Note: The intent is to provide a range of vibration inputs, not from signals developed from sensors.

   ii. With a frequency range extending to 1 1/2 times that of a representative vehicle.

4.3.2.6 Isolation

The steering feel dynamic subsystem shall be isolated from body/frame vibration to permit the emulation of ¶4.3.2.5 above.

4.3.2.7 Driver Attention Pulses

The steering feel dynamic subsystem shall provide short pulses to the steering wheel:

a. Variable via laptop computer commands.

b. From one to four pulses.

   i. Pulses shall be in clockwise, then counterclockwise, directions.

   ii. The steering wheel shall be returned to its previous location after completion of the pulses.

c. Time duration for each pulse:

   i. From 0.1 to 2 seconds.

   ii. Resolution shall be at least 0.2 seconds.

d. An angular displacement or torque, depending on the active emulation mode, which provides:

   i. A steering wheel angular displacement in a range of $\sim 2^{o}$ to $\sim 5^{o}$

   ii. A steering wheel torque in a range of -0.04 to -0.2 Nm.

   iii. The pulse resolution shall be at least 20% of the displacement or torque.

Note: The purpose of these pulses is to obtain driver attention, such as when the VDTV wanders near, or beyond, lane markers.

4.3.2.8 Feel Servo Bandwidth

a. The -3dB bandwidth of the front wheel feel servo bandwidth shall be greater than 10 Hz.

b. The damping factor of the front wheel feel servo shall be within the range of 0.5 to 0.9.

4.3.2.9 Deliverable Algorithms

Deliverable algorithms, selectable by laptop computer commands, shall be provided:

a. Three algorithms with steering ratio and power assist based on characteristics of a representative vehicle:
   - i. One typical of a representative vehicle.
   - ii. One with a steering ratio near the low (numerically) end of the range . of a representative vehicle and relatively high power assist.
   - iii. One with a steering ratio near the high (numerically) end of the range of a representative vehicle and relatively low power assist.

b. Three algorithms with restoring torque of ¶4.3.2.4 using characteristics of a representative vehicle as a base:
   - i. One which emulates typical restoring torque.
   - ii. One which emulates low restoring torque.
   - iii. One which emulates high restoring torque.

c. Three algorithms with steering wheel torque/angular displacement characteristics of Figure 4-2:
   - i. One which emulates typical steering wheel torque/angular displacement characteristics of a representative vehicle.
   - ii. One which emulates steering wheel torque/angular displacement characteristics near the lower bound of the emulation area.
   - iii. One which emulates steering wheel torque/angular displacement characteristics near the left bound of the emulation area.

d. Three algorithms with vibration characteristics of ¶4.3.2.5 using characteristics of a representative vehicle as a base::
   - i. One which emulates typical steering wheel vibration.
   - ii. One which emulates steering wheel vibration near the low end.
   - iii. One which emulates steering wheel vibration near the high end.

e. One algorithm which provides driver attention pulses of ¶4.3.2.7:
   - i. Four pulses.
   - ii. An angular displacement or torque, depending on the emulation mode, of 0.1% of the full scale range.
   - iii. A pulse time of 0.3 seconds.

f. The algorithms of (a) through (e) above shall be:
   - i. Independently variable.

ii. Capable of being combined into a single algorithm, via laptop computer commands, with one selection from each paragraph from (a) through (e) being combined into a single algorithm.

Note: Only one algorithm will be operational at one time, so the deliverable algorithms may be implemented separately by tables, lists, menus, or other methods which select the combinations of the various steering wheel feel algorithms.

4.3.3 BRAKE-BY-WIRE (BBW)

Note: ABS is treated separately in ¶4.3.9.

4.3.3.1 High Speed, Full Braking

The BBW S/S, combined with performance of the Mechanical S/S (brake discs, brake pads, suspension, wheels, and tires), shall be capable of locking all four wheels at a speed of 160 km/h under conditions of:

a. Brake pedal force applied manually in less than 0.5 seconds.

Note: The intent is for the test driver to apply full pedal force as quickly as possible, such as a panic stop response, with a maximum time of 0.5 seconds.

b. The brake pedal force of (a) above shall apply the maximum pressure to the brake hydraulic system.

c. Highest performance tires.

4.3.3.2 Brake Control

Note: AHS needs very fine longitudinal speed control to investigate platooning boundaries. This will require speed variations with fine resolution which may be accomplished with a combination of braking and throttle control.

a. Brake force shall be independently controlled at all four wheels.

b. AHS brake force resolution shall be capable of:

   i. Attaining a minimum deceleration of 0.005 g above that of closed throttle conditions (deceleration from rolling and aerodynamic drag) in a speed range of at least 80 km/h to 150 km/h.

   ii. A resolution of O.Olg at deceleration rates greater than (i) above.

   iii. For pulsed implementation, the pulse frequency shall be at least 100 pulses per second.

   iv. A time delay from start of the input signal to the rise of pressure, measured immediately adjacent to the most remote brake cylinder, not greater than 50 milliseconds.

   v. The maximum time delay difference between all four wheel cylinders shall be 10 milliseconds.

Note: The deceleration requirement may be accomplished by varying pressure, pulsed pressure parameters, or a combination of both.

c. Normal Braking Range

Note: The normal braking range applies to braking greater than the fine resolution required for AHS platooning scenarios.

i. Deceleration capability shall be continuous from that of the AHS requirement of (b) above to full braking deceleration.

ii. A time delay from start of the input signal to the rise of pressure immediately adjacent to the brake cylinder not greater than 100 milliseconds.

iii. The maximum time delay difference between all four cylinders shall be 20 milliseconds.

4.3.4 BRAKE FEEL

4.3.4.1 Emulation Range

The brake feel subsystem shall provide programmable control within the emulation range shown in Figure 4-4, subject to the zones defined in ¶4.3.4.2 below.

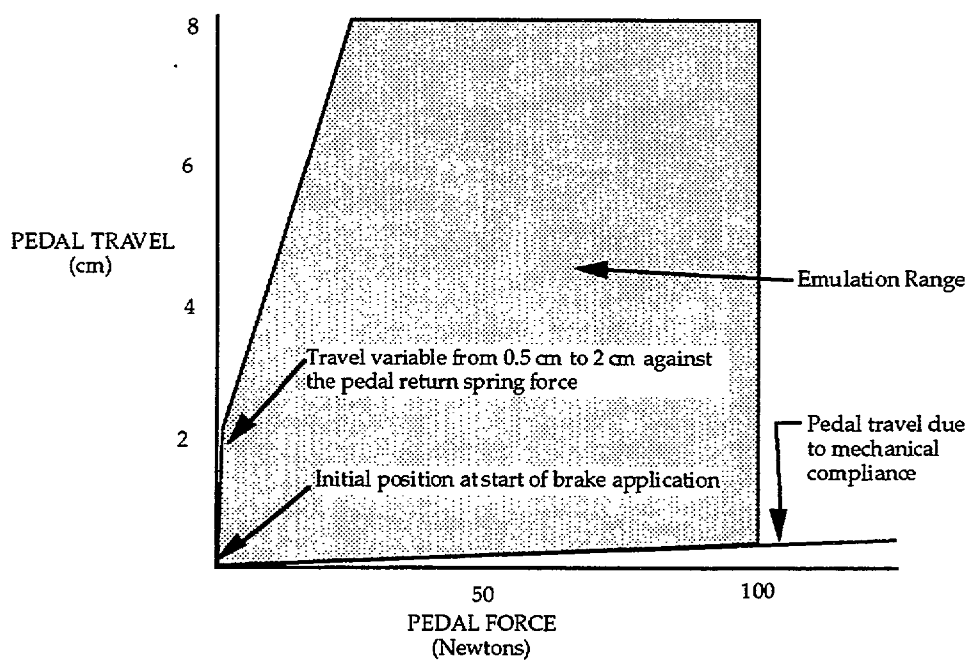


Figure 4-4. Brake Feel Emulation Range

4.3.4.2 Emulation Zones

During application, the brake feel shall provide three zones as shown in Figure 4-5:

a. Zone 1: emulate the resistance of the brake pedal return spring:

i. In a range of pedal travel from the rest position to 2 cm.

ii. With a force range from 0.1 N to 2 N over this range.

iii. With an essentially linear force vs. travel characteristic over this range.

b. Zone 2: emulate the normal range of brake application:

   i. A generally linear force vs. travel.

   ii. A monotonically increasing slope of the force vs. travel curve.

   iii. A variable slope from termination of Zone 1 to Zone 3.

   iv. A slope anywhere within the emulation range of Figure 4-5.

c. Zone 3: emulate the force vs. travel curve when the brake pedal is restrained by mechanical constraints:

   i. A generally linear force vs. travel.

   ii. A monotonically increasing slope of the force vs. travel curve.

   iii. A variable slope from termination of Zone 2.

   iv. A slope within the range of 70 Newtons/cm to 140 Newtons/cm.

d. Transitions between different zones shall be gradual, typical of a production car.

e. When pedal force is released, the pedal shall return to the rest position within 0.5 seconds.

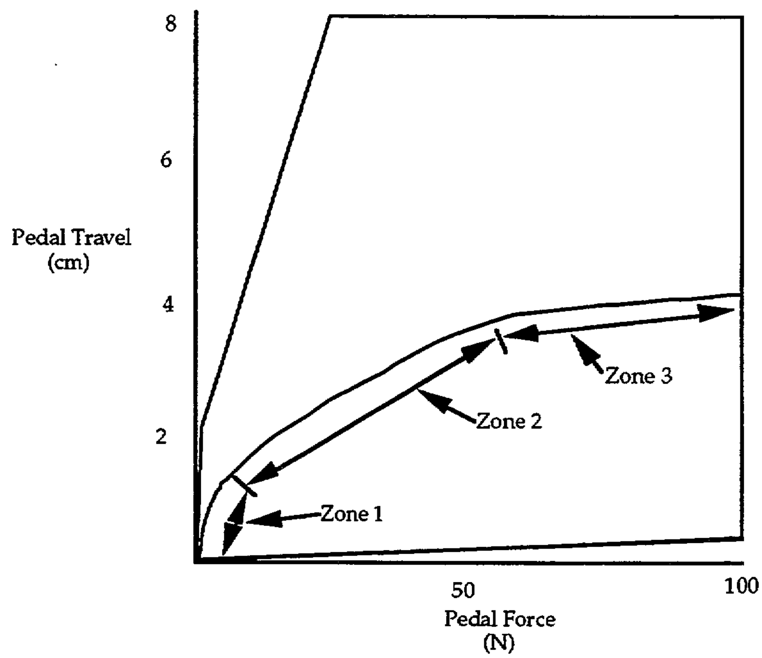


Figure 4-5. Brake Pedal Feel Zones

4.3.4.3 <u>Driver Attention Pulses</u>

The brake feel dynamic subsystem shall provide short pulses to the brake pedal:

a. Pulses shall be selectable via laptop computer commands:

i. Number of pulses.

ii. Displacement of each pulse.

iii. Time duration of each pulse.

b. From one to four pulses.

c. Motion:

i. Displacement shall be 2% to 10% of the full scale displacement.

ii. Resolution shall be 2% or less of the full scale displacement.

d. Time duration for each pulse:

i. From 0.1 to 2 seconds.

ii. Resolution shall be at least 0.2 seconds.

e. The brake pedal shall be returned to its original location after completion of the pulses.

f. The number of pulses and displacement shall be selectable via laptop computer commands.

Note: The purpose of these pulses is to obtain driver attention, such as when the VDTV exceeds limits defined by user-supplied algorithms.

4.3.4.4 Deliverable Algorithms

Deliverable brake feel algorithms shall include:

a. One algorithm which defines a pedal travel/pedal force characteristic at, or within 10% of, the zero pedal travel bound of Figure 4-5.

b. One algorithm which defines a pedal travel/pedal force characteristic at, or within 20% of, the left and upper bounds of Figure 4-5.

c. Three algorithms which define three different ranges of braking characteristics of typical production cars within the bounds of Figure 4-5.

d. One algorithm which adds pulses of ¶4.3.4.3 above:

i. Two pulses.

ii. Brake pedal displacement of 5% of the full scale motion. .

iii. The pulse resolution shall be 5% or less of the full scale motion.

iv. The brake pedal shall be returned to its original location after pulses.

e. The algorithms of (a) through (d) above shall be:

i. Independently variable.

ii. Capable of being combined into a single algorithm, via laptop computer commands, with one selection from each paragraph from (a) through (d) being combined into a single algorithm.

Note: Only one algorithm will be operational at one time, so the deliverable algorithms may be implemented separately by tables, lists, menus, or other methods which select the combinations of the various brake feel algorithms.

4.3.5 THROTTLE-BY-WIRE

The VDTV's throttle control has two different operational modes: (1) typical operation during research activities, and (2) fine power control for longitudinal distance keeping in AHS platoon research. The following requirements assume a rotary actuator at an air flow control valve with a 90° total angle from the full closed to full open position. Other implementations with equivalent performance are acceptable.

a. Throttle resolution shall be 0.1%.

b. Hysteresis shall be less than 0.15%.

c. Dynamic response shall be:

   i. 1000°/second.

   ii. Settling to within 0.1% of steady-state value within 10 milliseconds after a 10° command.

4.3.6 THROTTLE FEEL

The throttle feel S/S must provide a range of feel to the driver that is capable of emulating typical passenger vehicles as well as providing feel for research activities. These two requirement combine to require that the feedback system have reasonably broad performance characteristics.

A primary requirement is that "stiction" and hysteresis be minimized in the basic design and implementation so this characteristic can be controlled by the throttle feel algorithm. Typical passenger cars have a very non-linear relationship between accelerator pedal displacement and the throttle angle. This relationship must also be controlled by the throttle feel algorithm.

4.3.6.1 Emulation Range

The throttle feel algorithm shall be capable of implementing any smooth, monotonically increasing curve within the shaded area of Figure 4-6:

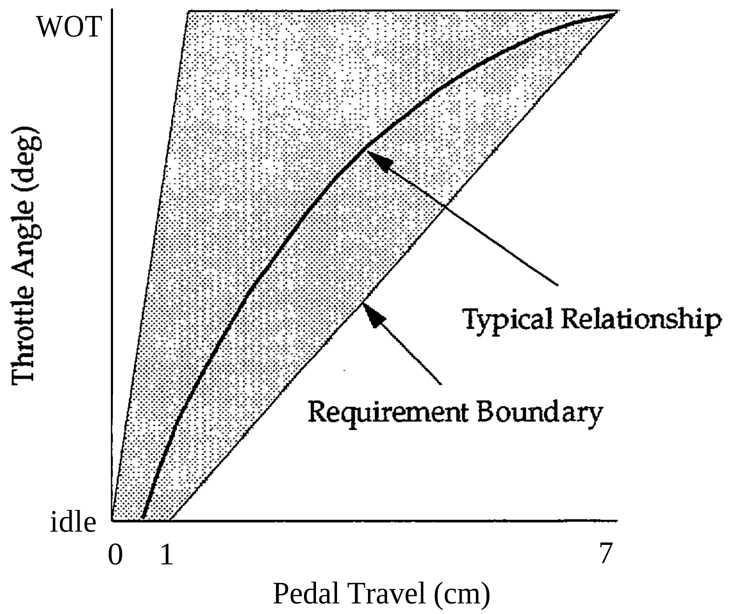


Figure 4-6. Throttle Feel Emulation Boundary

4.3.6.2 Variable Hysteresis

The throttle feel algorithm shall provide variable hysteresis:

a. At any point within the emulation range of Figure 4-6 above.

b. Variable from zero to 10% of the force range.

c. With a resolution of at least 1% of the force range of Figure 4-6 above.

d. Hysteresis shall be defined by measuring the pedal force vs. pedal travel in both throttle opening and throttle closing directions.

4.3.6.3 Driver Attention Pulses

The throttle feel dynamic subsystem shall provide short pulses to the accelerator pedal:

a. From one to four pulses.

b. A displacement of 2% to 10% of the full scale displacement range.

c. The pulse resolution shall be 2% or less of the full scale displacement.

d. Time duration for each pulse:

   i. From 0.1 to 2 seconds.

   ii. Resolution shall be at least 0.2 seconds.

e. The accelerator pedal shall be returned to its original location after pulses.

f. The number of pulses and displacement shall be selectable via laptop computer commands.

Nate: The purpose of these pulses is to obtain driver attention, such as when the VDTV speed exceeds limits defined by user-supplied algorithms.

4.3.6.4 Deliverable Algorithms

Deliverable pedal feel algorithms shall include:

a. One algorithm which defines a pedal travel/throttle angle characteristic near the right boundary of Figure 4-6.

b. One algorithm which defines a pedal travel/throttle angle characteristic near the left boundary of Figure 4-6.

c. Two algorithms which define two different ranges of throttle feel characteristics of typical production cars within the bounds of Figure 4-6.

d. For the algorithms of ¶4.3.6.4(a) through ¶4.3.6.4(c) above, one algorithm which adds pulses of ¶4.3.6.3 above:
   i. With two pulses.
   ii. With variable pulse height.

e. The algorithms of (a) through (d) above shall be:
   i. Independently variable.
   ii. Capable of being combined into a single algorithm, via laptop computer commands, with one selection from each paragraph from (a) through (d) above being combined into a single algorithm.

Note: Only one algorithm will be operational at a time, so the deliverable algorithms of ¶4.3.6.4 above may be implemented separately, by tables, lists, or menus which select combinations of the feel characteristics, or other methods.

4.3.7 REAR WHEEL STEER

4.3.7.1. Condition

- Conditions shall be the same as ¶4.3.1.1.

4.3.7.2 Full Scale Rotation

Rear wheel steering full scale rotation shall be the largest of:

a. That needed to support the emulations of vehicle's understeer coefficient, J-turn 90% rise time, and Consumer Union-defined obstacle avoidance maneuver as described in Section 3.5.2.

b. +/- 6^{o}.

4.3.7.3. Bandwidth

The -3 dB bandwidth shall be at least 15 Hz with a rotation of +/- 2 degrees at 80 km/h.

4.3.7.4. Engagement

The rear wheel subsystem shall include the capability to either:

a. Deactivate the rear wheel steering system (i.e., front wheel steering) with the rear wheels positioned for front-wheel steering only.

b. Control the rear steering angle according to algorithms selected via laptop computer commands. These linear/nonlinear algorithms shall:

i. Access data from any data channel via the Data Access Utility defined in ¶4.4.3.

Note: Examples are vehicle' forward speed, front wheel steering angle, lateral acceleration, yaw rate, and measured rear wheel steering angle.

ii. Transmit commands from the algorithms via the Data Output Utility defined in ¶4.4.4.

4.3.7.5. Backup Position

Both rear wheels shall return at the maximum safe rate to their positions for front wheel steering only under the following conditions:

a. From laptop computer commands.

b. As part of an autonomous fault protection response.

4.3.7.6. Deliverable Algorithms

Deliverable algorithms shall include:

a. One algorithm which constrains the rear wheel steering angle to the position for only front wheel steer.

b. A single algorithm used for the dynamic performance tests of ¶3.5.2.

c. One additional algorithm which uses, as a minimum, vehicle velocity, front wheel angle, and yaw velocity.

4.3.8 SEMI-ACTIVE SUSPENSION

Nate: The combination of semi-active suspension and dynamic anti-roll bars are an alternative to fully active suspension (a costed option in ¶7.1.1).

4.3.8.1 Damping Levels

At least three levels of damping forces shall be provided by the semi-active suspension system:

a. At a piston speed of 75 cm/sec, the "hardest" damping forces shall be at least 3400 and 900 N. in extension and compression, respectively.

b. At a piston speed of 75 cm/sec, the "softest" damping forces shall be at least 1200 and 670 N. in extension and compression, respectively.

c. At a piston speed of 75 cm/sec, the third damping force shall be approximately midway between the hardest and softest forces.

4.3.8.2 Damping Control

The semi-active suspension subsystem shall include a capability, via laptop computer commands, to either:

a. Set the damping at one of the three settings.

b. Control the damping according to selected algorithms which:

i. Access data from any data channel via the Data Access Utility defined in ¶4.4.3.

Note: Examples are vehicle forward speed, brake pressure, lateral acceleration, and throttle position.

ii. Transmit commands from the algorithms via the Data Output Utility defined in ¶4.4.4.

4.3.8.3. Delay Time

The delay between the time a new damping level command is given and the time that damping level is achieved shall be less than 12 msec.

Note: In addition, a continuously variable semi-active suspension is a costed option described in ¶7.1.3.

4.3.8.4 Deliverable Algorithms

Deliverable algorithms shall include:

a. One algorithm which permits laptop computer selection of one of the three damping ratios.

b. One algorithm which automatically selects the damping ratio as a function of vehicle speed and wheel vertical motion.

c. One algorithm which automatically selects the damping ratio as a function of vehicle speed, wheel vertical motion, and deceleration.

4.3.9 AUTOMATIC BRAKING SYSTEM

Note: Performance of the automatic braking capability must be greater than that of production anti-lock braking system (ABS) for research directed to advanced control stability technology. Variable control of slip ratio and capability of applying braking torques with fine resolution at each wheel is needed for this research. These requirements are in addition to those of the Brake by Wire S/S defined in ¶4.3.3.

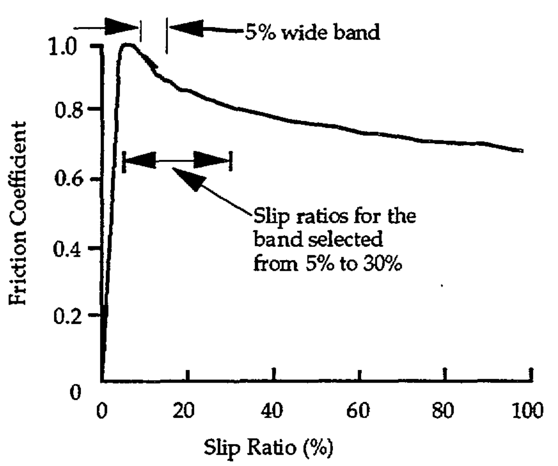


Figure 4-7 Braking Force vs. Slip Ratio

4.3.9.1 Slip Ratio

Slip ratio shall be variable via laptop computer commands:

a. Independently at each wheel.

b. From 5% to 30%.

c. Within the range of (b) above, in a band not greater than 5%.

d. For any selected band, the frequency of brake pressure pulses shall vary according to either:

   i. According to algorithms of representative vehicles.

   ii. Not more than 20% during the entire ABS application time.

e. Algorithms which implement the requirements of (a) through (d) above

4.3.9.2 Deliverable Algorithms

Deliverable algorithms shall include:

a. One algorithm which implements the ABS of a representative vehicle, including braking strategy for both rear wheels.

b. One algorithm which permits selection of the ABS to an individual wheel, or two wheels on the rear axle.

c. One algorithm which permits laptop computer selection of:

   i. The slip ratio.

   ii. The band of the slip ratio.

   iii. The parameters of (i) and (ii) above shall be:

      (a) Independently variable.

      (b) Capable of being combined into a single algorithm, via laptop computer commands, with the selected slip ratio and band being combined into a single algorithm.

d. One algorithm which minimizes both braking distance and yaw during a straight-line panic stop from 130 km/h.

e. One algorithm which maximizes deceleration and minimizes yaw during a brake and turn maneuver under conditions of:

   i. An initial speed of 100 km/h in straight-line driving.

   ii. Maximum deceleration initiated at the start of the maneuver.

   iii. Lateral acceleration starting from zero, then increasing to 0.5g within 2 seconds.

   iv. Maintaining the deceleration and the same turning radius until the VDTV comes to a complete stop.

4.4 CONTROL SUBSYSTEM

The Control Subsystem is responsible for four major functions as shown in Figure 4-8:

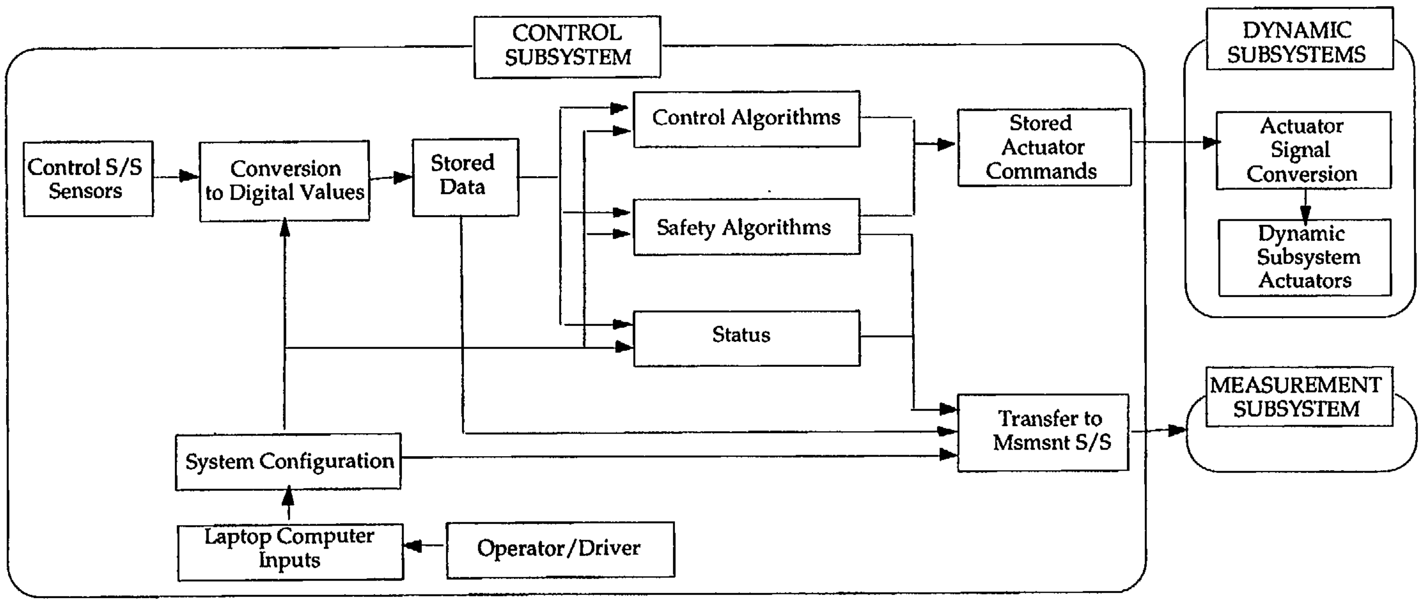


Figure 4-8. Strawman Control Subsystem Architecture

- All functions necessary to send signals to the dynamic actuators (sensors, conversion of raw signals to digital data, algorithms, and transmission of signals to each actuator).
- Interface between the driver or observer to the vehicle via a laptop computer.
- Real-time verification that the Control S/S and all dynamic S/Ss are operating safely.
- Transfer of all Control S/S data to the Measurement S/S.

Since data from feedback sensors will be available to the Control S/S, checks on safe operation of dynamic subsystems is included. The last function permits the Measurement S/S to store all data for transfer to the off-board Data Processing S/S.

4.4.1 SAFETY

To provide maximum assurance of safe operations, the Control S/S is responsible for monitoring safety critical items of the Control S/S hardware and software as well as the dynamic subsystems with safety critical functions.

4.4.1.2 Real-Time Monitoring

a. Computer Hardware

   i. A hardware-based watchdog timer shall be incorporated which verifies that the computer hardware is operating.

   ii. The timer shall check operation every 10 milliseconds.

   iii. In case of a failure, the watchdog timer shall send a warning signal to an output device, clearly visible to both front seat occupants.

   iv. The warning signal shall operate independently of the computer power supply, laptop computer, and all other normal functions.

b. Data Limit Checks

   i. For all safety critical data channels, the latest data shall be checked against high and low limit checks.

   ii. The checks shall be made before the new data is sent to the temporary storage or used in any safety critical control algorithm.

   iii. If any data is out of limits, a warning shall be issued to the laptop computer display which includes:

      (a). The data channel # and parameter name.

      (b) The limit (high or low) that was violated.

      (c). An audible alarm.

      (d) A flashing warning display.

c. Data Slope Checks

   i. Critical data, identified in Task 1 defined by the Statement of Work, shall have a slope check in addition to the limit checks.

ii. Changes from the current data to the previous data shall verify that the latest data is within reasonable bounds and shall consider, as a minimum:

(a) Magnitude change from the previous data.

(b) Time from the previous data.

(c) The VDTV configuration (its current emulation mode, tires, mechanical configuration, etc.)

(d) Input commands (steering, brake, and throttle) which define current vehicle maneuvers.

Note: Short-term averaged data may be used to reduce noise and other perturbations prior to slope calculations.

iii If any slope data is out of limits, a warning shall be issued to the laptop computer display which includes:

(a) The data channel # and parameter name.

(b) Definition that this is a highly critical data channel.

(c) An audible alarm.

(d) A flashing warning display.

4.4.1.3 Electrical Power Subsystem Output

a. The Control S/S shall monitor all voltages and the digital logic current from the Electrical Power S/S.

b. The Control S/S shall monitor noise on at least one Electrical Power S/S output.

4.4.2 DATA ACQUISITION

For purposes of this specification, the strawman architecture of Figure 4-9 is used to support the text. The Contractor will develop the architecture actually used and is not constrained by the strawman.

4.4.2.1 Control Subsystem Measurements

The Control S/S is responsible for acquiring data from three categories of sensors as shown in Figure 4-9.

Note: An estimate of possible sensors and signals is shown in Table 4-1. Sensors and signals will be defined in Task 1 of the Statement of Work.

Table 4-1 is to be used only as a guide. Sensors, frequency response, sampling rates, and other parameters in the final design are likely to have significant changes from the content of Table 4-1.

a. The Control S/S shall include all components necessary to provide data for the dynamic subsystems, including sensors, cable, connectors, conversion to digital values, and storage in a temporary data buffer.

b. The Control S/S shall include, as a minimum, signals and sensors for the engine and body status shown in Table 4-1.

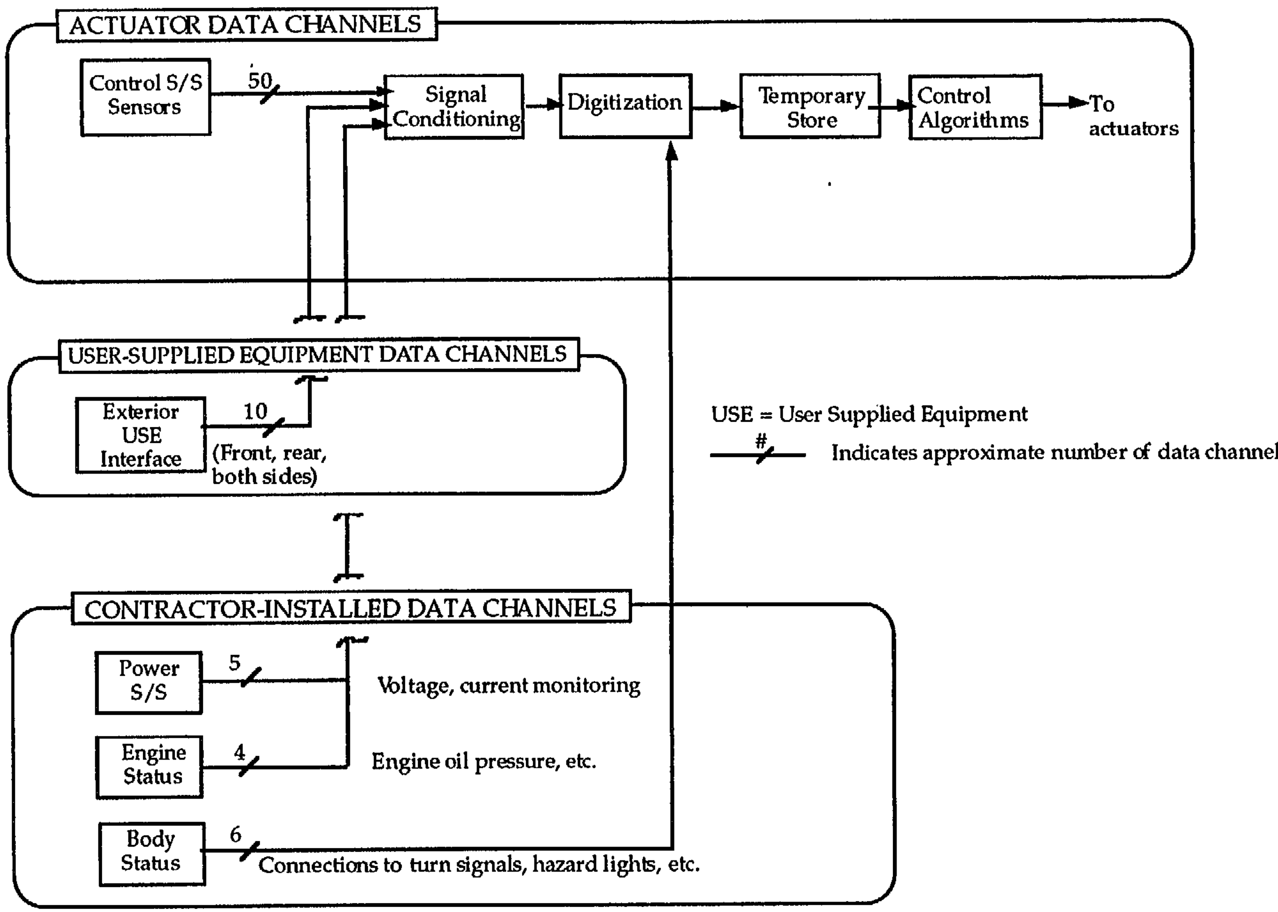


Figure 4-9. Sensors for Control Subsystem

Table 4-l. Potential Control Subsystem Sensors and Signals

AREA	POTENTIAL MEASUREMENT	SC1	TOTAL # CHNS	SAMPLING RATE Chn Freq	SAMPLING RATE Total
		(a)	(b)	(c)	(d.)
DYNAMIC SUBSYSTEMS					
Front Steer	Steering wheel position	Y	1	20	200
	Steering wheel torque	Y	1	20	200
	Steering wheel rate	Y	1	20	200
	Actuator position	Y	1	20	200
	Actuator force	Y	1	20	200
	Left wheel angle	Y	1	20	200
	Right wheel angle	Y	1	20	200
Front Steer Feel	Steering wheel position	Y	1	20	200
	Steering wheel torque	Y	1	20	200
	Actuator position	Y	1	20	200
Brake by Wire	Brake pedal position	Y	1	5	50
	Brake pedal force	Y	1	5	50
	Wheel cylinder pressure	Y	4	20	800
Brake Feel	Brake pedal position	Y	1	5	50
	Brake pedal force	Y	1	5	50
Throttle by Wire	Accelerator pedal position	Y	1	5	50
	Accelerator pedal force	Y	1	5	50
	Engine air flow position	Y	1	5	50
Throttle Feel	Accelerator pedal position	Y	1	5	50
	Accelerator pedal force	Y	1	5	50
Rear Wheel Steer	Actuator position	Y	1	20	200
	Actuator force	Y	1	20	200
	Left wheel angle	Y	1	20	200
	Right wheel angle	Y	1	20	200
Semi Active Suspension	Orifice position	N	4	20	800
ABS	Wheel speed	Y	4	20	800
Hydraulic system (if needed)	Reservoir fluid level	Y	1	0.1	1
	Pumppressure	Y	1	0.1	1
	Accumulator pressure	Y	1	0.1	1
	Manifold pressure	Y	1	1	10
DYNAMIC S/S X			36		-6000

Table 4-1. Potential Control Subsystem Sensors and Signals

AREA	POTENTIAL MEASUREMENT	SCI	TOTAL #CHNS	SAMPLING RATE Chn Freq	SAMPLING RATE Total
		(a)	(b)	(c)	(d)
USER SUPPLIED EQUIPMENT INTERFACE					
Front Interface DPU	Typical of four interfaces				
(Digital Processing Unit)	Serial digital data	Y	1	2	20
	Parallel digital data	Y	1	2	20
	Digitized analog data	Y	2	2	40
Rear Interface DPU	Same as front channel	Y	4	2	80
Left Side Interface DPU	Same as front channel	Y	4	2	80
Right Side Interface DPU	Same as front channel	Y	4	2	80
Physiological Msmnts	Measurement Subsystem	N	13	1	130
TV Interface	Measurement Subsystem	N	8	1	N/A
USEIF S/S 3			**29**		**~600**
BODY MOTIONS, ETC.	CG- yaw rate	Y	1	3	30
	CG- longitudinal acceleration	Y	1	2	20
	CG- vertical acceleration	Y	1	2	20
	CG-inclination	N	1	2	20
	Front axle lateral acceleration	Y	1	3	30
	Rear axle lateral acceleration	Y	1	3	30
	Longitudinal speed	Y	1	2	20
	Heading sensor	N	1	1	10
	Gas level	N	1	0.1	1
	Status	N	6	1	60
	GPS, 6 channel	N	6	1	60
	Pitch rate[2]	N	1	2	20
	Roll rate	N	1	2	20
BODY MOTION 3			**24**		**~600**
ENGINE					
	RPM	N	1	1	10
	Temperature	N	1	0.1	1
	Oil pressure	N	1	0.1	1
	Drive shaft torque	N	1	1	10
ENGINE 3					

[2]Optical gyros are preferred

Table 4-1. Potential Control Subsystem Sensors and Signals
(Continued)

AREA	**POTENTIAL MEASUREMENT**	**SCI**	**TOTAL #CHNS**	**SAMPLING RATE**	
				Chn Freq	Total
		(a)	(b)	(c)	(d)
POWER S/S					
	+ 5V	Y	1	1	10
	+15V	Y	1	1	10
	-15V	Y	1	1	10
	Total current	Y	1	1	10
POWER S/S 3					
COSTED OPTIONS					
Full active suspension	Hub to body position	Y	4	25	1000
	Force	Y	4	25	1000
	Hub to isolator position	Y	4	25	1000
Anti-roll bars (front and rear)	Actuator position	Y	2	5	100
	Actuator force (or torque)	Y	2	5	100
Dynamic tire pressure	Tire pressures	Y	4	0.2	8
COSTED OPTIONS 3			**12**		**~4000**
TOTAL SAMPLING RATE					**~12000**

Notes

(a) A "Y" (Yes) or "N" (No) in the SCI column indicates that the channel is a potential safety critical item.
(b) An estimate of the total number of channels for each item.
(c) Indicates an assumed frequency for each channel.
(d) Estimate of the sampling rate per channel, and the areas defined in bold in column 1, assuming a sampling rate 10 times the channel frequency. The per-area summary is in bold and is rounded upward by about 20% to give a general indication of the total sampling frequency with the assumed sensors and per-channel rates.

i. Sensors shall be provided- when necessary.

ii. Electrical isolation to protect normal vehicle performance shall be provided when necessary.

Note: An example is connection to an engine control parameter which could introduce noise or otherwise degrade performance of highly developed engine controls.

c. The Control S/S shall acquire data from User-Supplied sensors via the User-Supplied Equipment Interface S/S.

4.4.2.3 <u>Data Characteristics</u>

Since the Control S/S acquires data from many sensors which is transferred to the Measurement S/S, data from the Control S/S must meet the data quality and time correlation requirements of the Measurement S/S.

- The Control S/S shall comply with all measurement requirements defined in ¶4.7.5 through ¶4.7.9.

4.4.3 DATA ACCESS UTILITY

Data from all sensors will be stored in a temporary buffer, ready for access by control algorithms, calculations, or other on-board functions. These functions will be written as modules; many will change during the VDTV's life. To minimize future programming burdens, a data access utility will provide data to any module.

a. The Data Access Utility shall accept at least three parameters from any module:

i. Data channel number.

ii. Priority (defines latency time or other time-critical function).

iii Data storage location used by the calling module.

b. The Data Access Utility shall use this information:

i. After limit and slope checks have been completed.

ii. To store the latest data in the defined storage location.

c. Transmit the data to the storage location of (a)(iii).

4.4.4 DATA OUTPUT UTILITY

The Data Output Utility will provide the interface between control algorithm, calculation, or other modules and the end device (such as a dynamic subsystem actuator controller).

a. The Data Output Utility shall accept three parameters from a control algorithm, calculation, or other module:

i. Output device number.

ii. Priority.

iii. Storage location (such as hardware address of the controller).

b. The Data Output Utility shall format the data to the protocol required by the end device.

Note: This includes conversion to serial or parallel data streams, digital to analog conversion, etc. Any needed amplification can be done at the most appropriate location.

4.4.5 SOFTWARE

a. The Control S/S software shall include the functions shown in Figure 4-10.

b. All purchased Control S/S software shall be supported throughout the US.

c. Software deliverables shall include a single site license, documentation, and software for all items needed by a developer, other than the Contractor, to continue software development.

d. System-level software and the next level of software modules shall include built-in diagnostics to:

   i. Verify nominal operation in real time.

   ii. Assist debugging during problems and modifications.

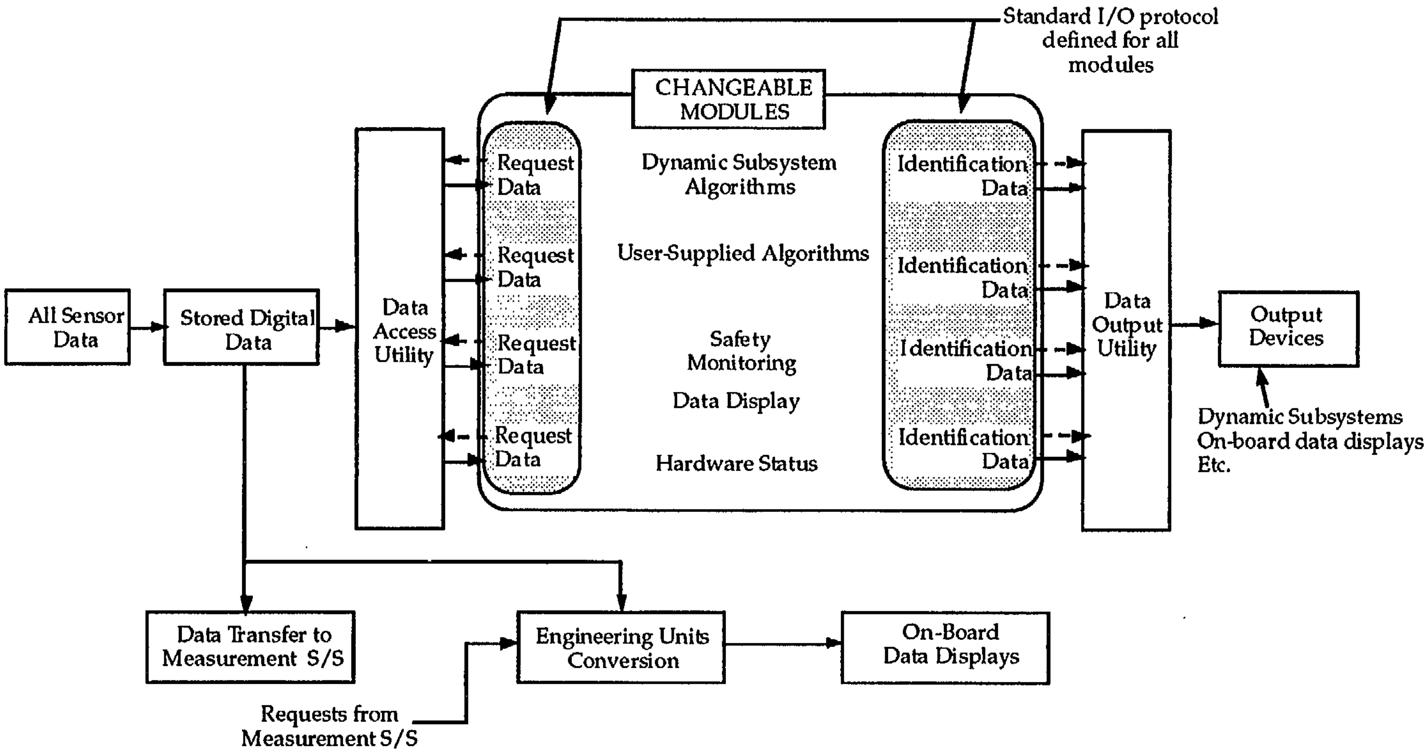


Figure 4-10. Strawman Control Subsystem Software Architecture

4.4.6 CONTROL ALGORITHMS

Control algorithms are expected to be changed during the VDTV's life, so must be written in modular form.

4.4.6.1 Deliverable Aleorithms

Note: This ¶ defines vehicle-level deliverable algorithms which will permit the VDTV to emulate the performance of vehicle classes. Deliverable algorithms for each dynamic subsystem are contained in ¶4.3.

a. Vehicle level algorithms shall define performance typical of generic classes, not detailed characteristics of specific vehicles.

b. Six algorithms which emulate the differences of crash avoidance maneuvers for a range of performance (good to poor) and vehicle classes (small to large) of the US vehicle fleet at the time of delivery shall be provided:

   1. A matrix of: (1) classes of large, medium and small vehicles, combined with (2) good and poor performance for each class.

   ii. Which are essentially evenly spaced over the emulation range of Figure 3-1.

c. Five algorithms which extend extremities of the range of the vehicles in the Us's fleet by a minimum of 25% shall be provided:

   i. Two shall extend the emulation range of Figure 3-1 to the upper right and lower right, representing performance of large vehicles with very good and very poor crash avoidance performance.

   ii. Two shall extend the emulation range of Figure 3-1 to the upper left and lower left, representing performance of small vehicles with very good and very poor crash avoidance performance.

   iii. One shall extend the emulation range of Figure 3-l to the most dynamic performance possible, representing the extreme upper left of Figure 3-l permitted by the VDTV design.

d. The algorithms of (b) and (c) above shall be:

   i. Be accessible via laptop computer menu-driven displays.

   ii. Fully configure the VDTV to emulate these vehicle classes.

Note: It is assumed that power assist and competitive design practices provide reasonably consistent feel characteristics, so the algorithms of this ¶ may use common steering, brake, and throttle feel characteristics.

4.4.6.2 User-Supplied Algorithms, Calculations, and Other Modules

Nate: Research activities throughout the VDTV's five year life will require many different algorithms, each addressed to specific objectives. These algorithms are expected to be written by researchers throughout the US, and may replace the deliverables. For purposes of this document, each algorithm is treated as a replaceable module.

a. The Control S/S shall provide additional memory for user-supplied modules:

   i. A minimum of 100% of the RAM memory space used for deliverable modules.

   ii. A minimum of 500% of the hard disk memory space used for deliverable modules.

b. The Control S/S shall provide a minimum of 100% unused computational capability.

c. The Control S/S shall provide links to data via the Data Access Utility for all data channels under its cognizance.

d. The Control S/S shall provide links from deliverable and user-supplied modules via the Data Output Utility:

   i. To all dynamic subsystems.

   ii. To all on-board data display devices.

   iii. Addressing for a minimum of eight additional output devices over those contained in the deliverable VDTV.

4.4.7 PERFORMANCE VERIFICATION TEST

Software for the Performance Verification Test shall reside in the Control S/S.

4.4.8 ELECTRONICS PLATFORM

Note: The Control S/S electronics is a broad term which defines minimum constraints on approach, design, and implementation activities.

4.4.8.1 Scope

- The Control S/S electronics platform shall include all hardware from input signals from individual sensors through control signals conditioned for output devices (such as on-board displays and actuators).

Note: This scope includes signal conditioning, digitizing, data communications, power amplification for actuators, etc. as well as the computer hardware itself.

4.4.8.2 Architecture

a. The Control S/S electronics platform shall consist of one or more assemblies located throughout the VDTV.

b. Cabling from individual sensors to submodules or to a single central module shall consider physical size of cable bundles, electrical interference, appearance from human factors viewpoint, maintenance, and modification difficulty.

c. Cabling from devices which transmit commands to output devices shall consider the same factors as (b) above.

d. The architecture shall consider the VDTV's five year life and the recent pace of electronics development to assure a flexible, expandable capability.

4.4.8.3 Capabilities

a. The Control S/S electronics platform shall include the following data acquisition capabilities:
   i. Hardware which meets industry standard data interchange protocols.
      (a) Available from several vendors.
      (b) Integrated circuits and circuit cards which implement the protocol.
      (c) Readily available to researchers throughout the US.

      Note: Auto industry standards are not required, and are not desirable if implementation is not readily available to researchers throughout the US.
   ii. A modular design and implementation which permits expansion and flexibility.
   iii. A capability to change circuit boards for data acquisition functions such as amplification, filtering, data scans, etc.
   iv. Software programmable data acquisition capabilities:
      (a) Selected data channels for analog signals.
      (b) Scan rates for analog data channels.

b. The Control S/S electronics platform shall the computational capability for all required functions defined in Exhibit II except those allocated to the Measurement S/S.

4.4.9 LAPTOP COMPUTER/OPERATOR INTERFACE

a. Except for driver commands via the steering wheel, brake pedal, and accelerator pedal the laptop computer shall serve as the primary interface between the operator/driver and the VDTV's on-board research capabilities.

b. The laptop computer interface shall have a capability for menu-driven commands.
   i. The menu applications software shall meet the same support requirements as other purchased software.
   ii. Menu displays, format, and commands shall be changeable during the VDTV's life.

c. The laptop computer interface shall have a capability for keyboard commands.
   i. All keyboard entries shall be checked to verify a valid command prior transmission to the Control S/S computer.
   ii. Error messages defining the problem with invalid commands shall be provided.

d. Every entry from the laptop computer shall be completely verified against safety criteria prior to transfer to a control algorithm.

4.4.10 SYSTEM CONFIGURATION

4.4.10.1 Introduction

The VDTV system configuration for any specific test will be controlled by inputs from two sources:

1. A floppy disk prepared in the Off-Board Data Processing S/S will contain information which defines major parameters for each test series. Examples are laptop computer menu variations, control algorithms and their constants, and active data channels. These major parameters could remain fixed during a long test series.

   The floppy disk will be developed on the Off-Board Data Processing system and entered into the VDTV via the laptop computer floppy disk port.

2. Manual entries via the laptop computer will select different emulation characteristics from the laptop menu or other parameters which would vary at intervals of severalminutes to hours. An example is varying the understeer coefficient for a series of runs during several hours of testing without returning to the garage.

4.4.10.2 Configuration Changes

a. The Control S/S shall include the capability to change the VDTV configuration from either:

   i. Data entered via the floppy disk port of the laptop computer.

   ii. Manual inputs, either keyboard or menu, via the laptop computer.

b. Data entered from either input shall be automatically checked to determine if changes comply with safety critical item constraints defined in Task 1 of the Statement of Work.

   i. No unsafe configuration shall be permitted.

   Note: An example of an unsafe configuration is a manual input which calls for an oversteering configuration when the test is being conducted on a two lane road at high speed The same configuration could be permitted on a large, flat area.

   ii. Confirmation that the safety critical item check has been passed or failed shall be displayed.

   iii. In case of a failure, a message indicating the cause of the failure shall be displayed.

   iv. In case of a failure, the command shall be rejected.

4.4.11 DATA TRANSFER TO MEASUREMENT SUBSYSTEM

Control S/S data, from both sensors and laptop computer commands, must be transferred to the Measurement S/S for storage in a data file.

4.4.11.1 Laptop Computer Commands and Status

a. Every manually-entered laptop computer command shall be transferred to the Measurement S/S:

i. Keystroke entries shall be coded into commands which are directed to on-board functional devices.

ii. The coded commands shall be transferred to the Measurement S/S.

iii. A time tag to the nearest 100 milliseconds when the command is entered (such as via a keystroke of an “Enter” key) shall be transferred.

b. Laptop computer information needed for header data shall be transferred to the Measurement S/S.

4.4.11.2 Control S/S Data

a. The Control S/S shall store data from all data channels, whose input will be directed to the Measurement S/S, in a format compatible with that of the Measurement S/S.

b. Data transfer from the Control S/S to the Measurement S/S shall occur at least as often as completion of each complete data scan of the Control S/S.

Note: Data transfer compatibility is expected to be determined during Task 1, defined in the Statement of Work.

4.4.12 SYSTEM RESPONSIBILITIES

a. The Control S/S shall provide the system clock for all on-board timing functions:

i. The resolution shall be at least one millisecond.

ii. Time shall be transferred to the Measurement S/S with a one millisecond resolution.

iii. Accuracy of the system clock shall be better than 0.01% over a period of one month.

b. The Control S/S shall provide engineering units conversion for all on-board data displays:

i. Conversion factors from raw digital data to engineering units shall be stored in the Control S/S memory.

ii. Conversion factors for each on-board data channel shall be provided.

iii. Engineering units conversion shall degrade resolution less than 1 digital bit or its equivalent.

iv. Conversion factors shall be changed via:

(a) Laptop computer keyboard inputs for scale factors and menus for function selection.

(b) Data files entered via the laptop computer floppy disk port.

4.5 MECHANICAL SUBSYSTEM

4.5.1 SAFETY

4.5.1.1 <u>Seat Belts</u>

Note: Seat belts are required and are not dependent on activities of Task 1, Statement of Work.

a. Seat belts for both driver and front seat occupant shall be included:

  i. The VDTV shall include provision to change seat belts:

    (a) Standard passenger car belts meeting FMVSS standards.

    (b) Five point racing seat belts and shoulder harness, including belt width, buckles, and attachment points for both belt and shoulder harness to the body/frame.

  ii. The seat belt change shall be made within a period of 30 minutes or less with no special tools other than those provided as part of the VDTV system.

4.5.1.2 Rollover Bar/Cage

Note: A rollover bar/cage, designed and fabricated to production car racing practices, shall be included if results of the analysis of Task 1, Statement of Work, shows this to be feasible:

a. The rollover bar/cage shall conform to the front seat appearance requirement.

b. The rollover bar/cage shall provide normal access between all four doors and the interior.

c. The rollover bar/cage shall be covered with padding.

d. The padding of (c) above shall be covered with material which matches that of the adjacent interior.

4.5.1.3 Air Bags

Note: Air bags, designed and fabricated to production car practices, shall be included if results of the analysis of Task 1, Statement of Work, shows this to be feasible.

a. Air bags shall have the same performance reliability as those of production passenger cars, including:

  i. Proper inflation in case of an accident which warrants air bag inflation.

  ii. No inflation from sources other than an accident which warrants air bag inflation.

b. The complete air bag system, including as a minimum the VDTV's body/frame crumple characteristics, sensors, inflation devices, cables, connectors, etc. shall be included in the determination of air bag feasibility.

c. Appearance requirements shall be met.

4.5.2 MECHANICAL SUBSYSTEM CHARACTERISTICS

4.5.2.1 Strategy Rigidity

The Mechanical S/S shall provide the structural rigidity necessary so:

a. Frame/body stiffness (torsional and beaming) does not interfere with performance of the dynamic subsystems.

b. Frame/body frequencies do not interfere with performance of the dynamic subsystems.

4.5.2.2 Mechanical Variability

The Mechanical S/S shall have the capability to vary the following components by mechanical changes to existing structure:

a. Overall VDTV Mass. Contingent upon results of the Contractor's analysis (defined in Task 1 of the Statement of Work), the VDTV mass properties shall be variable by adding physical weights within constraints imposed by appearance requirements and not below the body sills. These weights may be added to the front, rear, or other vehicle locations to change:

   i. Yaw inertia.

   ii. Roll inertia.

   iii. CG location, both vertical and longitudinal.

   iv. Sprung mass.

   v. Unsprung mass.

b. Front and rear anti-roll bars.

Note: These anti-roll bars are mechanically changed, different than those dynamically variable via commands from the laptop computer.

c. Springs at all four corners,

d. Tread width increases of 10 cm from the nominal tread width at both front and rear.

e. Wheels:

   i. Diameters of 14", 15", 16", and 17".

   ii. Rim widths from 5" to 10" with intermediate rim widths.

f. Tires:

   i. Aspect ratios: 40,50,60,70, and 78.

   ii. Performance: from tires commonly used on production cars to tires currently used in autocross racing (inside half with tread, outside half slick).

   Note: Full slick racing tires may be used to attain higher dynamic performance. The need for such tires must be defined in the proposals.

4.5.2.3 Body Functions

The body shall be fully functional for use in the environment specified in ¶3.5.7 including:

a. Front doors shall be as functional as a production car:

   i. Open and close with the feel of a production car.

   ii. Windows which lower and raise.

   iii. Opening angle of a production car.

b. Rear doors shall:

i. Open and close with the feel of a production car.

ii. Have the opening angle of a production car.

c. The body shall have the rain performance of a production car:

i. Interior leaks under conditions of a full stream of water from a garden hose, with no nozzle, directed at:

(a) All four door seals.

(b) All four windows.

(c) Trunk seal.

ii. Interior leaks under conditions of driving in a ram during the Performance Verification period.

iii Leaks into the engine compartment under the conditions of (i) and (ii) above.

4.5.2.4 Engine Map

An engine map which defines torque as a function of throttle angle, engine rpm, and intake pressure shall be provided.

4.6 ELECTRICAL POWER SUBSYSTEM

The Electrical Power S/S (EPS/S) provides electrical power throughout the VDTV. Since computers and some electrically-powered actuators are safety critical items, the EPS/S must have high reliability and be closely monitored to assure nominal operation. In particular, any slow degradation from nominal operation which might lead to a future failure must be detected so corrective action can be taken prior to a failure of either the EPS/S or any element depending on electrical power.

4.6.1 SAFETY FUNCTIONS

Note: An EPS/S failure can cause a sudden failure of many safety critical functions, so the EPS/S has an important safety role.

a. The EPS/S shall be implemented from components which have an expected MTBF of at least 10,000 hours.

b. The EPS/S shall include provision for monitoring all its output voltages, where the monitoring is performed by the Control S/S.

c. The EPS/S shall include provision for monitoring the total +5V logic current supplied to all computer hardware installed in the VDTV, where the monitoring is performed by the Control S/S.

4.6.2 PROTECTIONOF BASE VEHICLE POWER

a. The EPS/S shall provide a method to prevent discharge of the base vehicle’s battery into the EPS/S.

b. Implementation of the method of (a) above shall include the total EPS/S power during a test and charging of any EPS/S batteries from an external charger.

4.6.3 EPS/S POWER SOURCE

a. The EPS/S shall obtain its power during active tests from:

   i. An engine-driven alternator (which may be modified from that of a standard production car).

   ii. Additional batteries.

   iii. A combination of (i) and (ii) adequate for eight hours testing under conditions of the operational scenario defined in Appendix B.

b. If additional batteries are required:

   i. The EPS/S shall have a quick disconnect connector to permit any additional batteries to be connected to an external battery charger.

   ii. The charging time for the additional batteries to be restored to a full charge shall be a maximum of one hour.

   iii. The EPS/S shall include the external battery charger compatible with the EPS/S.

4.6.4 EPS/S OUTPUT POWER

The EPS/S shall provide all electrical power needed by theVDTV's subsystems. This electrical power shall include:

a. Electrical power required for all electrically-driven actuators.

b. Electrical power required by the Control S/S.

c. Electrical power required by the four exterior interfaces for the Customer-Supplied Equipment S/S (defined in ¶4.8.2.1):

   i. +5 V within 2% @ 0.5 amp.

   ii. +/- 12 V within 0.05% @ 1 amp.

d. Electrical power required by the Measurement S/S:

   i. +5 V within 2% @ 5 amps.

   ii. +/- 12 V within 0.05% @ 4 amps.

e. Electrical power required by the two interior interfaces for the Customer-Supplied Equipment S/S (defined in ¶4.8.2.2):

   i. +5 V within 2% @ 0.5 amp.

   ii. +/- 12 V within 0.05% @ 0.5 amp.

Note: Items (a), (b), and (c) interface with the Control S/S; items (d) and (e) interface with the Measurement S/S.

4.7 MEASUREMENT SUBSYSTEM

The Measurement Subsystem (MS/S) will acquire data from on-board sources not allocated to the Control S/S. All Control S/S data will be transferred to the MS/S, where it will be stored along with the MS/S data. This single point data storage will permit all test data to be time correlated within the MS/S, minimizing time correlation requirements allocated to the off-board data processing capability.

The MS/S will get data from the Control S/S, providing a relatively simple interface between these two subsystems. The interface between MS/S and Control S/S is shown in Figure 4-11.

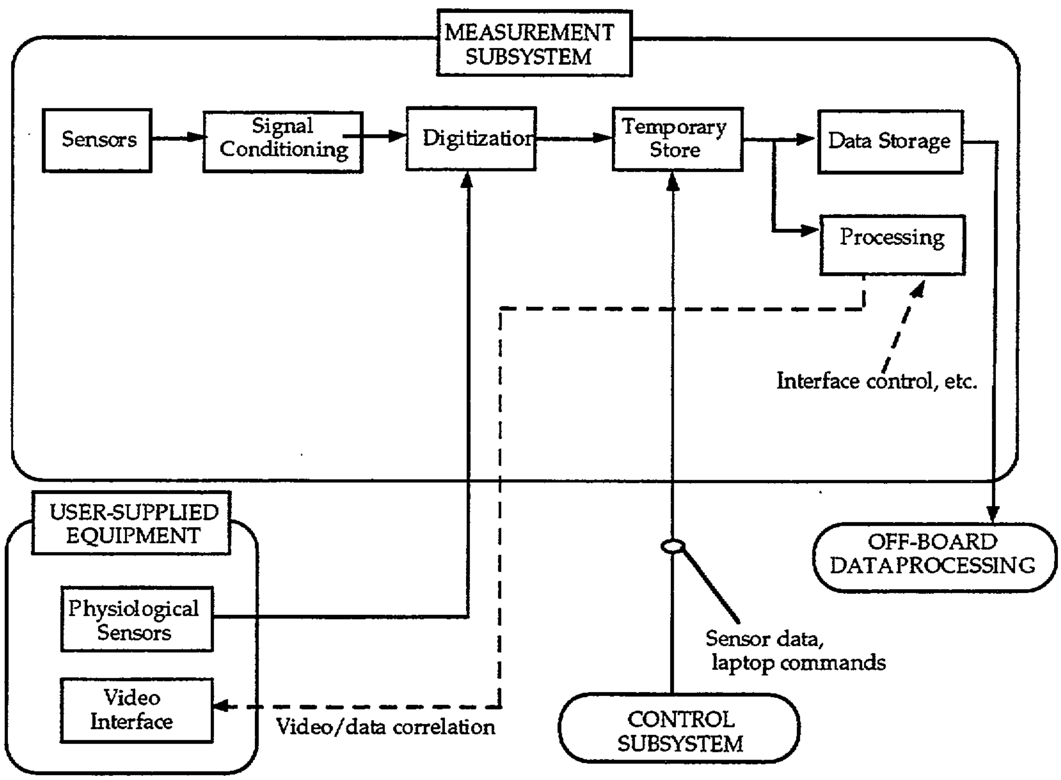


Figure 4-11. Strawman Measurement Subsystem Architecture

4.7.1 SAFETY

The Measurement S/S shall comply with all safety requirements of the Control S/S defined in ¶4.4.1.

4.7.2 MEASUREMENT SUBSYSTEM SCOPE

a. The Measurement S/S shall be responsible for acquiring, time tagging, identifying, and storing data in a manner which provides time correlation of data from all on-board sources.

b. The interface between Measurement S/S and Control S/S shall provide synchronization between these two subsystems to maintain time correlation of all collected data.

c. The Measurement S/S shall be responsible for the interface with physiological data:

   i. Sensors and signal conditioning shall be supplied by users and are not the responsibility of the MS/S.

ii. The Measurement S/S shall accept signals from the customer-supplied equipment and process these signals through the rest of the on-board data sequence.

d. The Measurement S/S shall be responsible for time correlation with all on-board video data.

i. The Measurement S/S shall transmit signals to on-board video equipment with a time resolution of at least 3 milliseconds.

ii. The Measurement S/S shall transmit start recording and stop recording commands to on-board video equipment.

e. Data collected from all on-board sources shall be stored by the Measurement S/S in a format compatible with utilities, resident in user's off-board systems which will process the data, to provide file formats compatible with the off-board data processing system's software.

4.7.3 ON-BOARD DATA STORAGE

a. The Measurement S/S shall store all data from on-board tests on a disk storage medium:

i. Which can be removed and physically transferred to the off-board data processing capability.

ii. Which stores all data from a four hour test with at least 100% spare capacity.

iii. Which permits 'multiple storage units to be used interchangeably.

b. The Measurement S/S shall store complete header information necessary so off-board processing can be completed with only the content of the media in 14.7.3 (a). As a minimum, the following header information shall be provided in the on-board to off-board data transfer:

i. Test identification: test number, run number within a test, date, and time.

ii. Driver identification:

(a) For a professional driver: name, employer, and employee identification.

(b) For a driver from the general public: name and Social Security Number.

iii. Observer identification, same as that for the driver.

iv. Complete vehicle configuration.

v. Definition of each active data channel.

vi. Engineering units conversion factors for each active data channel.

vii. Analog scan programs which control the scan sequence, gain setting, and all other programmable data system parameters for all on-board analog data channels.

viii. Analog signal conditioning parameters for any hardware that is controllable via external commands.

c. Headers shall be derived only from on-board information used to conduct the test, including:

i. Data keyed in via the laptop computer prior to the test, such as driver and observer information.

ii. Data used for on-board data processing, such as scan programs and engineering units conversion factors.

iii. Configuration information, such as:

(a) Settings of dynamic subsystems derived from configuration commands loaded into the laptop computer via floppy disk prior to a test.

(b) Mechanical configuration status (such as anti-roll bar diameters, tire definition, or spring rates) loaded into the laptop computer via floppy disk prior to a test.

d. Pre-test and post-test headers, of exactly the same information, shall be stored before and after test data.

Note: Both pre- and post-test headers permit the data analysis program to make an efficient check of the fixed parameters that control data acquisition from a single test. Changes during a test, which can affect data quality, can quickly be determined prior to an additional test or authorization to change the vehicle configuration.

e. All information manually entered into the laptop computer during a test shall be stored.

i. Information shall be time tagged with a resolution of 100 milliseconds.

ii. The time shall be when the entry key is actuated.

f. All data shall be entered into the data storage with time tags and identifiers which permit the time of each measurement to be determined within 1 millisecond.

g. Time correlation of (f) above shall apply to all data types: analog from different scan rates, serial digital data, parallel digital data, events (or contact closures), and any other data types.

4.7.4 ON-BOARD TO OFF-BOARD DATA TRANSFER

a The MS/S shall transfer all stored data for one test to the off-board data processing capability via manual transfer.

b. Electronic data transfer from the VDTV's on-board data storage capability to the off-board data processing capability shall:

i. Be completed, with the data stored within the off-board data processing capability, within 30 minutes after the VDTV stops at the facility where the off-board capability resides.

Note: Manual time, such as walking from the VDTV to the off-board data processing capability, is not included.

ii. Include storage which keeps data for eight hours of a test run (minimum of 1 Gbytes of data}

ii. Shall include verification that the data transfer was completed successfully.

4.7.5 DATA QUALITY

The Measurement Subsystem shall store Nationally-accepted data from all on-board data sources:

a. Calibrations shall be traceable to NIST.

b. Uncertainties of each measurement shall be defined.

c. Performance of all components, and of a complete data channel, shall have a minimum resolution of two extra digital bits above that required for minimum dynamic subsystem performance.

4.7.6 MEASUREMENTS

The MS/S shall include measurements from the following types of data sources:

a. Analog data
   - i. Varying full scale ranges for each data channel.
   - ii. Varying scan rates for each data channel.

b. Digital serial data
   - i. Asynchronous with any other event.
   - ii. Frequency range from 10 Hz to 1 MHz.
   - iii. Signal level shall be compatible with industry standard TTL/CMOS practices.

c. Digital parallel data
   - i. Asynchronous with any other event.
   - ii. Signal level shall be compatible with industry standard TTL/CMOS practices.

d. Event data (contact closures)
   - i. Asynchronous with any other event.
   - ii. Event data shall support signals:
     - (a) Compatible with industry standard TTL/CMOS practices.
     - (b) With off resistances of less than 100 ohms and on resistances of greater than 10,000 ohms.
     - (c) With a signal of 5V @ 20 ma.

4.7.7 MAINTENANCE AND REPAIR

The Measurement S/S implementation shall permit any sensor to be removed and replaced within a total of 15 minutes:

a. Sensors provided by customer-supplied equipment, all physiological sensors, and video equipment is excluded.

b. Sensor connections shall be made via connectors rated for a minimum of 50 remove/replace connections.

4.7.8 EXPANSION

The Measurement S/S shall provide the capability to add a minimum of 25% more data channels for each data category [analog, serial digital, etc.].

The computing power, processor speed, and memory of the MS/S shall provide a capability of 100% expansion.

4.7.9 ENVIRONMENT

a. The Measurement S/S shall operate in the environment of ¶3.5.7.

4.8 USER SUPPLIED EQUIPMENT INTERFACE (USEIF) SUBSYSTEM

Note: The USEIF provides electrical, mechanical, and logical interfaces with user-supplied equipment that will be changed throughout the VDTV’s life. Examples are lane following, longitudinal distance radars, video, and physiological sensors.

Data format shall be sufficient to accommodate all data from the test equipment, test/configuration description (in a header), and time tag with a resolution of at least 1 millisecond.

4.8.1 SAFETY

Note: The USEIF will accept signals from user-supplied sensors. These signals will be used by control algorithms which will control dynamic subsystems; an example is a lane-following sensor controlling lateral position via the front wheel steering subsystem. Therefore, the USEIF S/S must meet the same safety requirements as other subsystems. Detailed USEIF safety requirements will be defined in Task 1 defined in the Statement of Work.

a. The USEIF shall comply with all safety requirements of other subsystems.

b. Safety checks for data from the USEIF S/S will be performed by the Control S/S as defined in ¶4.4.1.

4.8.2 INTERFACE LOCATIONS

The USEIF S/S shall provide interfaces for user-provided equipment at the following locations:

a. Four exterior.

Note: I/O data for these four exterior interfaces is interfaced to the Control S/S.

b. One interior for physiological measurements.

c. One interior for video data.

Nate: Data from (b) and (c) is interfaced to the Measurement S/S.

4.8.2.1 Exterior Interface Locations

The USEIF S/S shall include interfaces to attach customer-supplied equipment at the following locations on the exterior of the VDTV:

a. One port at the front of the vehicle:

    i. Horizontally from 10 cm inside the innermost part of the headlights.

    ii. Vertically from the lowest part of the bumper to within 10 cm below the line of sight of the driver over the hood.

    iii. Anywhere within this area.

b. One port at the rear of the vehicle, with the tail lights and trunk lid replacing the corresponding parts for the front of the vehicle.

c. Two ports, one at side of the vehicle:

   i. Horizontally from 10 cm forward of the front door to 10 cm aft of the rear door.

   ii. Vertically from the lowest part of the body at the locations of (i) above up to 10 cm below the bottom of the windows at these locations.

   iii. Anywhere within this area.

4.8.2.2 Interior Onterface Locations

a. The USEIF S/S shall include one port to attach customer-supplied equipment for video recording:

   i. Located so it is not visible to the driver or observer.

   ii. Connected to the trunk with cabling which will support a minimum of 8 video cameras.

   iii. Connected to the Measurement S/S.

b. The USEIF S/S shall include one port to attach customer-supplied equipment for physiological measurements:

   i. Located so it is not visible to the driver or observer.

   ii. Provide a minimum of 16 data channels.

   iii. Connected to the Measurement Subsystem.

4.8.3 MECHANICAL INTERFACE DEFINITION

a. Mechanical interfaces for all USEIF shall provide attachment with conventional bolts or similar devices, readily operated with common tools.

b. Mechanical interfaces shall be documented to the detail necessary for machine shops to duplicate the mating user-supplied mounting points.

4.8.4 DATA BUS FOR USEIF INTERFACES

a. Bi-directional data buses conforming to industry standard protocol shall be provided to each interface.

b. The VDTV data bus connector and the mating connector shall be compatible with the above industry standard interface.

c. Any connectors exterior to the passenger compartment and trunk shall meet the environmental requirements of ¶3.5.7.

SECTION 5. PERFORMANCE VERIFICATION REQUIREMENTS

5.1 INTRODUCTION

Section 5 defines performance verification requirements for the VDTV system. In this context, “performance verification” means assurance that the VDTV system will operate as intended over the VDTV’s five-year operational life. Verification for dynamic subsystems is at the subsystem level, prior to integration into the system, followed by system level verification.

5.2 PRE-INTEGRATION PERFORMANCE VERIFICATION

Definition of safety critical items (SCIs) is required in Task 1 defined in the Statement of Work. Performance verification of SCIs, and each dynamic subsystem, prior to integration into the VDTV system is defined in this paragraph.

5.2.1 PRE-INTEGRATION DEFINITION

Integration is installation, in its expected final configuration, of any safety critical item or dynamic subsystem into the VDTV body/frae. Preliminary installation to verify volume compatibility, mechanical interfaces, interference with other components and subsystems, and basic functional performance is not included.

Any preliminary installation shall be followed by removal of the component or subsystem, then reinstalled for final integration after formal approval of its performance verification.

5.2.2 MECHANICAL HARDWARE

Mechanical hardware includes brakes, steering, suspension, wheels, tires, and all other equipment which may affect safe operation or performance over the VDTV’s five-year life. Performance shall be verified as defined in this paragraph.

5.2.2.1 Production Vehicle or Production Race Car Base

Any component used in, or taken from, a production or race vehicle which will function in the following conditions may be stated as having its performance verified:

a. Without modification which affects its function, and with no additional loads imposed by the VDTV’s frequent operation in the limit performance regime. Example, for a custom base vehicle: a windshield wiper mechanism which remains in the standard condition except for changes to its mounting to the body.

b. Whose design and implementation is intended to provide performance at least equal to the operational conditions defined in Appendix B. Example, for a base vehicle based on a production car: the standard brake and suspension assemblies may not be qualified because of loads imposed by the combination of: (1) the additional -300 kg weight of the dynamic subsystems and other modifications to the VDTV, (2) extensive operation in the limit performance regime, and (3) high performance tires. Components from a heavier vehicle may be qualified.

c. Components used in production car race vehicles of essentially the same or heavier weights.

d. Documentation which objectively defines the source of the component (such as a donor vehicle with specific make, model, year, and serial number) shall be provided to establish the above sources.

5.2.2.2 Manufacturer's Specifications

Manufacturer's specifications, particularly at the component level, directly applicable to the VDTV environment may be used to qualify components and subsystems. Examples are brake assemblies specified for a substantially heavier vehicle.

5.2.2.3 Previous Directly Applicable Operational Experience

Operations of a substantially identical subsystem or component for periods of time similar to those expected for VDTV operations. This is also applicable to race vehicles with the caveat that the component is one which is expected to be used until damaged, not one which is routinely replaced.

5.2.2.4 Analysis

Formal analysis by qualified engineering personnel may be used for performance verification. Example, for a base vehicle developed from a production car: structural analysis of front suspension components which have been modified to support the loads imposed by the weight of the dynamic subsystems and the operational conditions of Appendix B.

5.2.2.5 Test

Tests which include the following may be used for performance verification:

a. The number of operational cycles expected in the VDTV's five-year life as estimated by the scenario in Appendix B, with a 100% margin.

b. Over the temperature range specified in ¶3.5.7.

c. A minimum of 50% of cycles performed at the worst temperature extreme and 25% of the cycles performed at the other temperature extreme.

d. No provision for moisture, salt, or other effects if analysis shows no impact of all other environmental conditions.

5.2.3 ELECTRONIC HARDWARE

Electronic hardware shall be connected in its final configuration and functionally tested prior to integration. The configuration shall include:

a. Electronic modules.

b. The Electric Power S/S.

c. All cables and connectors which will be installed in the VDTV.

d. Sensors and other signal sources representative of those which will be used in the final configuration.

5.3 ACCEPTANCE TESTS

Acceptance tests will include two parts: (1) an availability demonstration which requires a period of one month (assuming no failures), followed by (2) a performance verification activity which demonstrate compliance with all other Exhibit II requirements. The availability demonstration will be an on-road testing activity which exercises the VDTV's capability to perform its intended dynamic performance while meeting its availability requirements. Compliance with many other requirements will be shown by inspection of the VDTV, records, analyses, and methods other than on-road tests. Dynamic performance requirements willI be demonstrated by road tests. It is the intent for on-board sensors to provide objective data which will verify compliance with dynamic performance requirements.

5.3.1 AVAILABILITY DEMONSTRATION

Availability is a critical characteristic which has a dominant affect on the VDTV's value as a research tool. Availability will be demonstrated as the first part of the VDTV's formal acceptance tests.

5.3.1.1 Demonstration Period

a. Availability shall be demonstrated over a period of four consecutive work weeks:
   i. Except for ambient conditions outside the environmental range specified in ¶3.5.7.
   ii. In the case of a delay caused by environmental conditions, the VDTV and all other deliverables directly associated with availability functions shall remain dormant. In particular, no maintenance, repair, or modification activities shall be performed.
   iii. Conditions outside the Contractor's control defined in ¶3.6.2.1(b).

b. A work week shall consist of a five eight hour days, not including weekends.

c. One eight hour day each work week shall be available for scheduled maintenance defined by deliverable draft documents.

d. In case of a failure defined in ¶5.3.1.6(e), the out-of-service time shall not be counted as part of the Demonstration Period. In case of a failure, the Demonstration Period shall resume when the failure has been corrected according to the conditions of ¶5.3.1.6(e).

5.3.1.2 Demonstration Location

The demonstration shall be conducted at either:

a. NHTSA's Vehicle Research and Test Center located at East Liberty, Ohio, or:

b. A location defined by the Contractor. In this case, the location shall have all roads necessary to conduct the availability demonstration.

Note: Weather at VRTC in the winter should be considered in the location selection.

5.3.1.3 Start of Demonstration Period

a. Prior to the start of the Demonstration Period, the Contractor shall complete all development activities to the level where only data acquisition, minor software changes, and performance verification activities are expected.

b. Prior to the start of the Demonstration Period, the Contractor shall complete a thorough inspection of all areas which may be subjected to mechanical stress during the Demonstration Period. This inspection shall include all suspension components, suspension pickup points, and adjacent structure.

Note: Visual enhancement, such as stress coatings, may be needed for a thorough inspection.

c. The Contractor shall formally define the start of the Demonstration Period:

   i. JPL shall be notified, in writing (fax or email is acceptable) not later than five working days prior to the expected start of the Demonstration Period.

   ii. JPL shall have the option of attending the start of the Demonstration Period, and shall notify the Contractor within one working day of receipt of (i) if this option is to be exercised.

   iii. If JPL exercises the option of (ii), the Demonstration Period shall not start until a JPL representative(s) is in attendance, subject to JPL being at the demonstration site within the allotted time.

   iv. The Contractor shall define the actual start of the Demonstration Period as the start of a working day.

5.3.1.4 VDTV System Content During Demonstration Period

a. The VDTV system shall include, as a minimum, the following items during the Demonstration Period:

   i. Draft copies of all relevant deliverable documentation. Examples are maintenance manuals and safety recommendations.

   ii. Completed VDTV hardware.

   iii. Completed VDTV software except for items defined in (b) below.

b. Software changes during the Demonstration Period shall be limited to the following unless configuration control or failure practices are followed:

   i. Control and Measurement S/Ss: scan programs, engineering units conversions, and related software-changeable functions in all on-board data acquisition electronics.

   ii. Adjustment of parameters (such as limits) used to verify satisfactory completion of a Performance Verification Test acceptance parameters but not the code itself.

   iii. Adjustment of parameters (such as coefficients) of all safety critical items, formally defined by the Contractor during Task 1 of the Statement of Work, but not the code itself.

   iv. Adjustment of the laptop computer's human interface parameters.

5.3.1.5 Configuration Control

a. The Contractor's deliverables of the VDTV system, as defined in Figure 3-2, shall be placed under formal configuration control at the start of the Demonstration Period.

b. All changes to the VDTV system shall be formally documented during the Demonstration Period, including:

   i. Redline changes to all documentation.

   ii. Hardware changes, including vehicle and maintenance items.

   iii. Software changes, excluding those of ¶(5.3.1.4)(b).

   iv. Every maintenance activity different than that defined in the draft deliverables provided at the start of the Demonstration Period.

5.3.1.6 Demonstration Content

a. The demonstration shall comply with draft copies of all relevant deliverable documentation.

b. All scheduled maintenance activities shall be recorded.

c. All unscheduled maintenance and repair activities shall be recorded.

d. All failures, including hardware and software, shall be fully documented.

e. In case of a failure, the VDTV shall be taken out of service and the Demonstration Period placed in a hold status until:

   i. A formal failure report is completed.

   ii. The failure of is analyzed.

   iii. Corrective actions based on the analysis is defined.

   iv. The analysis and corrective actions are approved by the cognizant design engineer or designated alternate.

   v. Corrective actions are implemented.

   vi. A Performance Verification Test is successfully completed for failures of:

      (a) Any dynamic subsystem actuator failure.

      (b) Any failure related to hardware or software SCIs.

      (c) Any failure related to structural failures.

      Note: an example is a stress crack.

5.3.1.7 VDTV Operation During the Demonstration Period

During the Demonstration Period, the VDTV shall conduct the following minimum operations during each of the four test days per work week:

a. Eight Performance Verification Tests.

b. Six hours of active driving time.

c. Checks of fluids, tire pressure, and other status checks may be made in the garage without being considered to be scheduled maintenance time.

d. Tire changes may be made without being considered to be scheduled maintenance time.

e. Operation at the following levelsand test conditions:
   i. 15 minutes decelerating between 0.3 and 0.5 g.
   ii. 25 minutes decelerating between 0.5 and 0.7 g.
   iii. 15 minutes decelerating >0.7 g.
   iv. 15 minutes turning at lateral g levels between 0.3 and 0.5 g.
   v. 15 minutes turning at lateral g levels between 0.5 and 0.7 g.
   vi. 15 minutes turning at lateral g levels >0.7 g.
   vii. 15 minutes operating at full throttle conditions.
   viii. 10 minutes operating at speeds greater than 160 km/h.
   ix. Two decelerations starting at 160 km/h to a complete stop at the maximum deceleration level permitted by the tires and ABS.

f. PVTs which verify limit conditions with various mechanical configurations have been completed, including:
   i. Highest, lowest, and mid-range performance tires.
   ii. Mechanical anti-roll bar changes which may result from the Task 1 analysis defined by the Statement of Work.

5.3.1.8 Demonstration Conditions

Conditions during the demonstration shall be:

a. Ambient environment.

b. Tests shall be conducted on a large, flat paved surface or approved proving ground roads.

c. Professional drivers and observers.

5.3.1.9 Demonstration Completion

The demonstration shall be completed when all the following conditions have been met:

a. The Demonstration Period time of ¶5.3.1.1 has been completed.

b. VDTV operations of ¶5.3.1.7 have been completed.

c. Maintenance activities comply with draft maintenance documentation at the start of the Demonstration Period and redlines during this period.

d. There have been no structural failures during the Demonstration Period:
   i. Body/frame structure.
   ii. Suspension-to-body/frame mounting points (A arms, brakes, wheels, etc.)
   iii. Any dynamic subsystem components.

e. The PVT has been finalized including:
   i. Provision for any mechanical changes.
   ii. Acceptance limits, based on actual performance during the Demonstration Period, including any variation for mechanical changes.

5.3.2 SYSTEM/SUBSYSTEM DYNAMIC PERFORMANCE VERIFICATION

System and subsystem dynamic performance shall be demonstrated in Dynamic Performance Verification Tests.

a. Dynamic Performance Tests shall be conducted after successful completion of the Availability Demonstration.

b. The VDTV shall not be serviced in any manner after formal completion of the Availability Demonstration Period prior to the Dynamic Performance Verification Tests.

c. Dynamic Performance Verification Tests shall demonstrate compliance with all relevant requirements of Exhibit II.

Note: This includes acceleration, braking from 160 km/h, and other requirements in addition to those of ¶3.5.2 {the VDTV itself) and ¶4.3 (dynamic subsystems).

d. After completion of the dynamic performance tests, the Contractor shall complete a thorough inspection of all areas which may be subjected to mechanical stress during the Demonstration Period. This inspection shall include the same areas as those in ¶5.3.1.3(b).

5.3.3 PERFORMANCE VERIFICATION ENVIRONMENT

Tire/road adhesion will have a dominant effect on dynamic performance, so the road surface will be an important parameter. Other environmental conditions may also effect test results.

5.3.3.1 Ambient Environment

a. All tests shall be conducted in dry weather.

b. All tests shall be conducted under ambient temperature conditions.

   i. In case of cold weather, the VDTV shall be driven under distance/maneuver conditions which permit tire temperatures to reach those of normal operation at 200C.

   ii. In case of extremely cold weather, the Contractor shall have the option to cancel tests. In this case, the constraints of ¶5.3.1.l(a)(i.i) shall apply.

c. All tests shall be conducted with wind conditions less than 7 m/s.

5.3.3.2 Roads

a. Road surfaces shall meet the intent of IS0 standards for test roads, which typically state:

   "All tests shall be carried out on a uniform hard surface which is free of contaminants and has no more than a 2% gradient measured over a distance between 5 and 25 m in any direction. For standard test conditions, a smooth dry pavement of asphalt or concrete or a high friction test surface is recommended."

b. The high friction surface of (a) above shall be limited to normal asphalt or concrete, and shall not include any treatment to increase the coefficient of friction.

c. In case of rain prior to a test, the road surface shall be given adequate time to dry to the point where moisture will not effect the test.

5.3.4. MAINTENANCE

The following maintenance performance shall be demonstrated during Acceptance Tests:

a. Demonstrate compliance of maintenance records and draft maintenance documentation, including any redlined changes made during the Demonstration Period, with Exhibit II requirements including:

    i. Personnel skills.

    ii. Special tools.

    iii. Supplies.

    iv. Maintenance procedures.

b. Demonstrate compliance of maintenance time, stated in terms of hours per week, complies with Exhibit II requirements of one day per week.

c. Demonstrate how electronic equipment can be removed within the 15 minute time defined in ¶3.5.1.3.

d. Demonstrate how each sensor can be removed within the 15 minute time defined in ¶4.7.7.

SECTION 6. DOCUMENTATION REQUIREMENTS

Delivered documentation shall include all items of Section 6.

6.1 SAFETY ANALYSES

Safety documentation must describe the Contractor's entire VDTV safety process from inception of the contract to delivery. The intent is to provide an objective base on which to build future operational decisions regarding safe VDTV operations.

6.1.1 DEFINITION OF SAFETY CRITICAL ITEMS (SCIs)

a. Documentation shall define the process leading to SCIs.

b. Documentation shall define criteria for definition of SCIs.

c. Detailed definition, to the subsystem or component level as appropriate, of every SCI.

   i. If at the subsystem level, every component of the subsystem shall be deemed to be an SCI.

   ii. For data channels, definition of the measurement process from sensor to the first level where data from multiple sensors is combined.

d. Documentation shall define all as-delivered SCIs.

6.1.2 ROLLOVER ANALYSIS ON A LARGE, FLAT, PAVED SURFACE

a. The result of the rollover analysis, conducted by the dynamics analysis activity, shall be included in the safety documentation.

b. The same requirements as those for the dynamics analysis shall apply.

6.1.3 HAZARD REDUCTION ACTIVITIES

Note: The Contractor's activities during alI work to reduce risks are described here.

a. Reduction of the probability of a sudden catastrophic failure.

b. Reduction of the probability of an undetected degradation failure.

c. Reduction of the probability of an undetected software failure, particularly from interaction of different software modules.

6.2 AS-BUILT DOCUMENTATION

6.2.1 SOFTWARE

Software documentation must be adequate to permit operational personnel to modify and totally change algorithms which control dynamic subsystems. During the VDTV's five year life, vehicIe modifications (such as adding additional sensors or modifying a particular subsystem) can be expected. Software documentation must support such changes to optimize VDTV availability.

6.2.1.1 Operating System

Complete description of the operating system, compiler, and lower-level software code, etc. shall be delivered.

6.2.1.2 Deliverable Control Algorithms

Detailed description of each control algorithm with the same content and format as that of ¶6.2.1.3 (c) below shall be delivered.

6.2.1.3 Specific Software

a. Data Access Utility, including detailed instructions necessary to use this utility to access input data from any on-board data channel.

b. Data Output Utility, including detailed instructions necessary to use this utility to transmit data from control algorithms to any on-board device.

c. Algorithm I/O specification, including specific calls to the Data Access and Data Output Utilities.

d. Control algorithm development, including detailed description of inputs required by each dynamic subsystem.

e. Input data channel modifications, including methods to change all software-addressable functions (active channels, gain, data rates, etc.) and engineering units conversion factors.

f. Detailed description of content, format, structure, addressing, parameter definition, and all information required to change the VDTV's configuration via a floppy disk prepared by an off-board computer facility.

6.2.2 DYNAMIC SUBSYSTEMS

6.2.2.1 Special Parts

Drawings, parts lists, material specifications, definition of special machine tools and personnel skills, materials, processes, and related information necessary for a firm other than the Contractor to replicate the special part during the VDTV's life.

6.2.2.2 Long-Delivery Items

Detailed definition of all long delivery item adequate to be placed in a purchase order and procure the item with no additional technical information.

6.2.2.3 Performance Specifications

Detailed performance specifications for all non-proprietary dynamic subsystems. If a subsystem is deemed to be proprietary, this status shall be specifically stated.

6.2.3 OTHER HARDWARE

6.2.3.1 Power Train

a. For parts taken from production cars:

   i. Definition of the power train source and its normal maintenance, parts replacement, and repair sources.

   ii. Manufacturer's maintenance and repair manuals.

b. For custom parts:

   i. Definition of the source and any maintenance, parts replacement, and repair sources.

   ii. The source's recommended maintenance procedures.

   Note: An example is an engine modification needed to provide the acceleration or top speed performance.

6.2.3.2 Interior

Information equivalent to that for the power train of ¶6.2.3.1.

6.2.3.3 Exterior

- Definition of all exterior equipment, body panels, paint, and related information shall be included:

   i. To the level necessary for replication by a firm other than the contractor.

   ii. For (i) above, assuming that the other firm has performed similar tasks and has the plant, equipment, and workforce skills commensurate with this activity.

6.2.4 DRAWINGS AND DESCRIPTIONS

In addition to the specific items above in ¶6.2, documentation shall include drawings and documentation necessary to modify, troubleshoot, and maintain the VDTV.

6.3 MAINTENANCE

Note: This section concerns documentation deliverables, not the tools, supplies, etc. defined in ¶3.5.10.

a. A detailed maintenance plan suitable for maintaining the VDTV for five years while meeting the availability requirement.

   i. , Assume resources available at VRTC: personnel skills, equipment, garage space, shop facilities, computer capability, etc.

   ii. Assume resources needed for VDTV operation at a location anywhere within the US for a period of at least three months.

b. Define all maintenance procedures:

   i. Scheduled intervals.

   ii. Parts, supplies, and equipment needed for each maintenance task.

   iii. Routine VDTV status checks such as battery condition, brake pad wear, hydraulic or electric power systems, etc.

   iv. Special personnel skills needed for any maintenance task.

   v. Special personnel training needed for any maintenance task.

   vi. Special equipment needed for any maintenance task.

   vii. Expected VDTV downtime for each maintenance task or group of tasks performed at the same time.

c. Define equipment which would enhance the VDTV's availability:

i. A battery charger directly compatible with the EPS/S.

ii. Hydraulic system cleaning equipment.

6.4 DYNAMIC ANALYSIS

Results of the dynamic analysis, including:

a. The analysis tool, including:

   i. The tool and a single-site license.

   ii. Documentation.

b. Results used to determine initial system design, including:

   i. Files used to describe vehicle configurations (physical properties, tires, steering profiles, speed profiles, etc.).

   ii. Results in the form of numerical performance, graphs, or other methods.

c. Results based on the final as-built VDTV configuration with the same content as (b) above.

SECTION 7. COSTED OPTIONS

Costed options are listed in two groups.

7.1 GROUP 1. PRIMARY VEHICLE SUBSYSTEMS

7.1.1 ACTIVE SUSPENSION

Note: The active suspension option is intended to support crash avoidance maneuvers which are mostly concerned with handling performance rather than ride motions. The active suspension should thus be capable of optimizing vertical tire loads at each wheel to maintain optimum tire/road adhesion. Active suspensions whose bandwidth is on the order of a few Hz, with a primary purpose of improving ride motions, is of little interest.

a. Active suspension shall have the following major characteristics:
   - i. Independent operation at alI four wheels.
   - ii. Bandwidth adequate to optimize tire/road adhesion:
     - (a) Of all four tires.
     - (b) Under conditions of combined braking and turning in limit performance maneuvers.
     - (c) On reasonably smooth paved surfaces.
     - (d) At a minimum, at least 1.5 greater than wheel hop frequencies.

b. The active suspension shall comply with all other requirements, particularly availability.

7.1.2 FRONT AND REAR ACTIVE ANTI-ROLL BAR SYSTEMS

Anti-roll bars can be mechanically changed. This requirement is for active anti-roll bar systems that are programmable via laptop computer control. Both the front and rear active anti-roll bar systems are needed to control total body roll for human factors investigations. These actively controlled systems will also facilitate control stability and dynamic maneuver investigations, providing more efficient VDTV use.

a. At a specified level of lateral acceleration, the VDTV shall be programmable to achieve a roll angle that falls between the upper and lower bounds depicted in Figure 7-l.

b. Approximate values of the roll gradients for both the upper and lower ‘bounds are also given in Figure 7-l. The term “roll gradient” is defined in Section 9.4.19 of Reference 1 (cf. Section 2.1.1).

c. The -3 dB bandwidth of these active anti-roll bar controlled systems shall be greater than 12 Hz.

7.1.3 CONTINUOUSLY VARIABLE SEMI-ACTIVE SUSPENSION

The semi-active suspension of ¶4.3.8 defines three different fixed settings.

a. The continuously variable semi-active suspension shall cover the range defined in ¶4.3.8 plus a margin 25% above and below the hardest and softest settings.

b. The continuously variable semi-active suspension shall be controlled by an algorithm residing in the Control S/S which can change the damping settings from any on-board data source.

c. The continuously variable semi-active suspension shall have the dynamic performance defined in ¶4.3.8.

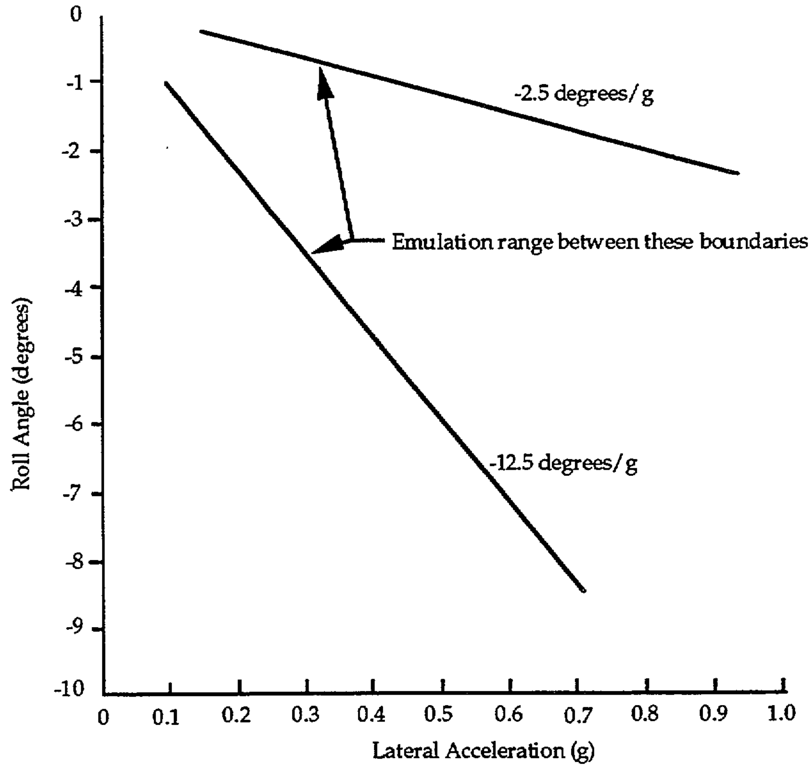


Figure 7-1. Emulation Range of an Active Anti-Roll Bar Controlled System

7.1.4 DYNAMICALLY VARIABLE TIRE PRESSURE

Tire pressure has a significant affect on crash avoidance maneuvers. To efficiently study this effect with typical production tires and dynamic characteristics of typical production cars, tire pressure which is variable during a test is desirable.

a. Tire pressure shall be varied by manual inputs from the laptop computer:
   i. Pressure shall be individually varied at all four tires.
   ii. Laptop commands shall select an individual tire, two tires from one axle, or all four tires.
   iii. Commands shall define an increase or decrease in tire pressure.
   iv. Commands shall define the magnitude, in terms of pressure, for the increase or decrease.

b. A complete system, including the capability to increase or decrease tire pressure, shall be included:

i. Pressure shall be increased simultaneously to all four tires at a rate of at least 35 kPa per minute.

ii. Pressure shall be decreased simultaneously from all four tires at a rate of at least 70 kPa per minute.

iii. Increase/decrease rates at one or two tires shall be approximately proportional to the rates of (i) and (ii) above.

c. Pressure at each tire shall be available for display in engineering units on the laptop computer:

i. At any time via a manual request.

ii. Automatically during a tire pressure change.

7.1.5 FOUR-WHEEL DRIVE

Four-wheel drive shall be provided:

a. The four wheel drive shall not interfere with:

i. The performance of any dynamic subsystem.

ii. Normal vehicle performance, such as forward acceleration, lateral acceleration, top speed, and braking.

iii. Availability.

b. Components shall have been available on a production car for a minimum of one year at the time the components were selected except for those specifically designated in the proposal.

c. The four wheel drive shall provide selection of front wheel drive only or rear wheel drive only.

7.2 GROUP 2. OTHER SUBSYSTEMS

7.2.1 CHANGEABLE DASHBOARD

The VDTV dashboard shall be changeable to facilitate human factors research. The changeable dashboard shall have these characteristics:

a. The changeable part of the dashboard shall include:

i. The entire surface visible to the driver, or:

ii. Only the instrument cluster.

b. The changeable part of the dashboard shall permit the entire volume between a normal instrument duster and the body'structure to be changed except for functional devices such as windshield wipers.

c. Mechanical mounting points shall conform to the appearance requirement that the interior, from the viewpoint of the driver, appears to be that of a representative vehicle.

Note: Covers over fasteners, not greater than 2 cm diameter, which match the dashboard surface and do not protrude more than 5 mm, are acceptable.

d. The mechanical subsystem shall provide mounting for an electrical connector(s) which carry alI wires between the changeable part of the dashboard and the body structure.

e. A mechanical buck shall be provided to permit complete development of the mating mechanical and electrical parts of an alternate dashboard while the VDTV is operational. This buck shall include:

   i. Attachment points and the mating mechanical devices (screw thread, quick connect device, etc.).

   ii. Volume constraints, including between the removable dash forward to the body, sides adjacent to the front doors, steering wheel column, windshield, and lower part of the dash.

   iii. Mating electrical connectors.

f. When combined with the mechanical buck of (e) above, a different dashboard shall be changed within one working day of two persons, certified as auto technicians by a National organization, with documentation and special tools provided within the scope of this costed option.

7.2.2 MAINTENANCE CONTRACT

Maintenance for a period of one year is intended to: (1) assure full availability during the period when problems often occur with a new system, and (2) increase training of VRTC personnel.

7.2.2.1 Period

The period of the maintenance contract shall be:

a. Starting one week after the VDTV is operational (not including acceptance tests) at VRTC.

b. Continuing for 52 weeks after start.

c. An option for an additional year with terms for this additional year to be negotiated.

7.2.2.2 Location

The location shall be at VRTC, East Liberty, Ohio.

7.2.2.3 Scope

The scope of the maintenance contract shall be:

a. Personnel for the maintenance contract shall be:

   i. As a minimum, personnel required to perform all scheduled maintenance according to the deliverable documentation.

   ii. Other persons deemed necessary by the Contractor to achieve the required availability.

b. Maintenance material and tools, according to the contract and deliverable maintenance documentation, will be brought to VRTC:

   i. All supplies required for scheduled maintenance.

   ii. AU special parts.

   iii. All long-delivery parts.

   iv. All special tools.

c. The maintenance support shall include update of all maintenance material, equipment, and documentation:

   i. Documentation delivered at the end of the contract shall be reviewed during the maintenance period, redlined as necessary to include operational experience, and updated.

   ii. All supplies used during the maintenance period shall be reviewed and revised.

   iii. The need for all special and long-delivery parts shall be reviewed and revised.

d. All supplies, equipment, special parts and tools needed for the next year shall be refurbished and delivered at the end of the maintenance period.

e. Updated documentation shall be delivered at the end of the maintenance period.

7.2.2.4 Maintenance Work Week

The standard work week shall be 40 hours per week with daily start and end times following VRTC practices.

7.2.3 MAINTENANCE TRAILER

The term "trailer" is used generically to define a capability to transport maintenance equipment to a site other than VRTC. It could be towed, self-powered, or other configuration. Its purpose is to support operations away from VRTC for a period from 3 to 6 months.

7.2.3.1 Configuration

a. The maintenance trailer shall be configured to travel anywhere in the US via air or ground transportation.

b. If towed, the maintenance trailer shall be compatible with a towing vehicle of the general class of a standard size pickup truck.

7.2.3.2 Trailer Content

a. The maintenance trailer shall accommodate at least the following equipment:

   i. Complete maintenance documentation.

   ii. Six months of maintenance supplies, excluding items commonly available from auto supply stores.

   iii. Special tools.

   iv. Any mechanical variability parts.

   v. Hydraulic cleaning equipment, if included as a costed option.

   vi. Technician tool chest.

   vii. Two week's supply of technician's uniforms.

b. If the maintenance trailer is included as a costed option, it shall support a minimum of two weeks of the Availability Demonstration.

7.2.4 HYDRAULIC SYSTEM CLEANING EQUIPMENT

If the VDTV includes a hydraulic system and servovalves, cleaning to assure satisfactory operation may be important. It is expected that such equipment would be used during initial assembly, but that such equipment would not be suitable for delivery. This costed option addresses such deliverable equipment.

a. The Hydraulic System Cleaning Equipment (HSCE) shall provide documentation for cleaning the VDTV's total hydraulic system:
   i. Skills level and tools of technicians associated with VRTC's auto research and development activities, but without experience in cleaning servovalve hydraulic systems, shall be assumed.
   ii. The HSCE shall include documentation which describes the level of cleanliness required for servovalve operation.
   iii. Detailed operation procedures shall be included.

b. The HSCE shall include all auxiliary parts necessary to efficiently clean the VDTV's hydraulic system:
   i. Blanks to replace servovalves, which may be removed from the system during cleaning operations.
   ii. Filter bodies with very fine elements.
   iii. Pumps, accumulators, and related devices.
   iv. Connecting hoses, fittings, etc. to the VDTV's hydraulic system.
   v. Special tools.

c. The HSCE shall be mounted such that it can be stored, without degradation, when not in use.

d. The HSCE shall be mounted so two technicians can transport it within a garage area.

7.2.5 VDTV REPLICATION

7.2.5.1 <u>Replication at Time of Contract</u>

A costed option to replicate the VDTV:

a. On or before completion of the Requirements Review.

b. Without any changes, or within the scope of changes agreed to by the Contractor as not causing an increase in the cost or schedule.

c. With the same deliverables less those which can be used by both VDTVs.
   i. Deliverables deemed usable by both VDTVs shall be defined.
   ii. Schedule of the second VDTV and its deliverables shall be defined.

7.2.5.2 <u>Replication at Later Time by Competitive Bid</u>

A complete data package meeting which can be used as a competitive procurement package shall be provided. This data package shall meet requirements of a military standard defined by the Contractor.

APPENDIX A

HIGH LEVEL VDTV SAFETY REQUIREMENTS

A.1 GENERAL VDTV SAFETY

The highest system-level safety requirement is:

The VDTV system, which includes drivers, roads, maneuvers, and operational experience as well as the vehicle itself, shall provide safety expected to be equivalent to that experienced in normal passenger car operation throughout the US.

Note 1: This is a high-level requirement stated in functional terms and serves as the foundation for lower-level requirements. The lowest level requirements in this document will be used by the Contractor to derive the detailed requirements used in the VDTV design and implementation.

Note 2: the VDTV will be used on approved roads, not on public roads. Approved roads will have safe runoff areas or barriers which significantly reduce the probability of a severe impact in case of a sudden failure. An example is the contour of the shoulder downslope, ditch, and upslope on the far side of the ditch; good design practices in these areasreduce risks of off-road excursions.

A.2 HIGH LEVEL REQUIREMENTS

a. Personnel safety shall be given primary consideration in all VDTV activities.

b. Consideration for safety throughout the VDTV's operational life, including NHTSA- controlled operations, shall be included in the VDTV System.

c. The VDTV safety program shall include a qualitative system-level analysis which includes all parameters that may affect personnel safety.

A.3 MID-LEVEL REQUIREMENTS

a. Occupant safety shall be given primary consideration.

b. Safety of observers not in the vehicle, but who may be in the area of VDTV operations and may be subjected to risk in case of a failure in any VDTV system, shall be included.

c. Vehicle safety shall be based on a design which expects only minor damage from planned operations, such as repairable damage to exterior body panels, .

d. Objective data from nationally-recognized sources shall be used as a reference for safety experienced in everyday driving.

e. Contracts shall impose safety requirements on all subcontractors.

f. An objective dynamic analysis shall show that the VDTV will not roll over on a large, flat surface.

g. The VDTV program shall establish an operational scenario, in the safest possible mode, which forms a baseline condition for all recommended VDTV operations.

h. The deliverable VDTV system shall include a set of operational scenarios which define recommended parameters for NHTSA's operations.

i. The deliverable VDTV system shall include a recommendation that operations be limited to a defined operational scenario, starting at the safest level, until objective criteria based on operational experience enable operations to be expanded.

j. The deliverable VDTV system shall include a means to objectively test limit performance maneuvers automatically.

k. Every safety-critical item shall be identified.

1. Safety-critical items shall be analyzed at the level of their identification (component, subsystem, etc.) to assure that their performance, in the VDTV's operational environment (road, driver, maneuver, and experience) are capable of being as safe as equivalent items on a standard production car.

APPENDIX B

VDTV OPERATIONAL SCENARIO

B.l PURPOSE

This operational scenario outlines potential VDTV use to support Exhibits I and II.

B.2 ASSUMPTIONS

The following assumptions are included in this scenario:

a. The time period is one year, assumed to support maintenance and availability requirements in Exhibit II. Operations during this year may be reasonably extended for the VDTV's five year operational life.

b. Tests are conducted at VRTC. Many tests are conducted on VRTC's Vehicle Dynamics Area (VDA), a flat, paved area about 500 meters square. Other tests are conducted on: (1) roads within the proving ground complex, and (2) other roads with approved safety characteristics at other locations in the US.

c. The VDTV is an expensive vehicle which must be fully utilized to gain the research data necessary to justify its cost.

d. Because of (c), a comprehensive test plan defines both long-term and short-term VDTV operation to a one week time resolution.

e. Holiday, modification, and VIP times are included in the year-long scenario.

f. The VDTV meets its availability requirement.

g. The VDTV meets it maintenance requirement.

B.3 DEFINITIONS

The following definitions are used:

1. Modification. Time required for VDTV modifications to provide additional capabilities needed to support research objectives. Modification is defined by NHTSA, so is not accountable in availability time. Five days are assumed.

2. VIP Time. Time defined by NHTSA to support requests for publicity events. Five days are assumed.

3. VRTC Availabilitv. VRTC roads will be closed several days a year because of snow and several days a year because roads are committed to proprietary tests. Five days are assumed.

4. VDTV Moving. The VDTV will be moved to different locations for tests. Five 'days are assumed.

5. Maintenance Time. Taken as one day a week, averaged over a period of one month as per Exhibit II. An additional week is used for recalibration of the sensors and entire system.

6. Driving to/from the Test Area. The VDTV will be housed in a garage when not involved in a test. A one-way driving time of 10 minutes is assumed from the garage area to the location where the test will actually take place.

7. Await Test. The VDTV is fully operational, but remains in the garage while other activities are occurring. Examples are morning and evening times when driver and observers are being briefed, and lunch times.

8. Time Between Tests. The VDTV is at the test location, but is idling while laptop computer commands are reconfiguring the VDTV, driving at moderate speed to the next test, or similar activities. The VDTV is fully operational and is being driven under normal driving conditions.

9. Test Maneuvars. The VDTV is actually conducting a test. The range of extreme maneuvers ranges from normal driving to limit performance, with the allocation throughout the time depending on the particular test.

B.4 YEARL OPERATIONAL SCENARIO

B.4.1 Modifications

After six months of operation, research data shows a need for additional physiological and body motion sensors. The need is reviewed, approved, and a week allocated to the modification. The modification is scheduled in three months.

Sensors are ordered in advance and a modification readiness review is conducted. Minor problems are disclosed and corrected. After all parts and procedures are approved, a weeks down time is approved. The modifications have no impact on the Performance Verification Test (PVT). The VDTV is modified, then a PVT test is conducted. The VDTV passes, so is declared operational.

B.4.2 VIP Time

During the year, many requests for demonstrations for VIPs are received. Criteria define acceptable use. A total of five weekdays during the year are occupied with VIP demonstrations.

B.4.3 VRTC Availability

Tests are scheduled for the entire month of January. However, two heavy snowstorms block many roads before VRTC's snow removal equipment can provide clear roads. The VRTC schedule is changes to follow VRTC's snow removal priority, resulting in a loss of only four days. Heavy rains in the cancel testing for two days.

B.4.4 VDTV Moves

The VDTV is moved twice during the year to support tests conducted by AHS and at a warm-weather proving ground. An analysis based on cost per test, and the over subscription of the VDTV's test time, shows that air transportation is the most economical method transportation method. The VDTV and its maintenance equipment are flown to and from the other test sites.

B.4.5 Daily Test Schedule

VRTC personnel arrive at work, and are briefed for about 15 minutes on the day's test activities. The crew goes to the VDTV, conducts a pre-test check according to a procedure, warms the VDTV engine, and checks its basic functionality via laptop computer and on-board displays. Checks are satisfactory, so the VDTV departs for the test area 30 minutes after personnel arrive at work.

The drive from the garage to the VDA is five minutes at speeds from 30 to 50 km/h. Ten minutes elapse before the first test starts.

The test crew initiates the Performance Verification Test. This requires about one minute, mostly in limit performance maneuvers, and is passed satisfactorily. The VDTV test schedule is then started.

The morning schedule consists of a.series of runs involving highly dynamic maneuvers intended to miss obstacles which are unexpectedly moved into the VDTV's path. The driver attempts to miss the obstacles for each run; the observer changes the VDTV's dynamic performance after each run. Since this is done by menu-driven laptop computer commands while the VDTV is driving straight at low speed (a criteria verified by the Control Subsystem checks prior to accepting any command), the change requires less than 30 seconds. The VDTV then goes on to the next test run.

This process continues until a short morning break, with the VDTV remaining at the VDA.

The crew initiates a PVT after the morning test series to verify that the performance is still satisfactory. The crew then breaks for lunch, drives to the central building, and has lunch.

The morning test sequence is repeated in the afternoon. This test sequence is typical of the VDTV's operational schedule.

B.4.6 Maintenance

Scheduled maintenance requires, according to deliverable maintenance plans, an average of one day a week to perform all maintenance activities. Simple maintenance is done in the garage area; some complex unscheduled maintenance activities require satisfactory completion of a PVT prior to placing the vehicle in the availability status.

B.4.7 Operational Data

After each day's test, data is transferred to the off-board computer capability. During the following day's tests, a standard data reduction activity provides summary data of the previous day's actual operating characteristics. This data provides information needed for preventive maintenance and includes time spent at different g levels for acceleration, deceleration, and lateral motions.

8.5 SUMMARY

This scenario indicates:

1. Over 200 hours a year are driven in limit performance maneuvers.
2. The VDTV is being driven nearly 6 hours a day, four days a week.
3. An average of nearly 30 PVT's are conducted each week.
4. About l/4 of the PVT's are conducted after maintenance or suspected problems.