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Inventory of In-Vehicle Technology Human Factors Design Characteristics

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16. Abstract

The National Highway Traffic Safety Administration (NHTSA)

A review and inventory of in-vehicle Telematics devices was conducted in order to better understand the current state of practice and trends relating to their design and implementation. The review focused on human factors characteristics and interface features using accepted human factors practices, principles, and guidelines as a basis for the assessing likely impacts on driver distraction. The inventory examined market-ready in-vehicle products (both Original Equipment Manufacturer and aftermarket products), and identified a range of interface design features (e.g., control and displays characteristics, safety features, etc.) noting aspects and dimensions that have implications for potential driver distraction. The review was not intended to be exhaustive, but rather provide a diverse and representative range of system designs and configurations. The review canvassed nearly 80 in-vehicle devices/systems, and provided in-depth inventories of over 20 devices using a standardized data collection form to inventory basic interface design characteristics and features; much of the data collected addressed navigation systems. The inventory form is available as an Access database. Results indicated that devices tend to incorporate a large number of features and options, making it a potential challenge for drivers to learn all of the capabilities of a system and resulting in lengthy manuals. Although devices also tended to provide large amounts of information, some designs may allow for increased information presentation without necessarily sacrificing performance. Warnings or cautions against interacting with systems while driving were common; however, relatively few systems disable equipment when vehicles are in operation. A number of other observations and "industry trends" are presented and discussed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

A review and inventory of in-vehicle Telematics devices was conducted in order to better understand the current state of practice and trends relating to their design and implementation. The review focused on human factors characteristics and interface features using accepted human factors practices, principles, and guidelines as a basis for the assessing likely impacts on driver distraction. The inventory examined market-ready in-vehicle products (both Original Equipment Manufacturer and aftermarket products), and identified a range of interface design features (e.g., control and displays characteristics, safety features, etc.) noting aspects and dimensions that have implications for potential driver distraction. The review was not intended to be exhaustive, but rather provide a diverse and representative range of system designs and configurations. Attention was primarily limited to in-vehicle systems that are specifically designed for use in the driving environment. Information collected as part of this effort can be used for a variety purposes including:

- Gauging the extent to which designers and developers are applying available guidelines and "best practices" gained through research and experience;
- Comparing systems in terms of design approaches and architecture (highlighting good and poor interface design features);
- Identifying areas where systems could potentially benefit from improved designs or guidance, and (where appropriate) possible safety implications of particular designs;
- Revealing industry trends and common practices in interface designs (are defacto standards emerging?); and
- Guiding future research needs.

The review identified 79 in-vehicle devices/systems across five different functional categories, including navigation and route guidance systems, productivity and mobile PC systems, entertainment, communication, and multi-function systems. The inventory captured information for both passenger and commercial vehicle systems. A subset of these systems (23) were subjected to in-depth examination using a standardized data collection form to inventory basic interface design characteristics and features. Items in the form were developed from available human factors guidelines documents and accepted engineering principles, and were intended to capture safety relevant design aspects and parameters. The form not only captured basic sensory and perceptual aspects associated with controls and displays, but documented interaction characteristics of systems, including the number of steps and button presses required to complete common tasks. The form provided for the collection of an extensive amount of information (over 150 individual parameters), and is available as an Access database.

Controls generally conformed to good human factors practices (e.g., layout, size, labeling, spacing, etc.); controls on Original Equipment Manufacturer (OEM) supplied systems tended to be larger with greater control spacing compared to aftermarket systems. This provides more space for labeling without the need to use abbreviations, and may limit inadvertent button presses. Personal Digital Assistant (PDA) based systems in particular tended to have small and closely spaced reconfigurable soft controls. Frequently used functions tended to have dedicated pushbuttons or controls, and many systems used a common or central control to scroll, highlight, and/or select menu items. Displays tended to provide large amounts of information, particularly navigation system map display screens, which went beyond providing essential information, oftentimes displaying nice-to-know type of information. Although devices tended to provide large amounts of information, some designs may allow for increased information presentation without necessarily sacrificing performance (increasing distraction). Many devices warn drivers against attempting to interact with the unit while driving, but few actually physically restrict access to demanding functions when the vehicle is in motion. Only 25 percent of the navigation systems inventoried, for example, locked out complex destination entry tasks when the vehicle is moving. Nevertheless, not all destination entry tasks appear to place equal demands on drivers. Even systems requiring visual and manual entry tend to provide a wide variety of destination entry input methods; some requiring only several keystrokes to execute. Furthermore, many systems incorporate features that may minimize glance times to displays (and eyes-off-road time) and manage information flow, such as limiting the number of available menu options or rows of items on a display, and use of auditory outputs for routing information and providing system feedback. The review also revealed some system designs that may encourage or facilitate the execution of complex and demanding tasks while driving. Systems that offer auditory feedback during data entry, for example, may allow drivers to keep their eyes on the road while manually interacting with the system (drivers can rely on the auditory feedback alone.)

A number of features and characteristics were frequently noted in our sample of Telematics devices, and while they may not necessarily constitute industry trends, or defacto standards they point to areas of common practice. These include the following, among others:

- Muting or reducing the volume of the radio/CD system when issuing auditory commands/messages/alerts.
- Use of dedicated hard controls for frequently used/accessed functions (e.g., repeat system message).
- Time-out functions to pace driver voice command inputs as well as the duration of displayed information.
- Warnings or cautions against interacting with systems while driving.
- Use of a switch to activate voice recognition systems in an attempt to increase system reliability.
- Provisions to provide both auditory and visual feedback to confirm driver inputs and availability of the speech commands.
- Use of auditory alerts to capture driver attention in advance of the presentation of information, and/or changes in display status.
- Alternative input methods and approaches for completing tasks. These alternatives often impact the number of operations and button/key presses required to complete tasks.
- Use of map-based information as the default both during pre-trip planning and active en-route navigation.
- Automotive suppliers and OEMs are doing more and more to accommodate consumers as they bring laptops, Personal Digital Assistants (PDAs), and cell phones into their vehicles. Many OEMs integrate cell-phones into their vehicles and numerous aftermarket products are available that provide value-added services and features such as text-to-speech technology which facilitate the use of PDAs in the vehicle.

This inventory does not represent a usability assessment, nor does it constitute a formal evaluation of the distraction potential of particular devices. Indeed, the relationship between particular system design elements (or configurations) and distraction is not wholly understood. As a result, the impact of a particular design strategy or approach on distraction may be difficult to predict. Moreover, since driver discretion and judgment are central to the distraction issue, even well designed systems are not immune to distraction induced problems. System design is only part of the distraction issue. Other major determinants of distraction risk include driver capabilities and skills, as well as willingness to engage. Additional research is needed to assess design impacts on distraction, as well as identify situations under which a design element may be distracting. Nonetheless, this effort provides basic information on a sample of available Telematics devices, and can be used to make relative judgments and comparisons among systems as well as begin to index general industry trends. Future efforts should follow-up (using a larger sample of devices) in order to more accurately gauge industry trends.

INTRODUCTION

A number of studies have attempted to characterize and quantitatively relate crashes to distraction, and although associations have varied in magnitude, most comprehensive crash analyses estimate that between 25-30 percent of crashes result as a consequence of driver inattention (Wang, Knipling, & Goodman, 1996; Hendricks, Fell, & Freedman, 2001). There is growing concern that Telematics devices and other in-vehicle devices may add to existing sources of distraction by engaging drivers in complex cognitive tasks and significantly increase exposure though their widespread use. Although Telematics devices bring the promise of enhanced efficiency and convenience, they also have the potential to negatively impact safety if they unduly divert driver attention from the primary task of driving, increasing driver's susceptibility to distraction.

In addition to Original Equipment Manufacturer (OEM) systems, we are now witnessing the introduction of aftermarket products developed by non-traditional suppliers of automotive electronics systems into vehicles. Even more concerning is the migration of Personal Digital Assistants (PDAs) and other forms of wireless technologies which are not specifically designed to be used in automotive environments. Aftermarket products also raise a host of problems for human factors integration since, by definition, they are added to a suite of other functions after that original suite has been designed. As these technologies are marketed to the public, there will also probably be a strong consumer push to provide a broader and less predictable range of functions unrelated to driving. The basic issue is how to design and implement these systems and devices so that safety is not compromised (minimizing driver distraction potential) while satisfying the growing demand for navigation systems, wireless communication devices, entertainment systems, on-board computers with Internet and e-mail access, and other like devices.

We are also witnessing a growing movement to establish rigorous design and evaluation practices to ensure that in-vehicle systems do not pose unacceptable safety risks to drivers. Many OEMs, for example, have adopted a set of principles to guide how Telematics systems are designed and promote safety. These include minimizing eyes-off-road time and the number of steps required to complete tasks, using consistent and functionally similar systems across their product lines, and restricting access to demanding tasks while driving. Work has been undertaken, both in the U.S. and internationally, to provide designers and engineers with accessible and usable guidelines for developing and evaluating interfaces that are compatible with safe driving. The Society of Automotive Engineers (SAE), for example, has ongoing efforts to develop standards and guidelines for in-vehicle systems; much of this work is being performed by the ITS Division Safety and Human Factors Committee. An example is the SAE recommended practice J2364 Navigation and Route Guidance Function Accessibility While Driving (the so called "15-second rule"), which specifies the maximum time allowed for completing a navigation system task involving manual controls and visual displays when the task is performed statically. Other relevant work includes guidelines for Advanced Traveler Information Systems (Campbell, et al., 1998: Green et al., 1995) and human factors guidelines for crash avoidance warning devices (Lerner et al., 1996), among others. In Japan, the Japan Automobile Manufacturers Association (JAMA) has been voluntarily advocating safety measures for the design and use of car navigation systems installed and sold by automobile manufacturers. Similarly, the European Commission has sponsored the development of a "statement of principles" intended to limit the distraction potential of in-vehicle systems by identifying key Man-Machine Interface issues to be considered in the design and implementation of driver information and communication systems. The Alliance of Automobile Manufacturers (AAM) is also currently drafting a similar set of principles.

Another promising approach is to assess the safety impact of various in-vehicle technologies by comparing them to generally accepted non-technology tasks – in essence, using societally accepted tasks performed while driving (e.g., radio tuning) as comparative baselines. This approach has been adopted by many of the Original Equipment Manufacturers who recently launched a driver workload metrics project intended to develop practical, reliable, and valid driver workload metrics and procedures. Under this program, workload evaluation procedures will focus on both visual and cognitive demands, and will enable designers to realistically assess which types of driver interface tasks are appropriate to perform while a vehicle is in motion. The distinguishing characteristic of this approach is the use of surrogate measures which can be easily captured, but strongly associated with other known and validated safety-relevant indices of driver distraction and performance. If successful, this approach will overcome the practical challenges of routinely evaluating new devices and systems using more difficult to assess measures such as eyes-off-road time, and will enable designers to gauge the distraction potential of systems much earlier in the design and development process, affording more opportunities for re-design.

Another step in this direction is work done by Virginia Tech on an In-Vehicle Information System (IVIS) demand tool (Hankey, et al., 2000). This prototype software package is intended to serve as a tool to support design trade-offs associated with in-vehicle devices and predict the degree of driver attention demand associated with a task and design. It uses simplified models of driver cognitive and perceptual processes, and derives figures-of-merit for information demand (including red lines, or overloads) based on features of the IVIS task and interface. The model represents a preliminary effort, and more work is needed to validate model assumptions and output, as well as expand the tool to include additional task dimensions that may impact distraction (e.g., whether or not events are driver initiated and paced, task urgency, driver willingness to engage, etc.).

Although designs can be developed to allow many system functions to be used while driving, understanding the relative safety impacts of various device designs, options, and features is not necessarily very well understood. Hands-free and speech recognition technologies, for example, may reduce some of the risks associated with performing particular tasks while driving, but they do not necessarily eliminate risk associated with cognitive distraction. Growing research suggests that cognitive aspects of interacting with in-vehicle technologies can lead to reduced situational awareness (Parkes and Hooimeijer, 2000); attentional narrowing and reduced visual search and mirror sampling (Recarte and Nunes; 2000; Janelle, Singer & Williams, 1999); and increased driver reaction times to roadway events (Lee, Caven, Haake, & Brown, in press). Indeed, these types of innovative technologies may actually increase risk by encouraging more frequent and lengthy use while driving, and enabling designers to expand the capabilities of their systems as well as the range of tasks and functions that can be accessed while driving. Technology trends, therefore, need to be carefully monitored and safety impacts assessed.

Study Objective & Scope

The aim of the present study is to better understand the current state of practice and trends relating to the design and implementation of in-vehicle Telematics and infomatics systems and their likely impacts on driver distraction as indicated by accepted, basic human factors practices, principles, and guidelines. Design characteristics not only influences a system's usability and acceptance, but may also contribute to driver distraction by negatively impacting the visual, cognitive, and/or manual attention demands required to interact with and operate devices while driving. An inventory of current in-vehicle technologies was conducted in order to measure and document the range of interface design characteristics of Telematics devices, noting aspects and dimensions that have implications for potential driver distraction. This information will help NHTSA understand the degree to which certain features are common across systems as well as the degree to which designs significantly differ in ways that might contribute to their relative potential for distracting drivers. This information will also help NHTSA to identify what design features should be studied in future safety research that could help determine guidelines for equipment design and performance. Thus, information collected as part of this effort may be useful for a variety of purposes including:

- Gauging the extent to which designers and developers are applying available guidelines and "best practices" gained through research and experience;
- Comparing systems in terms of design approaches and architecture (highlighting good and poor interface design features);
- Identifying areas where systems could potentially benefit from improved designs or guidance, and (where appropriate) possible safety implications of particular designs; and
- Industry trends and common practices in interface designs (are defacto standards emerging?).

The review was not intended to be exhaustive, but rather provide a diverse and representative range of system designs and configurations. Technology reviews were primarily limited to in-vehicle systems that are specifically designed for use in the driving environment. Portable, wireless devices which can be transported into vehicles and used while driving, but not specifically designed for this environment (e.g., cell phones, personal digital assistants) were selectively reviewed on a limited basis in order to serve as benchmark/comparison systems. The review included technologies used in passenger vehicles as well as commercial trucks, with both domestic and international systems canvassed. Reviews targeted systems that are currently available on the market. Operational aspects of the systems such as timing, processing speed, reliability, and accuracy of information were not directly assessed as part of the inventory; measurements focused on system interface characteristics as opposed to system performance characteristics.

Overview of Approach, Method and Devices

The Telematics industry is an emerging, dynamic market with new products and services introduced daily. The present study represents an analytic effort intended to canvass a representative sample of in-vehicle Telematics devices and document objective system properties and man-machine interface characteristics. In essence, it represents a "snapshot" of available, market ready Telematics devices captured at a fixed point in time. Nevertheless, it provides a basis for assessing the extent to which current industry practices conform to published and available human factors design principles, and guidelines, as well as reveal industry trends and innovative designs and approaches. It provides a benchmark for future comparisons as well.

The review canvassed 79 in-vehicle devices/systems across five different functional categories, including navigation and route guidance systems, productivity and mobile PC systems, communication, and multi-function systems. Twenty-three of these systems were subjected to in-depth reviews using a standardized data collection form to inventory basic interface design characteristics and features. Items in the form were developed from available human factors guidelines documents and accepted engineering principles, and were intended to capture safety relevant design aspects and parameters. The inventory form not only captured basic sensory and perceptual aspects associated with controls and displays, it also documented interaction characteristics of systems, including the number of steps and button presses required to complete common tasks. The form provided for the collection of an extensive amount of information (over 150 individual parameters).

Although the primary (and preferred) means of collecting information was through direct interaction and experience with the device itself, a number of other methods was also used to collect this information (e.g., interviews with product designers, product user manuals, system demonstrations, etc.). Oftentimes, a combination of sources was used to complete the inventory (e.g., product interactions plus manual and telephone interviews), and/or supplement our experience with the product. Accessibility to systems was an important determinant of which specific devices/systems were actually reviewed; however, our sampling scheme ensured that products from different functional classes and markets (OEM vs Aftermarket; passenger car vs. commercial vehicle) were examined and represented. Product manufacturers were also provided opportunities to review and comment on completed forms.

METHODOLOGY

A systematic approach, incorporating five basic tasks, was used to achieve the project objectives and lead to compiled information on available in-vehicle technologies. These interrelated tasks are outlined in Figure 1 and include: (1) Identifying potentially safety relevant in-vehicle system interface characteristics and dimensions to be explored and inventoried; (2) Developing an organizational scheme for classifying in-vehicle systems and devices; (3) Creating a consistent, reliable and practical methodology for inventorying and assessing system interface characteristics; (4) Canvassing and inventorying a sample of in-vehicle systems; and (5) Interpreting and summarizing the results of the system/device inventories and assessments. Each task is described in detail below.

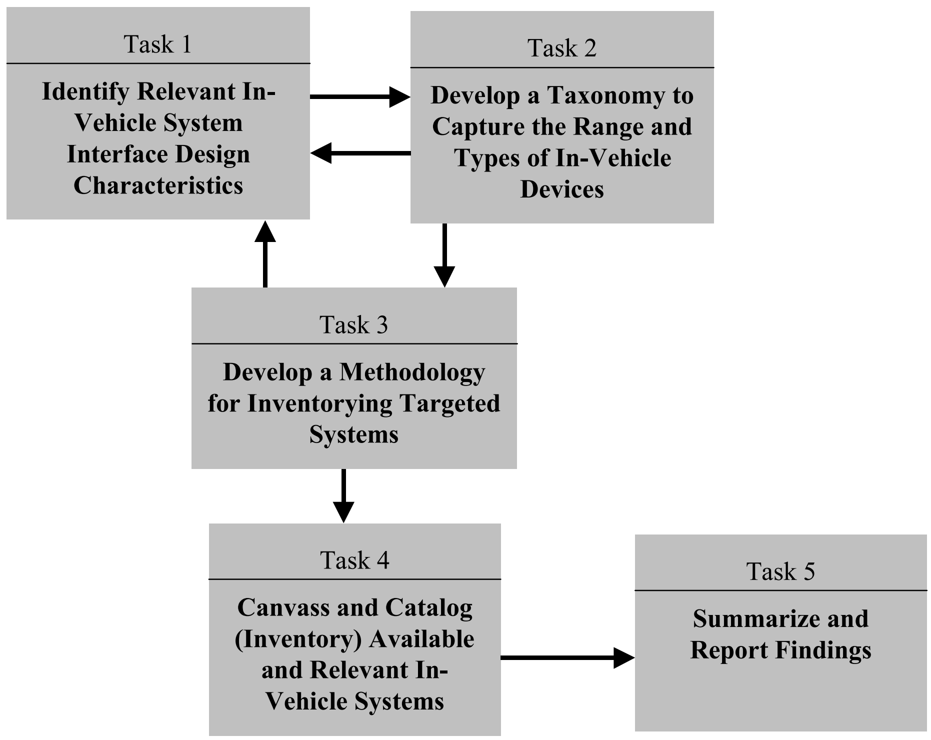


Figure 1. Study Approach and Tasks

Identification of System Interface Design Characteristics

The purpose of this task was to define relevant in-vehicle system interface characteristics and dimensions to be explored and inventoried. Results of this work formed the basis for defining objective system properties and man-machine interface characteristics to be examined in subsequent tasks, and narrowed the scope and focus by identifying design parameters likely to contribute to driver distraction. Characteristics to be documented as part of this effort were derived from a number of sources including existing human factors literature, design standards, guidelines, and recommended industry practices and principles specific to the design and development of in-vehicle devices. Key resources included, among others: the European Statement of Principles on Human

Machine Interface (European Commission, 2000); the Japan Automobile Manufacturers Association guidelines; Transport Research Laboratory's Safety Checklist for the Assessment of In-Vehicle Information Systems (Stevens, et al., 1999); FHWA's Human Factors Design Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations (Campbell, Carney, and Kantowitz, 1997); and the American Automobile Manufacturers Association's (AAMA) draft statement of principles Driver Interactions with Advanced In-Vehicle Information and Communication Systems (AAMA Driver Focus-Telematics Working Group, 2001)

Over 200 design parameters were identified as part of this processes spanning a range of interface characteristics, features and implementation aspects including the following elements:

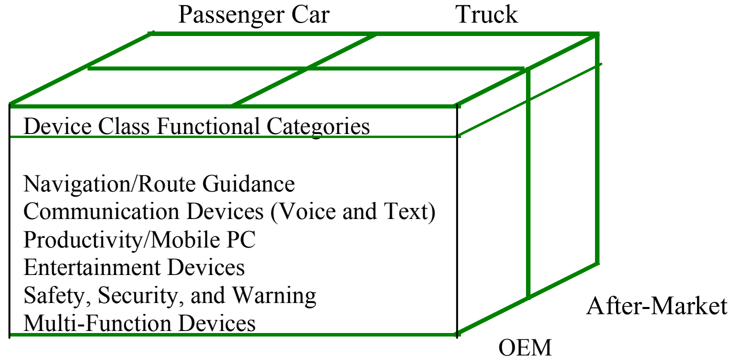
- Display and control characteristics (type, location, legibility, number of menus, etc.)
- Type of interaction modes (auditory, visual, haptic, etc.)
- Device interlocks or design restrictions
- Range of device functions/features
- Level of integration (stand-alone versus integrated within and across systems)
- Number of operations required to perform selected tasks
- Use of consumer product use warnings and guidelines

The initial list of characteristics was culled to a list of approximately 150 key interface design parameters and characteristics to be subsequently measured and inventoried. A data dictionary was also developed as part of this processes in order to provide a method for quantifying and objectively scaling these parameters (additional detail associated with this activity is presented in the Task 3 description below).

Taxonomy Development

Some form of organizational scheme was needed to ensure that the review encompassed the many types and varieties of in-vehicle Telematics and infomatics systems currently available or soon to be released on the market. Such a framework allowed individual devices to be classified within general functional categories, provided a common language for organizing and relating different systems, and ultimately enabled the broad range of systems to be mapped. Since the pool of available systems was extremely large, the taxonomy also provided the necessary structure to guide the selection of candidate systems and device types to be subsequently inventoried and examined. As indicated Figure 2, six broad functional categories were developed, each crossed by two additional dimensions capturing the availability of the device (OEM vs Aftermarket) and resident vehicle platform (passenger car vs. commercial vehicle).

Figure 2. Taxonomy of Devices and Grouping Factors



Thus, a taxonomy was developed to capture the range and types of in-vehicle devices to be inventoried. The classification system provided a framework for organizing the pool of available in-vehicle systems and devices, allowing the review to proceed in a focused and efficient manner by sampling within different classes of devices.

Inventory Form & Methodology

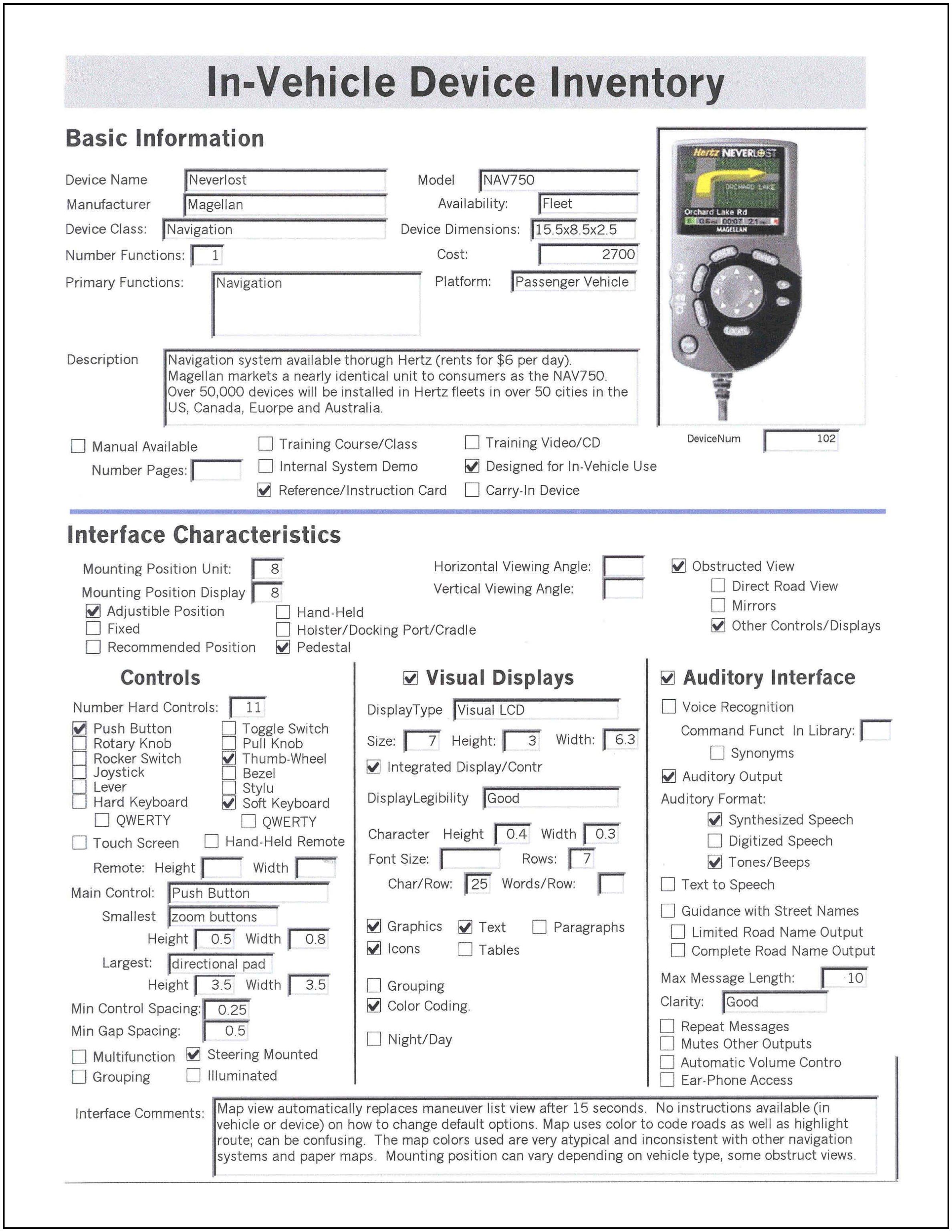
Development of the inventory form and associated methodology represented a key step in the project and was designed to serve as a common framework and protocol for inventorying and assessing targeted in-vehicle systems/devices. The goal was to develop a consistent, reliable and practical methodology for inventorying and assessing system interface characteristics. The challenge here was to specify objective measurement procedures for system interface design characteristics (identified earlier in the project). The tool would need to be sufficiently flexible to apply to a wide range of different systems, focus on system interface characteristics as opposed to system performance characteristics, and allow comparisons among systems. A standardized inventory form and associated data dictionary were developed to meet these requirements.

Basic Assessment Areas, Dimensions, and Criteria

The inventory form consisted of eight basic sections, each documenting different device features and aspects, including:

- Basic system information (product name, manufacturer, functions)
- Interface characteristics (controls, visual and auditory displays)
- Safety features (warnings and lockouts)
- General interaction dimensions (menu depth, feedback, etc.)
- System specific data (unique aspects associated with a device class)
- System architecture
- Photo gallery (pictures of displays, controls, symbols/icons)
- Task interactions (capturing steps to complete typical interactions)

Figures 2-5 presents the standardized inventory forms capturing these information and interface elements. The computerized form provides check-boxes and pull-down menu items as well as narrative components describing functions, interface elements, and other unique features of the system/device. The inventory form was developed in a relational database (Microsoft Access) to allow data to be readily tabulated and summarized. This feature also facilitated comparisons across systems and key classification dimensions (e.g., OEM vs. aftermarket). The data dictionary (see Appendix A) contains a description of each information element recorded in the form, along with the measurement approach used to quantify the interface characteristics.



In-Vehicle Device Inventory

Basic Information

Device Name: Neverlost
Model: NAV750
Manufacturer: Magellan
Availability: Fleet
Device Class: Navigation
Device Dimensions: 15.5x8.5x2.5
Number Functions: 1
Cost: 2700
Primary Functions: Navigation
Platform: Passenger Vehicle

Description: Navigation system available thorugh Hertz (rents for $6 per day). Magellan markets a nearly identical unit to consumers as the NAV750. Over 50,000 devices will be installed in Hertz fleets in over 50 cities in the US, Canada, Euorpe and Australia.

DeviceNum: 102

- [ ] Manual Available
- Number Pages:
- [ ] Training Course/Class
- [ ] Internal System Demo
- [x] Reference/Instruction Card
- [ ] Training Video/CD
- [x] Designed for In-Vehicle Use
- [ ] Carry-In Device

Interface Characteristics

Mounting Position Unit: 8
Mounting Position Display: 8
Horizontal Viewing Angle:
Vertical Viewing Angle:

- [x] Adjustible Position
- [ ] Fixed
- [ ] Recommended Position
- [ ] Hand-Held
- [ ] Holster/Docking Port/Cradle
- [x] Pedestal
- [x] Obstructed View
  - [ ] Direct Road View
  - [ ] Mirrors
  - [x] Other Controls/Displays

Controls

Number Hard Controls: 11

- [x] Push Button
- [ ] Rotary Knob
- [ ] Rocker Switch
- [ ] Joystick
- [ ] Lever
- [ ] Hard Keyboard
  - [ ] QWERTY
- [ ] Toggle Switch
- [ ] Pull Knob
- [x] Thumb-Wheel
- [ ] Bezel
- [ ] Stylu
- [x] Soft Keyboard
  - [ ] QWERTY
- [ ] Touch Screen
- [ ] Hand-Held Remote

Remote: Height Width
Main Control: Push Button
Smallest: zoom buttons
Height: 0.5 Width: 0.8
Largest: directional pad
Height: 3.5 Width: 3.5
Min Control Spacing: 0.25
Min Gap Spacing: 0.5

- [ ] Multifunction
- [x] Steering Mounted
- [ ] Grouping
- [ ] Illuminated

[x] Visual Displays

DisplayType: Visual LCD
Size: 7 Height: 3 Width: 6.3

- [x] Integrated Display/Contr

DisplayLegibility: Good
Character Height: 0.4 Width: 0.3
Font Size: Rows: 7
Char/Row: 25 Words/Row:

- [x] Graphics
- [x] Text
- [ ] Paragraphs
- [x] Icons
- [ ] Tables
- [ ] Grouping
- [x] Color Coding.
- [ ] Night/Day

[x] Auditory Interface

- [ ] Voice Recognition

Command Funct In Library:

- [ ] Synonyms
- [x] Auditory Output

Auditory Format:

- [x] Synthesized Speech
- [ ] Digitized Speech
- [x] Tones/Beeps
- [ ] Text to Speech
- [ ] Guidance with Street Names
  - [ ] Limited Road Name Output
  - [ ] Complete Road Name Output

Max Message Length: 10
Clarity: Good

- [ ] Repeat Messages
- [ ] Mutes Other Outputs
- [ ] Automatic Volume Contro
- [ ] Ear-Phone Access

Interface Comments: Map view automatically replaces maneuver list view after 15 seconds. No instructions available (in vehicle or device) on how to change default options. Map uses color to code roads as well as highlight route; can be confusing. The map colors used are very atypical and inconsistent with other navigation systems and paper maps. Mounting position can vary depending on vehicle type, some obstruct views.

Figure 3. Inventory Form: First Page, Basic Info and Interface Characteristics

Safety Features

- [x] Warning Against Use While Driving
  - [ ] Warning in Manual
  - [ ] Warning Labels on Device
  - [x] Warning Start-up Screen
  - [x] Warning When Operating
- [ ] Hands-Free
- [ ] Voice Activated Controls
- [x] Can be Operated with 1 Hand
- [ ] Auto Re-Routing

- [ ] Manages Info Flow to Driver (Adaptive Syste
- [ ] Non-Adaptiv
  - [ ] Locks Out Functions While Driving
  - [ ] Optional Locks
    - [ ] View Maps
    - [ ] Destination Entry
    - [ ] Map Scrollin
    - [ ] Destination Selection
    - [ ] Modify Route/Detour
    - [ ] Display Blank While Driving

Other Locked-Out Functions:

Comment: No mandatory lockout is available. A warning advising driver, "WARNING, during vehicle operation driver cannot program the unit" is provided when vehicle is in motion. Driver can resume programming (override warning) with a single button press.

General Interaction Dimensions

- [x] Control Activation Feedback
  - [x] Auditory Feedback
  - [ ] Visual Feedback
- [x] System Status Feedback
- [x] Interaction by Passenger
- [x] Restricts Input Options

Max Depth Menus:

Max Number Items in Menu:

- [x] Alert Tone
- [x] Self-Paced
- [x] Scrolling List
- [ ] Smart Spelling
- [x] SR Compatibility
- [ ] Auto Fill-In
- [x] Highlighting

- [ ] Prompts Response
- [ ] Time Out ____ Seconds
- [ ] Confirmation of Speech Command
- [ ] Presence of Ads/Distracting Items
- [x] Dynamic Elements
  - [x] Moving Map
  - [ ] Flashing Items

Other Items:

Comment: Alert cue can be distracting when multiple are issued in close proximity; sometimes occurs without any obvious reason. When scrolling through the soft keyboard keys, the system speaks the letter that the cursor has highlighted.

System Architecture

Operating System:

- [ ] Blue Tooth (Wireless Comm)
- [ ] Add-On Capability

Type

System Specific Data

Dest. Entry Method

- [x] Street Address
- [x] Intersection
- [ ] Previous Dest
- [ ] Phone Number
- [x] Freeway Entrance/Exit
- [x] Point of Interest
- [x] Pre-Programmed List
- [ ] Latitude/Longitude
- [ ] City
- [ ] Map
- [ ] Town Center

Map Orientation: [x] North-Up [x] Heading-Up

Map Perspective: [x] Top-Down [ ] Birdview

Number Views: 3

- [x] Map View — Element 6
- [x] Maneuver List — Element 5
- [x] Turn by Turn Instruction — Element 8
  - [x] Voice Turns
  - [x] Visual Turns

- [ ] Route Preview
- [ ] Route Simulation
- [ ] Combined Views

Default View: Map View

General Comments

Voice guidance sometime uses odd exit/turn distances (e.g., "exit in .4 miles," "exit in 1.1 miles"); not generally consistent with highway signing practices. The small screen size and mounting position make the display difficult for the driver to see, especially while in motion.

Figure 4. Inventory Form: Second Page, Other System Features and Data

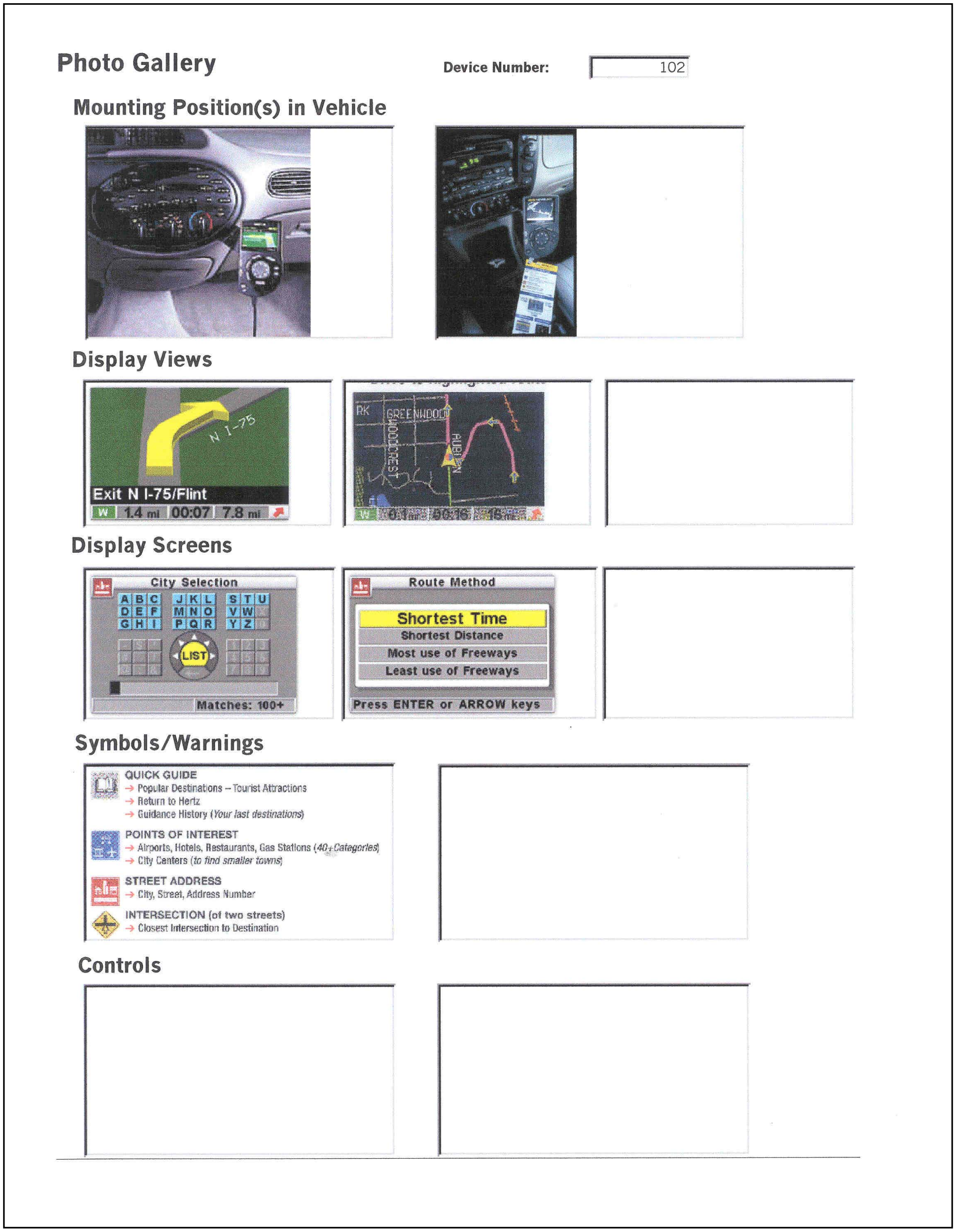


Figure 5. Inventory Form: Third Page, Photo Gallery

Task Specific Interaction

Device Number: 101 | TaskNum: 1

TASK Sample Task: Destination Entry

Method: Street Address

Min Steps: 8 | Max Steps: 10 | Min Keystrokes: 15 | Max Keystrokes: 45

Type Control: Joystick and Push Button

Step 1:	Power System On
Notes Step 1	The system options can be set so that the display opens automatically when the vehicle's engine is turned on. Read and accept the safety disclaimer.
Step 2:	Access Guidance Menu
Notes Step 2	Press 'DEST' button.
Step 3:	Select Destination Entry Method
Notes Step 3	Select 'City' - This step is not always necessary. Skip this step when calculating Min Number Keystrokes.
Step 4:	Enter/Select City
Notes Step 4	Enter city name using soft keyboard, then select city from list. User is then automatically returned to Guidance Menu. Skip this step when calculating Min Number Keystrokes.
Step 5:	Select Destination Entry Method
Notes Step 5	Select 'Address/Street.'
Step 6:	Enter/Select Street Name
Notes Step 6	Enter street name using soft keyboard, then select street from list.
Step 7:	Enter/Select Street Address
Notes Step 7	Enter house number using soft numerical pad. When finished, select 'Enter' to return to Guidance Menu.
Step 8:	Map Destination
Notes Step 8	Select 'Map' to map entered destination.
Step 9:	Confirm Route
Notes Step 9	View mapped destination. Press the 'PUSH ENTER' switch to confirm the destination.
Step 10:	Select Route Criteria
Notes Step 10	Accept the default criteria. Select 'OK' to calculate the route and begin active guidance.
Step 11:	
Notes Step 11	

☑ Multiple Methods (Shortcut ☑ Error Prevention ☑ Escape ☑ Cancel

☑ Resume Without Interruptio ☑ Error Recovery ☑ Back ☑ Undo

Comment: Rather than guide the user through the destination entry process in a linear sequence, this system returns the user to the Guidance Menu after each destination entry step is completed. This results in additional steps, but allows the user to more easily change entered information.

Figure 6. Inventory Form: Fourth Page, Task Interactions

Inventorying In-Vehicle Systems

Detailed inventories of in-vehicle system interface designs and features were conducted as part of this task. A two-step process was adopted in order to provide some structure to the review. First, a high level survey of market-ready devices was performed. This preliminary survey was intended to be broadly encompassing (revealing a wide range of systems, manufacturers, styles, and types of systems) and led to a relatively large pool of candidate in-vehicle Telematics and infomatics systems and devices. Information on available in-vehicle technologies was acquired through Internet searches, industry magazines and periodicals (e.g., ITS World, Automotive Engineering, etc.), conferences and exhibits (e.g., SAE World Congress, SAE Truck and Bus), as well as industry contacts. Nearly 80 in-vehicle Telematics and infomatics devices were identified as part of this process. In the second step, detailed inventory reviews were conducted on a limited subset of the pool of identified devices using the inventory forms and procedures developed earlier. Inclusion in the review was driven by a number of factors including, among others, access to systems or devices themselves. The goal was to examine a broad range of interface approaches and styles while maintaining a mix of Original Equipment Manufacturer (OEM) and aftermarket systems. The review emphasized market ready systems specifically designed for use in the driving environment for both passenger cars and commercial vehicle fleets.

Inventories were normally completed by interacting with the products themselves; in a few cases, detailed information was extracted from product manuals, system demonstrations, or interviews with product designers/representatives. Despite attempts to access key systems or devices directly, there were situations where the primary means of gathering system information was from product user manuals or product brochures/specifications documents and only limited information was available. These cases were typically limited to situations where products were not readily accessible, but reviews were warranted. Coordination with product manufacturers was extremely helpful in gaining access to candidate systems and product materials (e.g., manuals), and ensuring that the information collected was up-to-date and accurate. Opportunities to review completed inventory forms were also provided to manufacturers; this also served as an additional opportunity to gather product information which was not readily extracted from product manuals or through limited interactions with the product itself. Appendix B contains system thumbnail descriptions for many of the systems identified, while Appendix C contains the completed inventory forms for systems reviewed as part of this effort.

RESULTS

Three basic levels of product information are documented in this report, each reflecting the degree to which project staff was able to access and interact with individual products and services. The first is the set of completed inventory forms. These document a range of information parameters for each device (e.g., display/control interface characteristics, safety features, interaction dimensions, etc) and represent the deepest level of information extracted. As indicated earlier, information compiled in these forms generally required direct access and interaction with the device or system. Over 20 devices were reviewed and documented using these inventory forms. System thumbnail descriptions represent the second level of information collected. These present basic system level information with a brief 2-3 sentence description of system components and features along with a picture and information about system functions, availability and manufacturer. Thumbnail descriptions are recorded for systems where direct access was not possible or feasible. Finally, our initial survey of the area identified dozens of Telematics devices and while resource constraints would not allow detailed descriptions of all systems, many of them are identified in the report (product name, function and manufacturer).

Overview of Inventoried Devices

Table 1 lists the number of devices identified and reviewed (inventoried) across each of the functional product classifications; although safety, security and warning was identified as a device category, the review was limited to devices outside of this class. Our review accessed and obtained the most detailed information for navigation systems, with in-depth inventories completed for 13 systems. As a result, we were able to compile summary statistics characterizing this group of technologies (e.g., compute averages, etc.). Many of the other product classes (e.g., entertainment systems, multi-function devices, etc.) are limited to qualitative discussions of the technology and associated features since samples tended to be limited to a few devices or systems.

Table 1. Number of Identified and Reviewed Systems By Functional Class

Device Class	Number Devices Identified	Number Devices Inventoried
Navigation/Route Guidance	28	13
Communication Devices (Voice and Text)	9	5
Productivity/Mobile PC (includes Truck Systems)	23	4
Entertainment Devices	10	1
Safety, Security, and Warning	--	--
Multi-Function Devices	9	0
Total:	79	23

NAVIGATION SYSTEMS

The market for in-vehicle navigation is expected to grow from $70 million (U.S.) in 1999 to over $190 million by 2004, with expectations of significant growth in the U.S. with the integration of real-time traffic information (ITS Journal, Jan/Feb 2001). In the U.S., the number of new vehicles with factory installed navigation systems has increased to 135,000 for 2000 model-year vehicles. Consumers perceive value in these types of systems, in part, because they provide assistance in executing navigational tasks, relieving drivers of this sometimes burdensome task and providing a sense of security, particularly in unfamiliar areas. Consumer satisfaction with navigation systems is strongly related not only to operational aspects of these systems (speed and accuracy), but with their ease-of-use as well (J.D. Power, 2000). User friendly designs are especially important since the majority of consumers purchasing navigation system are first-time users with no experience operating these types of complex devices (J.D. Power, 2000).

Twenty-eight navigation systems were identified in our review of available systems (see Table 2), many more than could reasonably be inventoried and examined as part of this effort. Our goal, therefore, was to select a subset of systems that would provide a diverse and representative range of system designs and configurations. Access to the systems/devices themselves also played a key role in determining whether they were ultimately included in the review. As indicated in Table 2, detailed inventories for 13 navigation systems were completed, while thumbnail descriptions outlining basic aspects and features of the device were developed for 9 additional systems (see Appendix B for system thumbnails). Systems included in the review (marked as "Reviewed" in Table 2) were subject to detailed examination using the standard inventory form. Although first-hand experience with the systems was typically used to complete the forms, some were completed with the aid of the system manufacturer and/or user manuals. Each of the sections below highlights some of the system interface characteristics documented in the inventory. Table 3 summarizes some of the key interface characteristics for each of the navigation systems reviewed.

Table 2 . List of Candidate Navigation Systems for Review

Navigation Systems	Status
Alpine NVE-N871A	**Reviewed**
Blaupunkt Travel Pilot DX-N	Described
Blaupunkt Travel Pilot RNS-150	**Reviewed**
BMW Navigation System (Siemens VDO)	Described
Cadillac Navigation System	Described
Clarion AutoPC 310c	Described
Denso NAVIRA DV-D30S Plus	
DestinAtor by PowerLOC Technologies	**Reviewed**
Fujitsu Ten Eclipse	
Garmin StreetPilot III	**Reviewed**
Hertz NeverLost (Magellan 750NAV)	**Reviewed**
Honda Navigation System	**Reviewed**
Infinity Navigation System	**Reviewed**
Kenwood KNA-DV2100	

Navigation Systems	Status
Lexus 2001 LS 430 Navigation System	**Reviewed**
Magellan Pathmaster	Described
Mercedes Benz COMAND (Siemens)	**Reviewed**
Nissan Pathfinder Navigation System	**Reviewed**
Philips Carin 522 GPS	Described
Pioneer AVIC-9DVD	Described
Pioneer AVIC-505 with voice recognition	
Pronounced Technologies AudioNav AN221	Described
Rand McNally TripLink	**Reviewed**
TravRoute Co-Pilot 2001	**Reviewed**
Visteon NavMate	**Reviewed**
VDO Dayton MR 6000	
Volvo Navigation System	Described
Xanavi BIRDVIEW XN-770A	

Table 3. Summary of Key Interface Characteristics for Sampled Navigation Systems

	Original Equipment Manufacturer Systems						Aftermarket Systems							
	Honda	Infinity	Lexus	Mercedes	Nissan		Alpine	Blaupunkt RNS 150	Destinator	Garmin St Pilot	Hertz	Rand McNally	TravRoute Copilot	Visteon NavMate
Nav Specific Hard Controls	6	14	4	12	7		14	19	7	11	11	30	4	13
Touch Screen	Yes	No	Yes	No	Yes		No	No	Yes	No	No	No	Yes	No
Display Size (diagonal, inch)	5.5”	5.5”	7”	4.7”	5.5”		6.5”		3.8”	4.3”	3.5”	2”	3.9”	3.5”
Voice Input	No	No	Yes	No	No		No	No	No	No	No	No	No	No
Voice Output	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Repeat Output	Yes	Yes	Yes	Yes	Yes		Yes		No	Yes	No	No		Yes
Mute Audio	Yes	Yes	No	Yes	No		No		No	No	No	No	No	No
Locks Out Destination Entry While Driving	No	Yes	Yes	No	Yes		No	No	No	Option	No	No	No	No
Warnings on Screen	Yes	Yes	Yes	Yes	Yes		Yes		Yes	Yes	Yes	No	No	Yes
Auto Reroute	Yes	Yes	Yes	Yes	Yes		Yes		Yes		Yes	No	Yes	Yes
Dynamic Elements	Yes	Yes	Yes	Yes	Yes		Yes	No	Yes	Yes	Yes	No	Yes	Yes
Default View	Map	Map	Map	List	Map		Map	List	Map	Map	Map	List	List	Turn
Dest. Entry Methods	8	7	8	5	7		8	8	6	6	5	3	6	7
Map View Elements	13	9	10	5	14		15	--	17	9	6	--	13	14
Maneuver List Elements	6	6	7	2	8		4	10	10	6	5	2	16	8
Turn-by-Turn Elements	7	9	14	5	12		10	6	4	9	8	--	7	11
Min/Max Keystrokes	4/22	5/45	7/24	7/38	5/25		6/47	8/40	7/23	12/52	15/38	4/23	3/28	5/38
Max Number Items In Menu	10	9	8	8	9		7	6	9	7		--	9	9
Max Depth of Menus	8	7	5	5	7		5	5	10	7		--	8	5
Rows in Scrolling List	5	5	4	6	5		6	5	6	7	7	2	9	5

Interface Characteristics: Controls

Number of Hard Controls

Since drivers may devote significant attention searching for and manipulating in-vehicle controls, reducing and simplifying the number of controls in the vehicle cockpit is generally viewed as a desirable characteristic. The primary concern is that as the number of controls and displays increase, so may driver workload and the potential for distraction. Even conventional in-vehicle devices such as radios have become increasingly complex and confusing with controls that are small, serve multiple functions, are poorly labeled, and are difficult to reach and operate. A recent survey by the AAA Foundation for Traffic Safety, for example, found that the number of new car radios with more than 10 buttons has increased dramatically over the past decade, rising from under 30% prior to 1990 to over 60% in 2001 (AAA Foundation for Traffic Safety, 2000).

Navigation systems reviewed as part of this study varied in terms of the number of controls physically present on the device (hard controls), ranging from 4 to 30 controls. Some navigation systems were integrated with other functions (e.g., stereo, CD, HVAC, etc.) so that hard controls for non-navigation functions were located on the same in-dash unit. Figure 7 depicts both the number of overall controls on the unit and those specific to navigation system interactions. Since the Rand McNally unit was so unique in its design, serving as a general Advanced Traveler Information System, it was excluded from the analysis below.

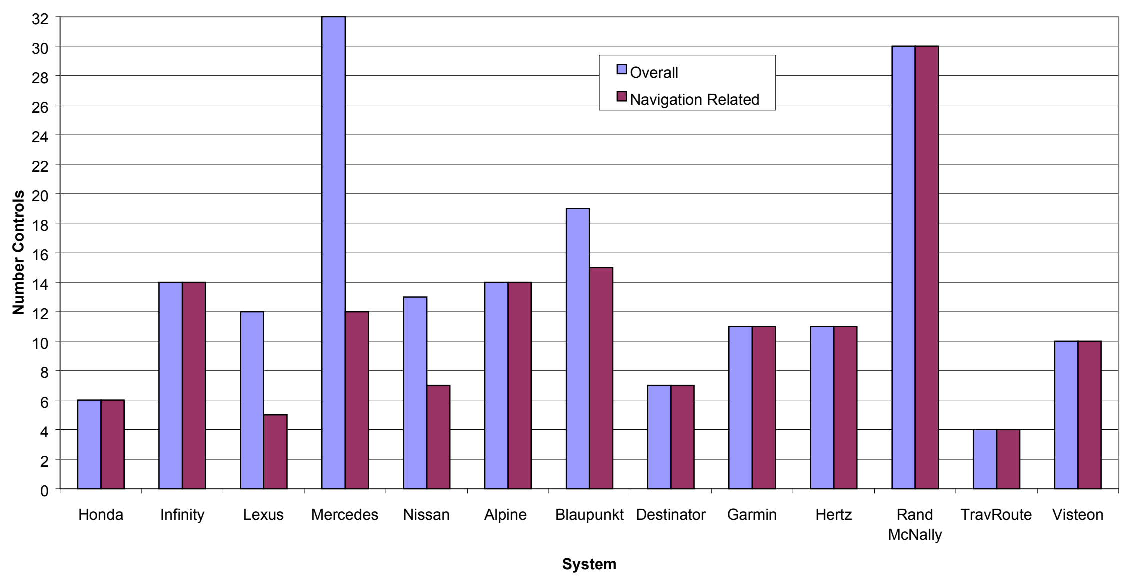


Figure 7. Number of Hard Controls: Overall and Navigation-Specific Controls

Overall, across all of the navigation systems reviewed (excluding the Rand McNally unit), devices averaged slightly over 11 hard controls (11.53) located on the system units. Systems furnished by OEM's tended to have fewer controls (8.80) than aftermarket suppliers (10.85). Navigation systems with touch screen interfaces (e.g., Honda, Lexus, Pathfinder, TravRoute) tended to have the fewest number of physical hard controls, ranging from 4-7 controls . These designs enabled drivers to select among displayed menu items by simply touching the screen or using a pointing device. Since our review included more OEM systems with touch screen interfaces than aftermarket systems, this may also account for some of the difference in hard controls between the two classes.

Control Characteristics: Types, Spacing, Labeling

As a group, navigation systems appeared to conform to established guidelines with regard to aspects associated with their physical controls, including type, spacing, and labeling. Controls on many of the systems were back-lit for night operation. There was, however, quite a lot of variation across these dimensions as manufacturers attempt to differentiate their products. Pushbuttons were the most common type of control used – every system reviewed used some form of pushbutton. Rocker switches, joysticks, bezel switches and rotary knobs were also incorporated into most of the designs. Almost half of the systems (47%) used multi-function controls. Frequently used functions tended to have dedicated pushbuttons or controls, and many systems used a common or central control to scroll, highlight, and/or select menu items. One of the systems (Alpine) used a hand-held remote control unit through which drivers accessed and selected all system functions; this is not a unique design (see Philips Carin and Pioneer AVIC systems in Appendix B). One concern with the use of a remote is the possibility that the driver could drop the unit while driving leading them to search for the device. Since remotes are not tethered or anchored to the system and can easily become misplaced, drivers may also become engaged in searching for or locating the remote while driving. Although remotes, such as the one used in the Alpine system, can be operated with a single hand, it can be challenging. This is particularly true if the unit includes a multifunction or two-axis joystick used to both highlight and select items; inadvertent menu selections can be a problem.

As a group, controls on OEM supplied navigation systems were generally larger with greater control spacing compared to aftermarket systems (See Table 4 which lists the average values for the largest and smallest controls, as well as control spacing). Larger controls not only minimize the likelihood of pressing the wrong control, but also provides more space to label the controls without the need to use abbreviations. PDA-based system in particular tended to have small and closely spaced reconfigurable soft controls.

Table 4. Control Size and Spacing Averages

	Overall	OEM	Aftermarket
Largest Control	1.49 x 1.77 cm	1.82 x 2.38 cm	1.25 x 1.34 cm
Smallest Control	0.59 x 0.89 cm	1.02 x 1.68 cm	0.28 x 0.33 cm
Min Control Spacing	0.71 cm	1.22 cm	0.35 cm

Interface Characteristics: Visual Displays

All of the systems inventoried included some form of visual display which drivers could use to program destinations, view maps, receive systems status information, access visual-based routing and guidance information, and perform other navigation related tasks. Our review of available systems only found a single device on the market (the AudioNav AN221 developed by Pronounced Technologies) that did not have a visual display, relying exclusively on voice interactions. Over 80% of the systems examined consisted of a single common unit with integrated displays and controls. Exceptions were the Alpine which used a remote control, and the Infinity which incorporated a pop-up display positioned on the dashboard. Although a host of parameters were documented, three general characteristics associated with visual displays were of particular concern: (1) the location of the display, (2) the size and quality of the display, and (3) the type and amount of information content presented on the display.

Mounting Position

As shown in Figure 8, the vast majority of systems (80%) located their visual display in the center stack area of the instrument panel where conventional radio and HVAC controls are traditionally found. A few systems positioned the display on the dash area over the center stack closer to the driver's line of sight; controls for these types of systems tended to be located in the center stack area. The Infinity system used this type of configuration which featured a retractable display that is only visible when the system is in operation. This design positions the display closer to the driver's line of sight, yet limits distraction when the system is not in operation. Other manufactures also offer retractable displays, but not all are necessarily located along the top of the dashboard. A few manufacturers mount or position displays low in the vehicle cab near the floor console; some of these systems, such as the Hertz NeverLost, were mounted on a pedestal. All systems allowed the display to be easily viewed by a front seat passenger.

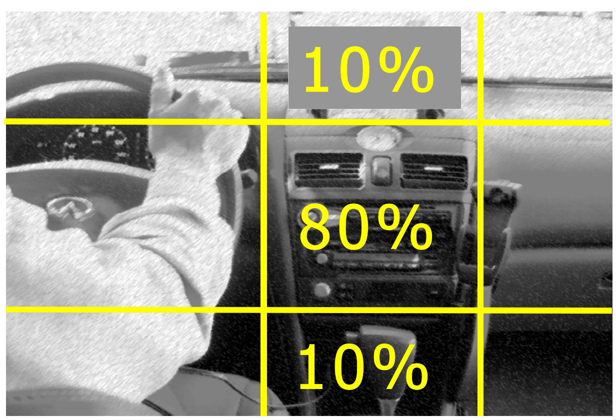


Figure 8. Percentage of Systems Locating In-Cab Visual Displays in a Region.

It is important to note that there can be considerable variation across systems and vehicle models in terms of where displays are positioned. Aftermarket systems, in particular, are generally subject to greater variation than OEM systems since they are not part of the vehicle's original equipment. Based on our sample of aftermarket systems, most manufacturers tended to provide or offer mounting equipment with recommendations on where to locate and position visual displays. For example, portable or carry-on systems (e.g., Pocket Co-Pilot and DestinAtor) come equipped with mounts that attach to the vehicle's air vents; others provide suction cup-mounts allowing the driver to attach the device to the windshield.

Size and Quality of Visual Displays

Since a combination of factors contribute to good visual displays, our review characterized display quality qualitatively (e.g., poor, fair, good, excellent) rather than quantitatively. Nevertheless, a number of factors were considered in the review, and aspects leading to poor designs were noted. The size and quality of the visual displays were generally very good; OEM systems tended to have larger higher quality, and more consistently good visual displays compared to aftermarket devices. Nevertheless, some aftermarket manufacturers, such as Alpine, offer a variety of display units which can be purchased separately and used with the navigation unit; these include large high end displays capable of supporting Digital Video Disk (DVD) movies. Display sizes in our sample ranged from 2" to 7" diagonal displays, with the Rand McNally TripLink, Blaupunkt RNS 150, and PDA-based systems (DestinAtor, and TravRoute Copilot) possessing among the smallest displays. Systems that presented map-based information tended to have large displays. With the exception of the Blaupunkt and the RandMcNally systems, all devices used color displays – a feature which was heavily used in color coding map displays. All systems provided a means for viewing during nighttime or low light conditions, sometimes providing a separate night-day switch to change the display mode.

Glare may be a potential problem for all of the displays. Low mounted displays and those recessed into the console may be somewhat less prone to glare effects, but no designs were immune from glare. Other factors contributing to the quality of a visual display were contrast, resolution, font size and type, and viewing angle. The Rand McNally system was among the worst display encountered in our review. It consisted of a small monochrome display with very hard to read text displays. Another factor which made the text difficult to read, aside from the low resolution display, was the use of all CAPS which made some letters difficult to discriminate. Since most aftermarket systems are not integrated into the vehicle, they tended to have adjustable position displays, allowing the driver or front-seat passenger to fine tune the viewing angle of the display. As described in the next section below, the amount of information presented on a display also contributed to the quality of the display by impacting font sizes, and the number of rows or information elements displayed in a single screen. Many systems further reduced the usable display area by including header and footer information; thus, not all of the available display area was necessarily used to present dynamic information.

Type and Amount of Information

As in-vehicle visual display screens become increasingly larger, so too does the potential to make available more and more of information to drivers. Since drivers oftentimes desire significantly more information than necessary to guide performance or decision making (Llaneras et al., 2000), it is important to assess which specific information items drivers need to accomplish a particular task in order to avoid overloading displays. Display format may also play a significant role, influencing not only usability (including the ability to efficiently extract information), but safety as well. Moving map displays, for example, can be potentially distracting because they may induce the driver to glance at the display. Displays presented while driving should be as simple as possible to avoid information overload and distraction. Limiting the amount of information presented to drivers as they are driving is critical. Displays that require frequent and lengthy glances might prevent drivers from monitoring the environment.

Most navigation systems rely on three primary guidance display screens to communicate navigation information to drivers: (1) maps, (2) maneuver lists with sequenced turn directions, and (3) turn-by-turn guidance displays which generally "pop-up" in advance of a turn. The overall utility of each depends on the particular task being performed. Maps, for example, can be effectively used to plan a route (Bartram, 1980) since they provide a pictorial representation of an area or region, while ordered lists of directions can limit information processing and lead to fast and accurate navigation performance (Streeter et al., 1985). Systems tend to use or make available all three types of information displays.
ce, the need to zoom in and out (this was the case).
Figure 9 provides examples of each type of navigation guidance display. With the exception of the Blaupunkt and Rand McNally systems, which have very small monochrome screens, all of the systems provided some form of map display. Indeed, 67 percent of the systems reviewed used the map as the default display screen following destination entry (i.e., during active navigation). This suggests that designers perceive that drivers will use map-based information not only for trip planning purposes, but also during en-route navigation. As described in later sections, maps tended to contain relatively large amounts of information resulting in complex display screens with landmarks, street names, color-coded roadways, and dynamic elements. Although most systems allow the default to be changed or other views (e.g., maneuver list) to be accessed directly via a button press, changing default settings may not always simple or straightforward. In the case of the Hertz NeverLost system, the manual did not accompany the system, and no resident help screen menus were available to instruct users on how to change the default settings. Furthermore, once the maneuver list was accessed by the driver, the view automatically reverted back to the map display after 15 seconds requiring the driver to periodically press a button in order to maintain the turn list view. One unique map design feature was found on the Infinity and Nissan system which provided a "Birdview" perspective depicting map information from an elevated perspective as opposed to a top-down view. This particular map perspective allows drivers to view more detail close-in to the immediate surround, while retaining the larger route perspective. It is intended to eliminate, or significantly reduce, the need to zoom in and out (this was the case).

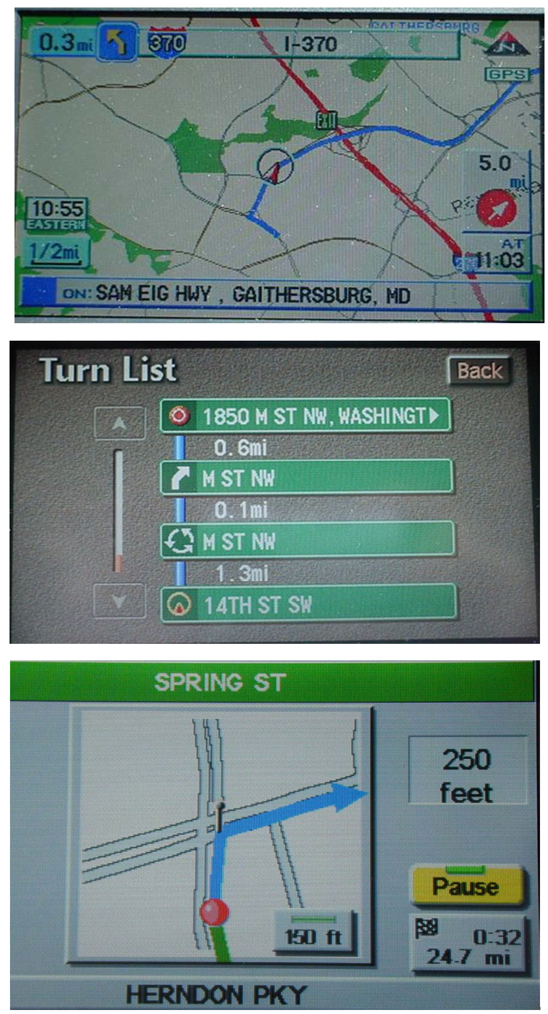


Figure 9. Map, Maneuver List, and Turn-by-Turn Display Screen Examples.

A few systems used the maneuver list view as the default guidance screen, providing drivers with a set of detailed turn instructions for the entire planned route. No uniform or consistent pattern was observed in terms of how maneuver list information was sequenced and presented. Most systems ordered street information in a top-down fashion (e.g., Infinity, Garmin, Alpine); however, sometimes items in a turn list were sequenced from bottom-to-top (e.g., Lexus). Nearly all systems provided turn-by-turn displays which automatically appeared in advance of a maneuver; these tended to provide drivers with information in both visual and auditory modes to announce an impending turn. Less than half of the systems (42%) issued an alert tone to capture the driver's attention before presenting turn-by-turn guidance information. This feature may reduce the need for drivers to repeat audio messages by notifying and preparing drivers to receive navigation commands. Drivers can access (or configure the system to provide) split-screen views in 50% of the systems reviewed, providing drivers with overlays of more than one type of display.

One consistent finding across systems was the fact that drivers can access relatively large amounts of information to aid in their navigation tasks. Table 5 lists many of the information elements presented across map, maneuver list, and turn-by-turn displays – over 20 separate pieces of information are represented. While not all systems presented all of these items, some included most of the items listed. All systems presented icons/symbols, text, and tables (maneuver list), and most presented graphics (i.e., maps). Although none organized material in paragraph form, the PDA-based route navigation systems because of their small screens tended to wrap text across multiple lines.

Table 5. Types of Information and Display Elements Available to Drivers Across the Various Navigation and Guidance Display Screens.

General Types of Information	
▪ Road Map (including street identifiers)	▪ Time of Day (Clock)
▪ Enlarged Intersection Display	▪ Cardinal Heading/Compass
▪ Route Highway Shields/Markers/Icons	▪ Vehicle Speed
▪ Landmark/Service Icons	▪ Distance to Turn (number and/or countdown bar)
▪ Map Scale	▪ Current Position (street name)
▪ Vehicle Icon	▪ Next Turn (street name/number)
▪ GPS Indicator	▪ Lat/Long Coordinates
▪ Route Distance (Distance to Destination)	▪ Scroll Bar (not soft control)
▪ Arrival Time/Travel Time to Destination	▪ Destination Address
▪ Turn Arrows	▪ Soft Controls (each control)
▪ General Direction (Arrow) to Destination	

Figure 10 illustrates the average number of information elements contained within each type of display across all 12 systems (excluding the Rand McNally system). Map displays contained the most information (an average of over ten items), and generally served as the default guidance view (the one drivers would see first when operating the system) despite the fact that they rely heavily on spatial processing capabilities of the driver and tend to be a poor presentation method when the vehicle is moving (Mitchell, 1993). Most systems, however, provided supplemental turn-by-turn guidance displays. Of course, systems also enabled drivers to change the default view, and/or access alternative views directly (often via a single button press). In addition, many systems provided a wide range of options for configuring the types of information displayed on maps. For example, icons representing various points of interest such as hotels, gasoline stations, and ATMS could be programmed to be overlaid on maps. Some systems also allowed the display screen to be blanked-out while driving, allowing drivers to receive audio guidance only. Although turn-by-turn guidance displays generally contained fewer information items than map displays, they still presented a considerable amount of information, averaging 8.5 information elements. General types of information on these displays tended to include turn arrows, countdown bars to indicate the distance to the next maneuver, an indication of the current and next turn street name, and an abbreviated map depicting the intersection roadway geometry. One interesting design, adopted by several systems, was to integrate display elements such as the turn arrow, countdown bar, map, and vehicle position indicator. This arrangement allows drivers to focus on a single overall graphic representation rather than several individual display elements to extract the information (exercising Gestalt principles). Another characteristic common to turn-by-turn displays was the redundant audio component announcing the upcoming maneuver. Some systems only announced the direction and distance of the next turn, rather than the specific street name. Exceptions were the Infinity, Nissan, Alpine, Lexus, Honda, and Garmin systems which provided some road name outputs. The display type with the least resident amount of information was the maneuver list view (averaging about 6 elements). This view provided drivers with as few as 2 items of information in some cases, but generally provided turn arrows to indicate the direction, the street name, and distance to the next turn, as well as display elements (e.g., scroll bar). One of most Spartan maneuver list displays in our sample was provided by the Mercedes-Benz COMAND system which simply provides a sequenced list of street names with no turn direction or distance indications.

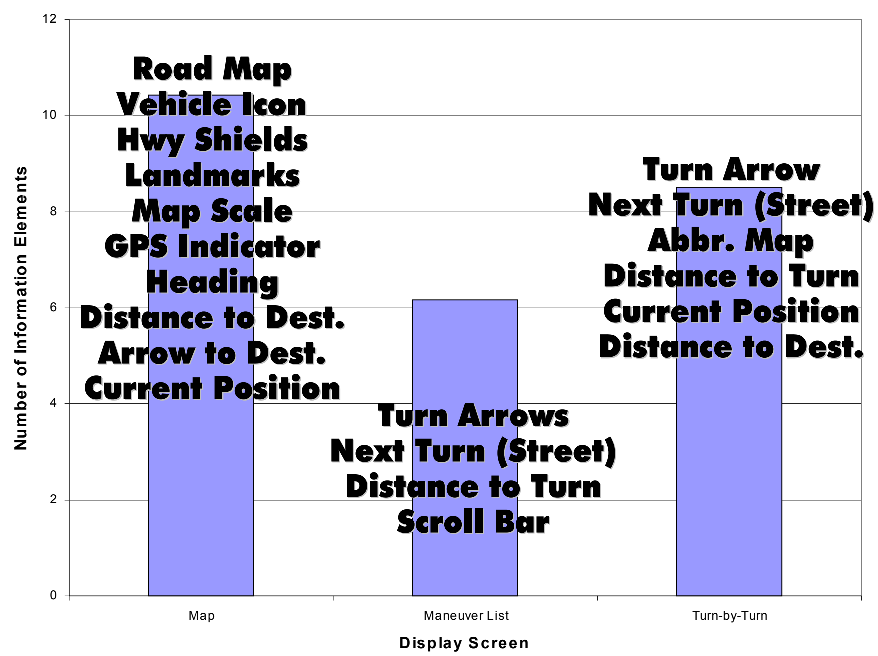


Figure 10 . Average Number of Information Elements Presented Across Display Screen Types

Interface Characteristics: Auditory Displays

Many automotive and Telematics industry representatives (and system designers) are relying on speech recognition technology (and other forms of auditory interactions such as text-to-speech) to keep the driver's eyes on the road and hands on the wheel – a philosophy adopted by many OEMs. While speech recognition systems may address some forms of distraction, voice systems are not a panacea. Speech-based interfaces can potentially reduce the visual and biomechanical demands associated with executing certain tasks, making them more usable while driving, but these types of interfaces are not resource independent and may still place considerable cognitive demands on drivers. Llaneras, Lerner, Dingus, and Moyer (2000) demonstrated, in an on-road study, various driving deficits associated with concurrent auditory displays, including variations in speed maintenance. Further, a host of outstanding human factors issues still need to be addressed if the benefits of auditory and voice response systems are to be fully realized and consistently applied (Llaneras, 2000). These include, among others, determination of: appropriate message lengths; nature of voice commands; diversity of the vocabulary; error handling and recovery procedures; system time-out protocols; and impacts on situational awareness and object/event detection. There are also unique problems and aspects of speech recognition related to their application to the automotive environment. Vehicles, for example, are subject to a wide variety of noises that can confuse speech recognition software, and systems relying on cellular links introduce other problems such as echoes, electrical interference, and poor signal strength. Unreliable systems and those with low recognition rates can impose greater cognitive loads on the driver, and may lead to increased errors and frustration.

Our inventory documented a variety of auditory display characteristics ranging from system interaction features, to the format of auditory output (synthesized or digitized speech), to the number of voice command functions and the driver's ability to repeat system messages. The most prominent use of voice interaction in our sample of navigation systems was the use of speech output to issue navigation guidance information. All systems incorporated some form of auditory output message during route navigation; these were predominately digitized speech messages providing turn information to drivers and served as redundant voice guidance for turn-by-turn displays. Only half of the systems included the name of the next turn street or intersection along with turn direction and distance information. Some systems also issued an alert tone or beep prior to issuing auditory navigation guidance in order to capture the driver's attention and prepare them to receive instructions; however, fewer than half of the systems (42%) incorporated this feature.

The quality of the speech systems was generally very good, particularly for OEM systems which were integrated through the vehicle's speaker system. This configuration also enabled the radio/CD to be muted (or the volume to be temporarily adjusted) when the navigation system issued an auditory message. In our sample, this capability was restricted to OEM systems; however, some aftermarket systems were also capable of being configured in a similar manner. Others, such as the Lexus navigation system, opted not to mute the radio when navigation commands are issued (a design which may annoy some drivers since the radio cuts in and out), but elected to transmit voice messages through the driver's side speaker only. Two-thirds of the systems provided a means for the driver to repeat system messages; most systems with this feature had a dedicated control for this function. One PDA-based system's (i.e., the TravRoute Copilot) audio output was barely audible over the background noise (even with the volume at the maximum setting), and its synthesized speech made it difficult to decipher guidance messages.

Only a single navigation system in our set possessed voice recognition capabilities – the Lexus LS 430. This system includes a library of 49 command functions with alternative command words and phrasings (synonyms) for issuing different functions. The system operates using this set of defined keywords which are spoken by the driver to activate system functions. In order to enhance system reliability (increasing accuracy and reducing errors), the voice command function features a control switch located near the steering wheel which drivers must press prior to each interaction. Once activated, a beep sounds and a visual icon appears on the screen to indicate that the voice command feature is active. If no voice commands are issued within 6 seconds, a beep sounds and the system becomes inactive. Similarly, if a command is not recognized, the system responds with an auditory error message, "System does not recognize this command, please rephrase your command." Both auditory and visual feedback are used in this system. This is consistent with research indicating that auditory feedback confirming driver speech command inputs is a valuable feature and minimizes the need for drivers to glance to the screen to confirm their action had been executed/acknowledged (Kamp et al., 1999). The system recognizes nearly 100 commands with typical interactions averaging approximately 2 words in length (e.g., Show Destination, Split Screen, Go Home). Nevertheless, not all navigation functions are controllable via speech command. Destination entry, for example, is limited to selecting a previously stored destination such as one's home address; the route is automatically calculated from the current location once the command is issued. Destination entry using the street address method, for example, cannot be accomplished using voice command.

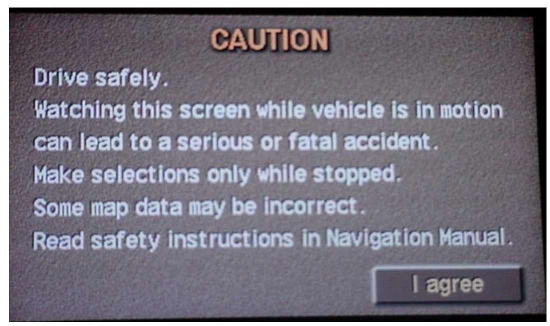
Safety Features

Well-designed displays and controls are perhaps one of the most simple and basic safeguards against distraction. Nevertheless, even well designed navigation systems can include demanding tasks that are best performed while stopped when drivers can devote their full time and attention to the task without compromising safety. At a minimum, drivers need to be alerted to the fact that these systems can potentially interfere and distract them from their primary task of driving. This section is intended to capture current industry practices, designs and methods for ensuring that drivers do not attempt to perform complex task interactions while the vehicle is in motion; this includes system designs that restrict or limit the amount of information presented to drivers.

Warnings

Almost all of the navigation devices included some form of warning or caution against use while driving; these specifically targeted significant interactions with the unit such as programming a destination. Warnings were incorporated into product start-up screens, user manuals, and sometimes integrated so that advisory messages are displayed when attempting to access a function while driving. Figure 11 depicts some example warning screens which are displayed upon system start-up. These require drivers to read and confirm or "agree" with the warning before launching into the application. The following warning content or information elements were commonly found in these types of messages (irregardless whether lockouts were or were not available):

- Driver responsibility for safe driving and compliance with traffic regulations
- Glancing at the display screens only when it is safe
- Programming the system or making selections only when the vehicle is stopped
- Data may not be 100% reliable; some errors in maps.
- Becoming distracted as a result of using the device.



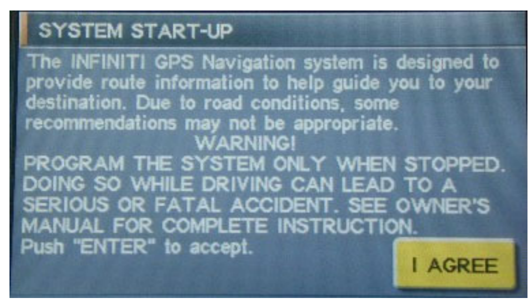


Figure 11. Example Navigation System Warning Screens

In addition to warnings issued during start-up, some systems used a "pop-up" warning strategy whereby attempts to program a destination into the system while driving would result in a warning/advisory message displayed on the screen. In some systems the warning served to alert or remind drivers that the function was locked-out, and advised drivers to "pull over before using this function." In other systems, such as the Hertz NeverLost, the driver could elect to continue the operation by merely pressing a button to acknowledge the message. Warnings tended to include most of the basic elements believed to contribute to effective warnings, including: (1) identification of the hazard, (2) consequences of ignoring the warning, and (3) and instructions on how to avoid or control the hazard - actions to avoid the hazard. Although many systems adhered to these basic principles, it is unlikely that warnings alone will dissuade all drivers from performing complex task interactions while the vehicle is moving. Lock-outs which prevent drivers from attempting complex task interactions while the vehicle is in motion represent more proactive methods. As shown in Table 6, mandatory restrictions and lock-outs to complex functions while driving was not a commonly adopted strategy, with less than 1 in 5 systems incorporating such features.

Table 6. Percentage of Sampled Systems Incorporating Safety Features.

Safety Feature	Percent of Systems Incorporating Feature
Warnings in Manual	100%
Warning Labels on the Device	0%
Warning on Start-up Screen	83%
Warning During Operation	17%
Mandatory Lock-outs While Driving	17%
Optional Lock-outs While Driving	6%

Aside from locking-out or restricting certain functions while driving, no real advanced or adaptive methods of managing information flow to the driver were incorporated into any of the systems sampled in our review. This perhaps reflects the relative immaturity of the state-of-the-art in real-time workload and environmental assessment where, despite years of research, reliable, robust, and easily implementable systems for monitoring driver workload are lacking. Some systems, however, managed the flow of information non-adaptively by restricting the number of available menu options to a few (usually five or fewer) while the vehicle is in motion. Other automated forms of information management included auto-reroutes and the use of turn-by-turn displays. Nearly all of the systems automatically re-programmed routes to the destination following a missed turn, and provided voice and visual turn-by-turn routing information. Both features eliminate or significantly reduce the need for drivers to interact with the system to achieve these tasks and access information.

General Interaction Dimensions

Data Entry Screens

Although there is no standard configuration for displaying screen elements, or for organizing on-screen items/controls for data entry, most systems tended to list alphanumeric items in linear order (A-Z, and 0-9). Nevertheless, there was considerable variety in how this was implemented. The Hertz NeverLost system, for example, (bottom, Figure 12) groups items into character sets or clusters, while a few systems (PDA-based systems) used standard QWERTY keyboard configurations. Similar observations were made by Tijerina (Tijernia et al., 2000), who suggested that research is needed to characterize the relative benefits of various type of data input and retrieval methods.

In general, the task of selecting an item can be accomplished via direct manipulation through the use of a touch screen, remote control, or other physical controls such as thumbwheels, joysticks, etc. These methods have a direct impact on the number of key/button presses required to complete task interactions. Usually two operations are required to select an item: highlight and entry. Touchscreens reduce this to a single operation. The Task Interactions section of this report includes additional details regarding this issue.

Some system designs actually facilitated destination entry while driving. The Hertz NeverLost system, for example, not only visually highlights characters, it also "speaks" items as they are highlighted thereby providing visual and auditory feedback during data entry. This feature may ensure greater accuracy during data entry, but it also allows drivers to keep their eyes on the road while manually interacting with the data entry screens since drivers can rely on the auditory feedback alone to complete the task. This type of design could encourage some drivers to attempt complex tasks like destination entry while driving.

Figure 12. Sample Data Entry Screens for Navigation Systems

Navigation System Task Interactions

Programming a destination into a navigation system is arguably one of the most complex tasks drivers will perform with a Telematics device. Concern over these types of multi-step and potentially demanding tasks while driving has spawned the development of several guidelines and recommended industry practices, both in the U.S. and abroad. In Japan, for example, the Japan Automobile Manufacturers Association (JAMA) has developed a set of voluntary guidelines for navigation system interface designs to promote safety; this includes restricting destination entry in moving vehicles. In the U.S., the Society of Automotive Engineers is in the process of adopting a recommended practice that attempts to lock-out demanding tasks while the vehicle is in motion (Society of Automotive Engineers, 2000); the recommended practice addresses lengthy navigation entry tasks which rely on visual displays and manual controls. Despite the complexity of destination entry tasks, many commercially available systems do not lock-out destination entry while the vehicle is moving. Of the 12 passenger car systems examined as part of this study (excluding the Rand MacNally ATIS device), only 3 restrict the driver from accessing destination entry functions when the vehicle is in motion. Further, only one of the systems examined (Lexus) supported voice-based destination entry: nevertheless, even this system limited destination entry via voice input to the selection of previously defined destinations (e.g., "go home," "go to previous destination," etc.). All of the other systems required visual and manual interactions to program destinations and execute other task interactions such as modifying routes.

Destination Entry: Methods, Steps and Key Presses

A variety of methods exist for programming a destination into a navigation system, and almost all of the systems reviewed support at least 5 different methods, with street address, point of interest, and address book entry methods among the most prevalent. Table 7 indicates the proportion of systems sampled which support various types of destination entry methods.

Table 7 . Range of Available Destination Entry Methods and Corresponding Proportion of Systems Supporting Each Method.

Destination Entry Methods	Proportion of Systems Supporting Entry Method
Street Address	100%
Intersection	92%
Point of Interest	92%
Address Book	92%
Previous Destination	83%
City	67%
Map	67%
Freeway Entrance/Exit	42%
Town Center	17%
Phone Number	17%
Latitude/Longitude	8%

Although the number of steps or operations required to complete a destination entry task can vary depending on the method and interface, typical steps required to program a destination into a navigation system using the street address entry method include:

1. Powering up the system,
2. Accessing the guidance menu,
3. Selecting the destination entry method,
4. Entering or selecting the state,
5. Entering or selecting the city,
6. Entering or selecting the street name,
7. Entering or selecting the street number,
8. Selecting routing options, and
9. Confirming the route.

Our review documented the number of steps and key presses required to complete destination entry interactions using three basic destination entry methods: street address (100 Main Street, Rockville, MD), point of interest (Starbucks Coffee), and address book (select a previously entered destination). All interactions were completed starting with the system in its off state, and the process documented the necessary number of key presses (both minimum and maximum) required to complete the task assuming error-free performance. Realistically, errors while completing these types of interactions may occur, and evidence with novice users suggests that errors during destination entry while driving are common and can add several keystrokes (Chiang, Brooks, and Weir, 2001). Thus, our analysis of the number of keystrokes or button presses required to complete typical destination entry task should be considered a conservative estimate. Since any given input method tended to have shortcuts (e.g., use of default values, quick-spell, etc.) our inventory noted both the minimum and maximum number of key presses for each method.

Figure 13 illustrates the mean minimum and maximum number of button presses required to program a destination across all systems for each of three methods. As a group, destination entry tasks in our sample of navigation systems averaged from as few as 6 keystrokes to nearly 33 keystrokes. Individual systems with the fewest keystrokes in our sample required 3-4 keystrokes, and those with the longest required upwards of 50 button presses. In general, destination entry via address book required the least number of button presses, while entry using street address tended to require the most button presses. Compared to street address entry, for example, selecting a destination via an address book required half as many key/button presses under the best of circumstances. Differences in the number of steps or operations across methods accounted for differences in the observed number of key/button presses; as the number of steps increased, so too did the number of key presses. Destination entry using the address book to select a previously entered destination tended to have the fewest number of steps (averaging 4-5), while both POI and street address required drivers to complete an average of 6-8 operations.

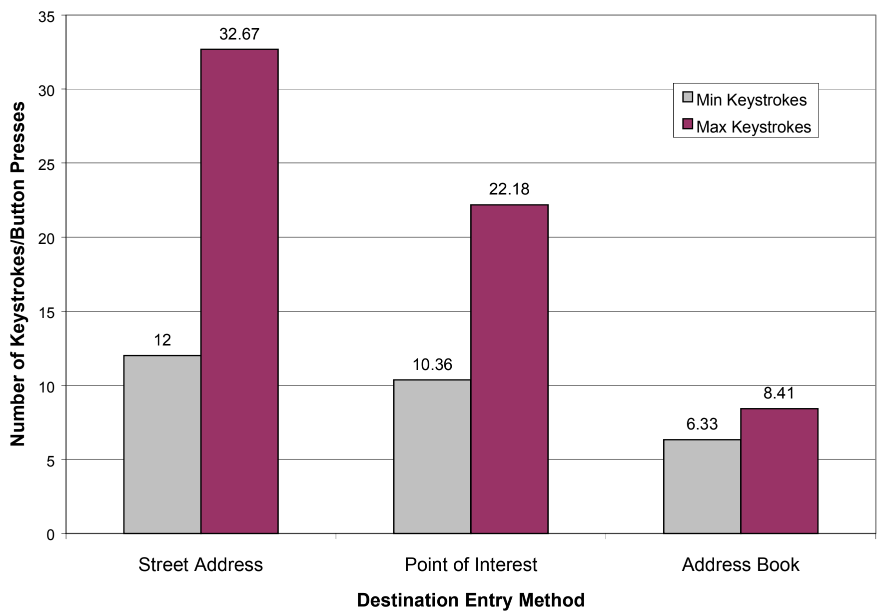


Figure 13. Navigation System Destination Entry: Mean Minimum and Maximum Key/Button Presses As a Function of Destination Entry Method

There were no substantial differences between OEM and aftermarket systems in terms of the minimum or maximum number of button presses required to program a destination (Mean maximum keystrokes for OEM's and aftermarket systems were 19.06 and 22.55, respectively. Mean minimum keystrokes for OEM's and aftermarket systems were 9.06 and 9.90, respectively). Type of interface did appear to have a significant impact on the number of key/button presses required to complete a destination entry task. Specifically, touch screen displays required substantially fewer interactions than non-touch screen interfaces, averaging between 3 and 6 fewer keystrokes (mean minimum of 6.85 for touch screen input and 11 for non-touch screens; mean maximum of 16.14 for touch screen input and 23.39 for non-touch screens). Figure 14 depicts the mean number of maximum keystrokes for touch screen and non-touch screen systems across each of the three destination entry methods. In all cases, fewer button presses are required with touch screen inputs; in the case of street address entry an average of 14 fewer button presses. The advantage of the touch screen is that it eliminates the need to both highlight and select menu items, essentially reducing a two-step procedure to a single operation. Minimizing the number of necessary button/key presses is important since it likely decreases task completion times and opportunities for errors. Touchscreen displays do, however, tend to have some disadvantages such as lack of tactile feedback and high visual demand needed to locate virtual controls.

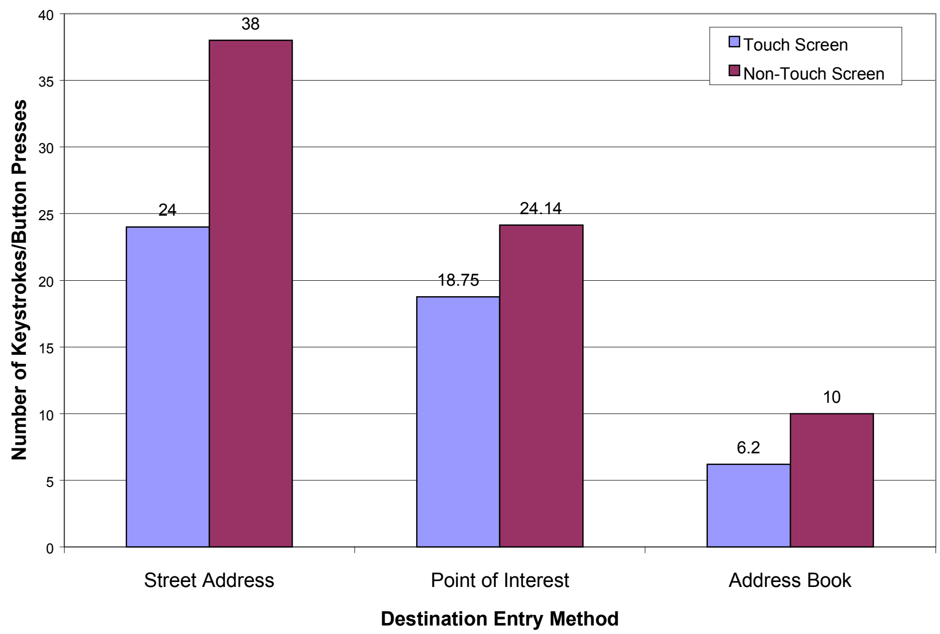


Figure 14. Mean Maximum Keystrokes/Button Presses As a Function of Touch Screen Versus Non-Touch Screen Systems

Icons/Symbols

Current research sponsored by the U.S. Federal Highway Administration (FHWA) is attempting to provide in-vehicle product designers with design guidelines for the development and evaluation of in-vehicle display icons. Early work in this area suggests that the process of developing and choosing icons is very subjective with no defined or systematic standards in place to drive their development or selection. As a result, multiple icons for the same messages are common (Carney, Campbell, and Mitchell, 1998). This practice appears evident with respect to the design and selection of icons and symbols for navigation systems.

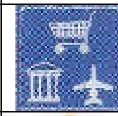
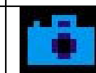
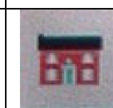
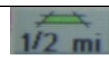
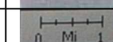
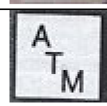
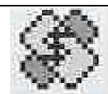
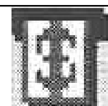
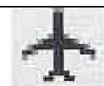
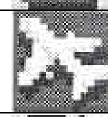
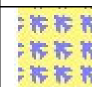
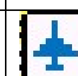
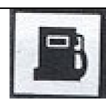
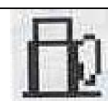
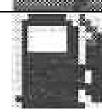
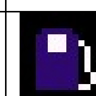
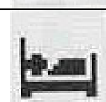
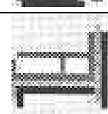
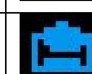
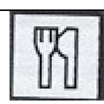
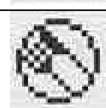
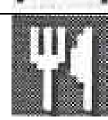
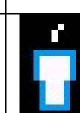
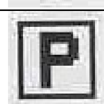
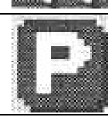
Although the number and type of icons used varied, all navigation systems employed some form of visual icons and/or symbols. Icons were used for a variety of purposes: as menu items associated with text (address, point of interest, previous destination), map-based representation to denote landmarks and roadways, and to denote system status information (GPS reception/signal, availability of system features, etc.). Common uses for Icons/Symbols encountered in our set of reviewed navigation systems included, among others, the following representations:

- Vehicle Icon
- GPS Indicator
- Warning/Caution
- Origin & Destination
- Heading
- Turn Direction
- Audio/Speech Command Function Availability
- Destination Entry Methods (Address Book, Street Address, Point of Interest, Intersection)
- Map Scale
- Points of Interest (Gasoline Station, Hotel, Food, etc.)

Table 8 presents some of the icons and symbols used across the various systems examined. Vehicle icons, GPS availability, destination markers, heading, and turn direction arrows were among the most frequently or consistently visually represented items. The Honda Odyssey navigation system used very few icons/symbols, limiting their use to map displays to denote landmarks such as gasoline stations, restaurants and automated teller machines. Some systems such as the Hertz NeverLost, Alpine, and Lexus provided icons on menu selections (with accompanying text) to further distinguish menu items. The most prevalent use of icons, however, was on map displays. Some systems, such as the Infinity, included a library of Icons from which drivers could select to denote different items (this system also used slightly different icon versions for the planview and birdview displays.)

Table 8. Common Icon Representations Used in Navigation Systems

Icon Type		Honda	Infinity	Lexus	Mercedes	Alpine	Hertz	Visteon	Destinator	Garmin	Pocket CoPilot
Vehicle Icon											
GPS Indicator				GPS		GPS		GPS	GPS 4		
Warning/Caution											
Origin											
Destination											
Heading								N			
Turn Direction											
Address Book											
Street Address											

Icon Type		Honda	Infinity	Lexus	Mercedes	Alpine	Hertz	Visteon	Destinator	Garmin	Pocket CoPilot
Point of Interest											
Intersection											
Previous Destination											
Home Address											
Map Scale											
ATM											
Airport											
Gasoline Station											
Hotel											
Food											
Parking Lot											

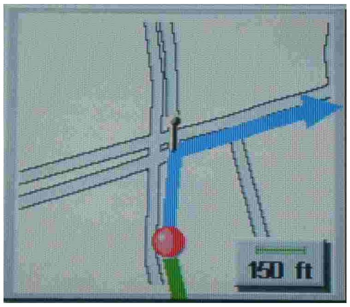
Summary of Navigation System Findings

All of the navigation systems inventoried included some form of visual display, some retractable. The location, size, and quality of these displays tended to conform to accepted human factors practices, but considerable variation exists, particularly for aftermarket systems. PDA-based systems possessed among the smallest displays yet tended to present the most information. In general, no standard configuration for displaying screen elements or for organizing screen items was apparent. The number of physical controls present on our sample of navigation system is not out of line with conventional radio controls, averaging slightly over eleven. OEM systems generally possessed fewer controls compared to aftermarket devices; 40% of our sampled OEM systems contained more than 10 controls, compared to 62% of aftermaket systems. The physical characteristics of the controls (layout, size, labeling, spacing, etc.) also appeared to conform to good human factors practices.

Most systems include a scalable map depicting streets, roadway networks, street names, and other information elements (e.g., landmark icons, highlighted routes, vehicle position indicator, etc.). Since most maps tend to include moving elements (particularly if set to represent “North-Up”), they may tend to attract attention away from the road. Although most systems do provide alternative views (maneuver lists, voice guidance, split-views, etc), map views tend to be the default and will remain active unless drivers change or modify this option. Changing the default view may be a challenge for casual users such as those using a system in a rental car. Often system manuals do not accompany rented vehicles and information or instruction for changing system views or defaults are not easily accessible or available to drivers in rental vehicles. Some systems allowed drivers to access maneuver lists, but the system would automatically return to the map view after a short period of time (temporarily change the view from map to turn list).

Navigation systems all tended to provide large amounts of information, particularly map display screens, which included a variety of graphics, icons, and text-based elements. Many turn-by-turn screens went beyond essential information such as direction of turn, distance to turn, and street name (Means et al., 1993) and included distance to destination, current position, and other nice-to-know type of information. Although not specifically evaluated, the Palm-based Tracker navigation system, shown to the right, illustrates the potential for systems to present large amounts of information to drivers. In this case, the device even displays speed, altitude, estimated trip time, heading, waypoints, and landmark information despite the relatively small display area.

Nevertheless, some systems took advantage of perceptual principles and integrated information elements leading to unified object displays. The Infinity's turn-by-turn display, for example, integrates turn direction and distance information (along with site geometry) in their graphics display by using a moving vehicle icon as part of the turn arrow itself rather than using a separate countdown bar and turn arrow. This design may allow drivers to extract information in less time, and may result in more meaningful distance information (some drivers may not be able to translate or picture what a turn in 250ft means, but it becomes immediately apparent and usable when integrated in this manner). Thus, it may be possible to increase the number of information items presented on a display, without sacrificing performance (and even increase its utility) as long as the information is integrated and perceived as a whole. As a consequence, focusing merely on the number of displayed items may be misleading; the manner in which information is packaged should also be considered when evaluating system designs.



Despite current human factors guidelines, several OEM and many aftermarket navigation systems do not restrict or lockout complex tasks (i.e., destination entry) when the vehicle is moving. All warn the driver against attempting to interact with the device while driving, but few actually physically restrict access to demanding functions when the vehicle is in motion. Nevertheless, many system do incorporate features that may minimize glance times to displays (and eyes-off-road time) and manage information flow such as limiting the number of available menu options or rows of items on a display, and use of auditory outputs for routing information and system feedback. Systems also provide a wide variety of destination entry input methods, some requiring only several keystroke to execute.

Devices incorporate a relatively large number of features and options for configuring displayed information and executing tasks. As a consequence, manuals were voluminous, ranging from 41 to 145 pages, with most systems averaging about 80 pages. Given that some drivers may not read lengthy and detailed manuals, many systems include a separate abbreviated "quick start" guide or set of directions for executing common tasks. Although systems can be configured in a variety of ways, it would be beneficial for designers to package systems so initial defaults are consistent with driver tasks and needs. The use of "pop-up" turn-by-turn displays that automatically present routing information to drivers is a positive example of this strategy. One common practice which may not be widely accepted by drivers, however, is the use of map displays as the default screen during en-route navigation. This presents a number of concerns including the fact that they tend to include large amounts of information and dynamic elements. Map displays also may not be readily used or understood by a significant percentage of the population (i.e., people with poor spatial abilities). Some drivers may be motivated and willing to change default options (such as turning off the visual display or defaulting to turn lists), but others may not take the time to read manuals or instructions. Some may not even be aware that these options exist. From the perspective of the user, if functions are not easily accessed or clearly referenced or mapped, then they may never be used. This reinforces the need to ensure that default displays and options are not only consistent with driver needs and tasks, but encourage safe use and practices.

COMMUNICATION, PRODUCTIVITY AND MOBILE PC SYSTEMS

Mobile communication and productivity devices have become increasingly popular in recent years, fuelled by advances in wireless technology, increased processing power, customization options, pocket-sized devices, and a growing dependence on connectivity. The Cellular Telecommunications and Internet Association estimates that as of June, 2001, there were 118 million mobile-phone users in the United States, more than 4 of every 10 Americans. As the U.S. mobile phone market reaches maturity, the future growth of the mobile industry is likely to depend, in large part, on multifunctional devices that possess a number of features such as communication (voice and text), Internet access, time management tools, and personal computing.

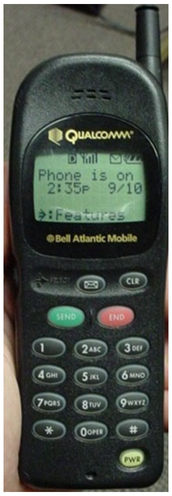
Though mobile devices have the potential to increase personal productivity, these products also have the potential for distraction if used while driving. The use of mobile phones while driving has become a controversial topic. Many recent studies, both epidemiological and experimental, have cited the use of a mobile phone while driving as a significant contributor to driver distraction. As a result, various state and local governments have considered banning the use of handheld mobile phones while driving. Some bans have been passed, most notably in the state of New York.

While the body of literature addressing the distraction potential of mobile phones has grown rapidly, less attention has been paid to other mobile devices such as pagers and personal digital assistants (PDA). While perhaps not as widespread as mobile phones, PDAs are likely to increase in popularity and may represent a significant source of driver distraction when used in vehicles. This section of the report identifies available mobile communication and productivity devices and inventories important device characteristics based on a sample of such devices.

Twenty-one mobile communication and productivity devices (not including truck systems) were identified in our review of available devices (see Table 9). These devices were divided into three general categories: a) mobile phones, b) e-mail and text messaging devices, and c) productivity and mobile PC devices. Many of the identified devices have numerous functions in addition to the functions by which they are identified. Accordingly, the categorization of these devices is not intended to indicate the sole function of the device. Refer to Appendix B for an overview of all identified devices. Of the available devices, seven that represented a broad range of system functions, designs, and user tasks were selected for review. Images of these devices are presented in Figure 15 and Figure 16. The reviewed devices were subjected to detailed examination using the standard inventory form. In most cases, reviews were completed following hands-on interaction with the device. For devices that were not accessible for direct interaction, information was gathered using user manuals, manufacturers' information, and online demonstrations. Each of the following sections below describes a key interface characteristic documented in the inventory. Table 10 provides a basic overview of the reviewed devices, while Table 11 presents key characteristics of the devices.

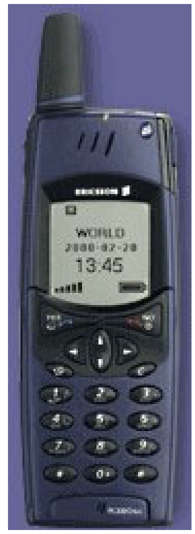
Table 9. List of Candidate Communication and Productivity Devices for Review

Voice Communication	Status
Ericsson R280LX Cellular Telephone	Reviewed
Ericsson R380s Smartphone	Reviewed
Motorola V Series 120c Phone	Reviewed
Motorola StarTAC ST7760 Phone	Described
Nokia 282 Analog Cell Phone	
QualComm QCP-820 Cellular Telephone	Reviewed
Text Communication (E-mail & Text Messaging)	
Motorola Timeport P935 Pager	Reviewed
Motient eLink Wireless E-mail	
Motorola T900 pager and e-mail	Described
Productivity & Mobile PC	
Cellport 3000	Described
Delphi Communiport	Reviewed
Ericsson Mobile Companion MC218	Described
Mobile Aria	Described
Motient MobileMAX2	Described
Motorola V100 Personal Communicator	Described
Nokia 9290 Communicator	Described
Palm m500 Handheld	Described
QualComm MVPc	Reviewed
Revolve Roadwriter	Described
Terion Mobile Messenger	Described
Valde Vehicle PC	Described

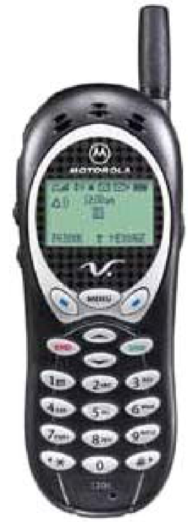


Qualcomm QCP-820

Ericsson R280 LX

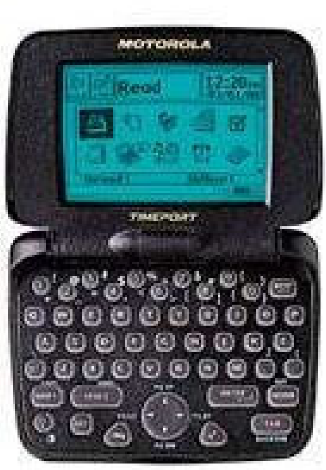


Ericsson R380



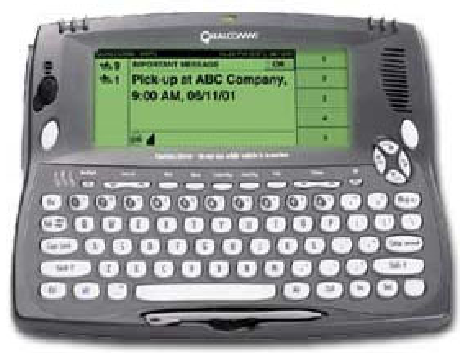
Motorola V120

Figure 15. Mobile Phones



Motorola P935

Delphi Communiport



Qualcomm MVPc

Figure 16. Other Communication Devices

Table 10 . Mobile Communication and Productivity Device Descriptions

Mobile Phones	Description
QualComm QCP-820	A relatively basic mobile phone with a phone book, recent calls list, caller ID, and voice mail
Ericsson R280LX	A phone with some advanced features such as Internet and text messaging. Features many customizable options.
Ericsson R380s Smartphone	An advanced mobile phone with added PDA functionality. With the flip closed, the device functions as a phone and is similar in operation to the R280LX model. With the flip open, the screen becomes much larger and a stylus is the primary interaction method. A number of other options become available, including e-mail, Internet, games, contact list, calendar, and notepad.
Motorola V Series 120c	A highly customizable phone with many advanced features including Internet, text messaging, voice notes, voice dialing, fax sending, FM radio, and software for 1-touch text input.
E-mail & Text Messaging	
Motorola Timeport P935	A pager with additional PDA functions. The device flips open to reveal a hard QWERTY keyboard and 9-line display. Text messages can be sent and received. Additional features include a contact list, canned responses, alarm clock, calculator, jukebox, task list, memos, and fax sending. The P935 has an interface that mimics many features of PC operating systems.
Productivity & Mobile PC	
Delphi Communiport	A device designed to cradle a PDA and a mobile phone that allows both devices to take input via voice recognition and give output using text-to-speech.
QualComm OmniTracs MVPc	A device intended for use in commercial vehicles. It performs a wide variety of functions, including route navigation/guidance, vehicle status, travel itinerary, e-mail, aid request, and trip monitoring. In addition to a large QWERTY hard keyboard, the MVPc has a touchscreen interface. The driver is not permitted to operate the device when the vehicle is in motion.

Table 11. Mobile Communication and Productivity Devices: Key Features and Specifications

	Mobile Phones				Other Communication Devices		
	Ericsson R280LX	Ericsson R380s	Qualcomm QCP-820	Motorola V120	Qualcomm MVPc	Delphi Communiport	Motorola Timeport P935
Number of Hard Controls	18	20	18	23	78	1	50
Touch Screen	No	Yes	No	No	Yes	No	No
Display Size	1.8”	1.7”	1.6”	1.4”	6.5”	N/A	3.0”
Backlit (Night/Day)	Yes	Yes	Yes	Yes	Yes	N/A	Yes
Voice Input	No	Yes	No	Yes	No	Yes	No
Voice Output	No	No	No	Yes	Yes	Yes	No
Repeat Output	N/A	N/A	N/A	No	No	Yes	N/A
Locks Out Functions While Driving	No	No	No	No	Optional	No	No
Phone Book/Contact List	Yes	Yes	Yes	Yes		Yes	Yes
Dynamic Elements	No	No	No	Yes	Yes	No	No
Flip-Open	No	Yes	No	No	No	No	Yes
Position in Vehicle	Handheld	Handheld	Handheld	Handheld	Dash Mount	Windshield Mount	Handheld
Hands-Free Operation	Kit sold separately	Kit sold separately	Kit sold separately	Kit sold separately	No	Yes	No
Auto Answer	Yes	Yes	No	Yes		Yes	No
Speed Dial	Yes	Yes	Yes	Yes		No	N/A
Text Messaging/E-mail	Yes	Yes	No	Yes	Yes	Yes	Yes
WAP Microbrowser	Yes	Yes	No	Yes		No	No
Min/Max Keystrokes	3/9	3/9	3/9	2/9		1/1	16/24
Max Number Items In Menu	10	5	7	6		14	4
Max Depth of Menus	6	6	4	8		7	10
Rows in Scrolling List	4	4	3	2		N/A	9

Interface Characteristics

Hard Controls

Figure 17 displays the hard controls of the four reviewed mobile phones. The mobile phones were very similar across a number of interface features. The number of hard controls present on each phone ranged from 18 – 23. All phones featured a standard push button numeric pad and “Send” and “End” (or “Yes” and “No”) buttons. All four phones also had controls to scroll on-screen information. The Motorola V120, the Ericsson R280LX, and the Ericsson R380 all possess up and down scroll buttons on the face of the phone. The Ericsson R380 also has left and right scroll buttons.

The Qualcomm QCP-820 uses a thumb wheel rather than push buttons to scroll through lists. The use of a thumb wheel allows very fast scrolling and the wheel’s location on the side of the phone reduces visual clutter. However, the wheel may be difficult to manipulate precisely. The wheel also has a dual function as a push button. This is a convenience because the wheel and the push button are often used in conjunction, but it is possible to accidentally operate the unintended function (e.g., rotate the thumb wheel while attempting to press the button).

A feature unique to the Motorola V120 is a pair of hot keys that have varying functions depending on the active visual screen. The active function is printed above each key. Generally, the hot key to the right of center functions as an “Enter” or “Select” command while the hot key to the left of center functions as an “Exit” or “Back” command. In many other mobile phones, the “SEND” and “END” keys perform a similar function. The Ericsson R280LX, for example, has the active function of the “SEND” and “END” keys listed above them. The use of hotkeys simplifies the menu navigation process by limiting the number of different keys that must be used. It is important, however, for each key’s function to be consistent across screens. For example, one key should always be used to progress or go a level deeper into a menu while the other should be used to cancel or move a level up in a menu.

Qualcomm QCP-820 Ericsson R280 LX Ericsson R380 Motorola V120

Figure 17. Hard Controls for Mobile Phones

The Ericsson R380 is unique among the reviewed mobile phones because when the cover is opened, the phone essentially becomes a PDA and the interface changes to stylus operation. With a larger screen to work with, icons are presented along with text labels and touchscreen elements are the only controls necessary to complete all tasks. Calls can be received and the phone can be dialed using the stylus. While the stylus operation allows a space-efficient design and fewer hard controls, completing tasks with the stylus generally requires two hands and a stable environment to make accurate selections on the small screen. Such tasks would be very demanding and difficult to complete in a moving vehicle.

The three other communication and productivity devices (Motorola Timeport, Delphi Comminuport, and Qualcomm MVPc) perform a wide variety of functions. This variety is reflected in the differences in device interfaces and features. The Motorola Timeport is primarily intended to be a pager and text messenger, though like the Ericsson R380 mobile phone, it has a number of PDA features as well. Although entering paragraphs of text can be an involved and time-consuming process, the Timeport has an address book and prefabricated messages to make the task simpler.

Unlike the majority of communication devices, the Motorola Timeport and Qualcomm MVPc utilize a QWERTY hard keyboard as the primary method of interaction. This allows quick text entry relative to devices in which the user must scan an on-screen cursor over each letter to select it. Although a QWERTY hard keyboard adds a large number of controls to these devices, most users are familiar with the keyboard layout and should be able to interact effectively with minimal searching for controls. A major difference between these two systems is that the Qualcomm MVPc is intended for in-vehicle use whereas the Motorola Timeport is not. Accordingly, the MVPc has a large keyboard and a mounting position convenient for the driver's use. The Timeport has a much smaller keyboard and no vehicle mounting hardware.

The Delphi Communiport is unique because it only has a single control. Since the purpose of the device is to operate a mobile phone and a PDA hands-free, it only has one hard control that is used to prepare the device to receive a voice prompt. The Communiport accepts 58 voice commands. To make interaction easier, the device accepts multiple phrases for some commands. If a verbal command is not received within 5 seconds of a prompt, the device will list the available voice commands. Additionally, the user may verbally request a list of available options. The Communiport allows access to most cell phone and PDA features; it does not limit the user to dialing or receiving calls.

Motorola P935

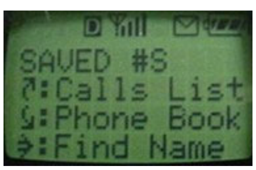
Qualcomm MVPc

Figure 18. Hard Controls for Other Communication Devices

Visual Display

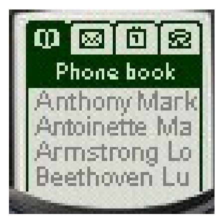
Generally, the visual displays of the four reviewed mobile phones were similar. See Figure 19 for sample display screens. The screen sizes ranged from 1.4 inches to 1.8 inches (diagonal) with a mean size of about 1.6 inches. When the flip of the Ericsson R380 is opened the screen size is enlarged to 3.5 inches. All four phones have graphic monochrome LED displays with backlighting. Display quality is low compared to the majority of navigation systems, but sufficient considering the type of information presented. Virtually all information on a mobile phone display can be presented using text and simple icons.

Character height and width were also similar across phones. Character height for uppercase letters varied between 3 and 4 millimeters and character width for uppercase letters varied between 2 and 3 millimeters. The Qualcomm QCP-820 displayed 12 characters per row. Both Ericsson phones are capable of displaying 14 characters per row. The Motorola V120 displayed 17 characters per row, the most of the four reviewed phones. The Ericsson R380 is capable of displaying 34 characters per row when the flip is opened. The limited amount of screen space also affects the number of rows of information that can be presented. All of the reviewed phones have either 5 or 6 rows of information. Some of these rows are dedicated to phone status icons, hotkey functions, and title bars. This leaves little room for items on a menu. Scrolling menus contained between 2 and 4 rows of information. With fewer menu items visible at a time, a target menu item may take more time to locate.

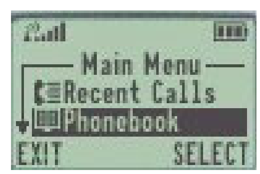


Qualcomm QCP-820


Ericsson R280 LX



Ericsson R380



Motorola V120

Figure 19. Sample Display Screens for Mobile Phones

Hands-Free Functionality

All four reviewed mobile phones have hands-free kits that must be purchased separately. The price of these kits ranges from approximately $20 to $150. The premium hands-free car kit sold by Motorola for the V120 is the Professional Hands-Free Car Kit model S9565 that retails for $129.99. This kit includes voice dialing, noise and echo reduction, high quality speaker, and mutes other audio outputs when a call is incoming and in progress (with compatible radios). Ericsson offers a similar kit for the R380. Most car hands-free kits include mounting hardware for the phone, power supply, one-touch or auto-answer for incoming calls and an earpiece or speaker. Premium features may include phone activation and dialing by voice recognition and radio muting. The Delphi Communiport essentially functions as a hands-free car kit with added functionality including menu navigation, text-to-speech output, PDA voice interaction, and synchronization between the two devices.

ENTERTAINMENT SYSTEMS

Although the concept of in-vehicle entertainment is not new, rear-seat infotainment systems featuring video, game portals, and computer access is a recent introduction to the automotive market. General Motors led the OEMs with the introduction of their rear-seat entertainment system, first launched onto the market in 1998 with its Oldsmobile Silhouette Premier minivan. Sales exceeded expectations with almost 12,000 units sold during the first year. Since that time, infotainment systems have become increasing popular (particularly with the minivan and SUV market), with more and more automobile manufacturers offering these systems as factory-installed options. Aftermarket suppliers have also introduced a wide range of infotainment systems available to consumers. Our review exclusively focused on video-based, rear-seat entertainment systems, as opposed to audio systems, with limited discussion devoted to front-seat entertainment systems. Table 12 provides a list of the systems identified in our review; system thumbnail descriptions for many of these devices are provided in Appendix B.

Table 12. List of Available Rear-Seat Entertainment Systems

Entertainment Devices	Status
Audiovox Video in a Bag	Described
Chevy Venture Warner Brothers Edition (Video System)	
Delphi Communiport Seat-top Rear Seat Entertainment System	
Ford Autovision	
Honda Odyssey Back Seat Theater	Reviewed
Johnson Controls AutoVision Rear Seat Entertainment System	Described
Steel Horse Universal Fit Entertainment Console	Described
Visteon Rear Seat Entertainment System	Described

Rear-seat entertainment systems offer a wide array of entertainment options including video cassette players, DVD, music CD, TV tuners, standard radio, and plug-in-play interface ports for game systems such as Nintendo 64, Sega, or Sony PlayStation. Systems generally include a basic control unit (housing the player, etc), an LCD flat-screen monitor, infra-red remote control unit, and headphones. As illustrated in Figure 20, three basic configurations exist: (1) systems which attach to a seat-back, (2) systems which are mounted on the floor console, and (3) systems which are integrated into the vehicle's headliner. Portable and retrofit models are also available; these typically come equipped with power jacks that plug into the vehicle's cigarette lighter or power receptacle. Some systems are integrated, "all-in-one" display and control units, while others locate the main control console separately from the display unit. In most systems, audio is presented via the vehicle speaker system, with the capability to plug-in headphones for privacy thereby eliminating potential driver distraction from the audio. Many provide the capability for front-seat occupants to listen to music, while rear-seat passengers watch videos or play games.

Figure 20. Different Rear-Seat Entertainment System Configurations

Although most in-vehicle video entertainment systems are marketed (and intended) as rear-seat entertainment systems, they are not necessarily devoid of interactions by front seat occupants, including the driver. Some rear-seat entertainment system configurations, for example, may position the main control unit in locations which restrict access by rear seat passengers requiring some interactions to be completed by the driver or front-seat passenger. The Honda Odyssey in-vehicle entertainment system, shown to the right, illustrates this point. In this case, the console housing the cassette player is mounted in the driver compartment on the floor below the center stack. Although the system does include a wireless remote control for use by rear-seat occupants, tapes must be inserted and ejected by front-seat occupants. The volume control is also only accessed using the main console. The remote only functions in the rear compartment (where the receiver is located), eliminating the need for drivers to search for and use the remote. The users' manual warns dealers against installing the system so the display is within the driver's view, but does not caution drivers against operating the unit (e.g., inserting or ejecting tapes) while driving. An integrated storage compartment for videos is also included which may reduce the need for drivers to search for tapes. However, the compartment only holds two tapes.

Another interesting, but subtle consequence resulting from the location of Honda's system is the fact that one of the vehicle's primary front-seat cup holders is positioned directly over the main control console. Indeed, the Video Cassette Player (VCP) unit is enclosed with a cover which is referred to as the "VCP console spill cover," specifically designed to guard against spilling liquids onto the VCP equipment. Aside from the obvious problem associated with spilling liquids onto the VCP equipment, when extended the cup holder unit blocks access to VCP equipment. This may create situations where drivers may need to remove drinks from the cup holder in order to access the control unit (i.e., insert or eject tapes) – leading to potentially awkward and unnecessary actions.

By occupying children, rear-seat entertainment systems do have the potential to minimize distraction associated with interactions with other vehicle occupants – one category of distraction which may contribute to a large proportion of crashes (Stutts, et al., 2001). Systems requiring interactions by the driver, however, may offset this benefit and contribute to increased crash risk through actions such as reaching and searching for videotapes. Usage patterns can also have a large influence on how these systems will impact safety. Manufacturers, for example, recommend operating systems only when the vehicle is running to avoid draining the battery. This may encourage some users to operate the system only after embarking on a trip.

There are also a host of in-vehicle entertainment systems that feature in-dash display units providing text and graphics information related to the operation of the audio system. Some manufacturers provide DVD capable units with retractable displays. Pioneer's AVX-P7000CD (shown below) has a detachable face and includes a single CD player and a 7-inch motorized wide screen color LCD display that pops out and flips up for front passenger viewing.

MULTIFUNCTION SYSTEMS

Integrated systems that offer control over communications, entertainment, navigation, and convenience functions are starting to emerge in the market place. Some of the navigation systems reviewed as part of this effort were integrated with climate controls, radio/audio system, vehicle diagnostics, cell phone, and even collision warning systems. A host of new products are expected to be released shortly offering a much greater range of integrated functions. Many feature speech interfaces with both text-to-speech and voice recognition capabilities, providing hands-free operation, and access to the Internet, e-mail, emergency services, wireless voice communications, and navigation, among other services. Table 13 provides a list of some of the systems identified in our review; many are prototype systems or not currently available and therefore are only briefly described.

Table 13. List of Multi-Function Devices

Multi-Function (Integrated) Devices	Status
Joyride, Clarion	Described
Communiport Infotainment PC (Delphi Automotive Systems)	Described
CAA CarPC	Described
Ford Rescu	
Harmony Generation 1 (Johnson Controls)	Described
Motorola iRadio Telematics System	Described
Mercedes-Benz TeleAid	
Onstar, GM	Described
Visteon ICES (Information, Communication, Entertainment, Safety & Security System)	Described

Perhaps one of the most popular and growing multi-functional Telematics systems currently available is represented by wireless communication services such as GM's Onstar, Ford's Rescu, and Mercedes-Benz' TeleAid , and other like systems. GM's OnStar, for example, has attracted over 300,000 subscribers and is currently a standard feature on all 2001 Cadillacs (and offered on most Buick, Chevrolet, GMC, Oldsmobile, Pontiac and SAAB models). Initially introduced as offering safety and security services, these systems have expanded to include off-board navigation functions, convenience features, and concierge services. OnStar, for instance, offers subscribers different plans providing not only emergency services and remote vehicle diagnostics and conveniences like remote door unlock, but routing support and concierge services (make reservations, purchase tickets, etc.) – all with real-time communications to a live operator. With the introduction of their Virtual Advisor, OnStar is planning to offer subscribers personalized, real-time traffic and road condition reports, and Internet access using speech technology.

OnStar's interface is simple, featuring a three-button control unit (with LEDs) located on the instrument panel, rearview mirror, or overhead. Each button performs a different function: (1) answer or terminate a call, (2) initiate a call to an Onstar advisor, and (3) notify OnStar in the event of an emergency.

More traditional in-vehicle systems are being introduced which provide access to a similar range of services integrating cell phone, navigation systems, entertainment, and Internet access. These devices include Visteon's ICES system, Delphi Automotive's Communiport Infotainment PC, and Motorola's iRadio Telematics system.

Visteon's ICES features voice technology that enables drivers to place phone calls, adjust radio and climate controls, and enter navigation system destinations via simple spoken commands (in a naturalistic style and syntax). The Windows CE-based system includes 22 hard controls, with both dedicated and programmable (application specific) controls, a large display area, and steering-wheel mounted controls which can be used to activate the speech system. The Internet can also be accessed, providing real-time new, stocks, weather, and sports. The system is not currently available, but is expected to be released in 2002.

The Communiport Infotainment PC is a Windows CE-based device with a nearly 6" diagonal reconfigurable color display offering integrated phone, e-mail and Internet access, entertainment (audio and movies), vehicle diagnostics, weather, and navigation functions. The device is targeted at OEM's as opposed to the aftermarket, allowing the system to be more readily integrated with other vehicle controls and functions. One feature of this device is that it can read e-mail stored on a PDA using text-to-speech technology, allowing drivers to listen, rather than read. Some prototype versions include steering-wheel mounted controls with touchscreen softkeys, minimizing the number of hard controls on the main unit. Another feature of the system is that it uses Wireless Application Protocol and Bluetooth universal connectivity. This allows other devices such as cell-phones and PDAs to be operated without physically connecting the devices to the unit.

Motorola's iRadio Telematics System features entertainment, navigation, personalized web page (with news, sports, weather, stocks, etc.), an integrated hands-free phone, and safety and security features (road-side assist and emergency). Voice recognition and text-to-speech technologies are used to minimize driver distraction. The product is undergoing consumer product testing, and is not currently available.

COMMERCIAL VEHICLE SYSTEMS

An array of fleet management devices, tools and software is available on the market including: Automatic Vehicle Location (AVL) systems, radio, voice and data messaging and communications devices, trip and data log recorders, and vehicle status monitoring systems. Although most fleet management systems generally provide dispatchers and back-office staff with more complex interfaces and software tools, they also include on-board (i.e., in-cab) devices to communicate with drivers. In additional to the large variety of aftermarket devices and systems, many OEM truck manufacturers are equipping cabs with on-board vehicle diagnostic displays providing engine and vehicle performance data to drivers. Table 14 lists many of the systems identified in our review. Three systems were inventoried, and others are described in Appendix B. Since these types of devices are intended for use by professional drivers, many of whom may work for large fleets, the opportunity for training on the use and operation of these systems may be substantially increased relative to passenger vehicle systems.

Table 14. List of Candidate Commercial Vehicle Systems for Review

Commercial Vehicle Systems	Status
CABIT	Described
Fleet Advisor from Qualcomm (formerly Eaton)	Described
Freightliner Driver Message Center	Described
Freightliner Truck Productivity Computer	**Reviewed**
Global Messenger from Global Data Communications	Described
HighwayMaster Series 5000, HighwayMaster Corp.	Described
Mac Truck, VIP	**Reviewed**
Mobius TTS Onboard Computer (from CADEC)	Described
Monitrux by TruckScribers	Described
Motient Mobile Max	Described
Qualcomm, MVPc,	**Reviewed**
PeopleNet Wireless Fleet Solutions	Described
Terion, Mobile Messenger	Described
Tripmaster Routes	Described
XATA Driver Information System	Described

Freightliner Truck Productivity Computer

This system is analogous in concept to the AutoPC, and integrates multiple functions into a single common interface unit. Functions can include: audio entertainment, wireless communications, navigation truck productivity programs, as well as other third party software applications. Several design elements have been integrated into the concept in order to reduce distraction; these include, among others:

- Limited access to information displays while driving (control the flow of information)
- Voice interface (automatic speech recognition and text-to-speech)
- Integration of functions within a single common interface framework
- Dedicated hard controls for frequently accessed functions
- System status and control input feedback in both visual and auditory forms
- Shallow menu structure

The system features Automatic Speech Recognition (ASR) and text-to-speech technologies. The ASR system is activated through a push-to-talk button in order to increase system reliability. When activated, the text-to-speech system will "read" displayed information and present it over the truck speakers. Drivers have access to available speech commands at all times, and a visual status symbol is displayed to indicate the availability of the text-to-speech system. The bright and high contrast electroluminescent monochrome display (320 x 80 pixel) is designed to be easily to read and viewed across a range of lighting conditions. The unit's 18 soft control keys are shape coded and designed to allow for easy operation with a gloved hand – not an uncommon driver practice in the trucking environment. Controls provide sufficient spacing for this purpose with keys spaced between 18-21 mm (between key center-points). Controls include dedicated program access keys which provide quick access to critical or frequently used programs; state dependent keys whose functions vary based on the particular program or application; and fixed function controls such as power, volume, back and eject buttons. The system is also designed to minimize, visual and cognitive load, by controlling the flow of information to drivers. Some programs, for example, can not be accessed while driving; only accessible programs are displayed while driving. System feedback includes simple confirmation of inputs, audio alerts when new information is presented, as well as visual indications when processing delays greater than 1.5 seconds are encountered. The system is being developed by Freightliner LLC in conjunction with Daimler-Chrysler and is not currently available on the market.

Figure 21. Truck Productivity Computer

Mack Vehicle Information Profiler (VIP) Display

This OEM furnished system consists of an in-dash display center which provides drivers with vehicle electronics data such as fuel mileage, trip data, and fault alerts. The high-resolution 6" diagonal display (41/2" x 3 3/8") supports information in various formats including text, charts, and diagrams. The system features 10 lighted, dual-function pushbuttons and a main menu with 9 items. Over 50 menu screens are accessible; however, drivers are provided limited access to information while the vehicle is moving (access to all 50 screens is resumed when the vehicle is stopped). No deeper than 3 menu layers are required to access information. The system also provides audible alerts to drivers, warning of potential problems (e.g., engine protection

warnings, engine and engine brake overspeed operation, idle shutdown, etc.). As illustrated in Figure 22, much of the information presented on the trip and sensor display screens is presented both graphically and in text format with precise numeric outputs. This practice tends to result in "busy" displays, but the information is well grouped and by bounding items, drivers may be able to quickly assess system status.

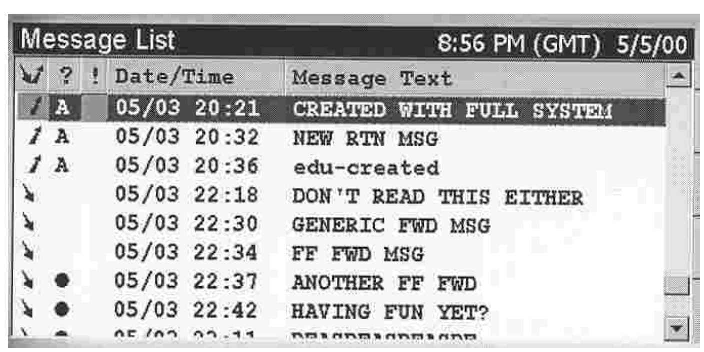
Figure 22. Sample Mac VIP Display Screens

Qualcomm MVPc

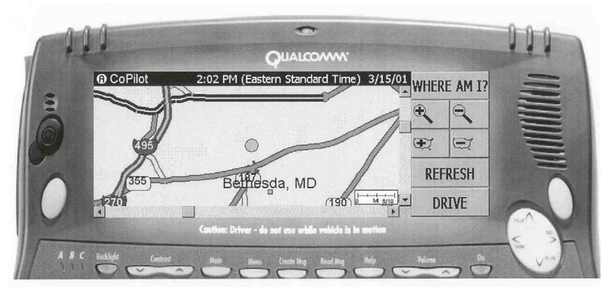
The MVPc is an in-vehicle computer that interfaces with Qualcomm software providing two-way mobile communications, satellite tracking and fleet management applications. The system is capable of running custom, third party Windows CE, Handheld PC Pro, and/or industry applications (driver logs, state fuel tax, etc.). All third-party applications must conform to internal system interface standards providing drivers with a consistent layout and functionality across all software applications. The MVPc includes an integrated 6.5" LCD touchscreen and QWERTY keypad with 24MB RAM and 16MB Flash memory; also included is a PCMCIA slot. The system comes standard with five Qualcomm applications, including a task manager that serves as the basic menu window for controlling software applications, a messaging applications for sending and receiving text messages, and a vehicle information application. These five applications can be accessed via dedicated pushbuttons located on the unit. Additional system features include:

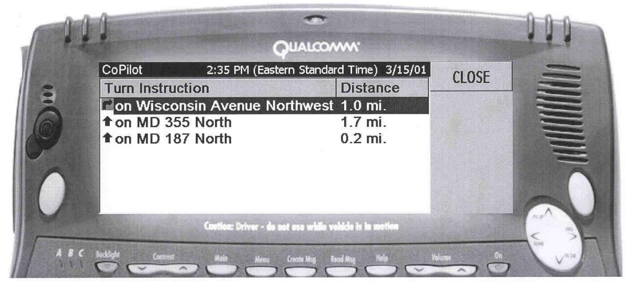
- 74 hard controls
- Monochrome display supporting graphics, icons, text, and tables
- Backlit keys and display for nighttime operation
- Auditory output
- An optional cellular phone with limited call dialing access
- Optional lockouts; the display can be configured to go blank when the vehicle is in motion; keyboard itself can be locked out when driving.
- No time-outs for messages
- Scrolling lists
- Programmable softkeys

The system is mounted in the vehicle cab using a specially designed cradle which is customized to the tractor. The display can be difficult to see off-angle, but the unit can be used by a passenger (it can also be configured for team driving). The main menu can be accessed from any screen with a single button press. The text messaging software features 38 pre-formed messages, and is capable of supporting free-form text messaging (38-41 characters per row), as well as text files. Drivers are alerted to incoming messages via an auditory beep as well as an LED on the unit which illuminates (steady burn) when a message is received; the unit also has three other LEDs which can be configured to flash if desired for other applications. Messages are presented in tabular form (much like e-mail) with the date, time, label, and status indications (incoming, outgoing, sent, read, etc.).



The navigation software, developed by TravRoute, provides the typical guidance displays found in most navigation systems: map, turn-by-turn, and maneuver lists. Turn-by-turn directions include voice prompts for upcoming turns, while the map contains limited display information (no moving elements). A unique feature of this software is that it provides information on bridge height, road weight, and turn restrictions - information relevant to commercial vehicles and extremely useful for routing. Destination entry can be accomplished via address books, points of interest, and street address entry methods. Also unique to this system is the fact that destination entry tasks can be completed by fleet dispatchers and wirelessly transferred and downloaded automatically to the MVPc, providing for minimal interaction by the driver.





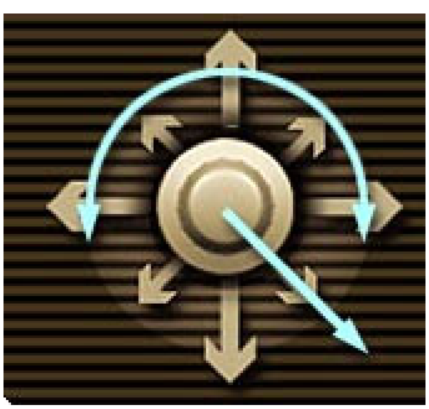
The MVPc is intended to be used by drivers when the vehicle is stationary, and the system provides some unique features intended to support this design goal, including lockouts of the display, keyboard, and specific applications. For example, MVPc can be locked (or frozen) into an application mode (e.g., navigation) when the vehicle is moving – drivers can't access other applications until the vehicle is stopped. Similarly, e-mails and other text messages can only be opened and read when the vehicle is stationary. Lockouts, however, are optional and customizable.

OTHER INDUSTRY & PRODUCT DEVELOPMENTS

The Telematics industry is dynamic with new products and partnerships continuously emerging to meet market demands. Delphi Automotive Systems and Palm, for example, have teamed to launch MobileAria, offering hands-free access to e-mail and internet features in their cars. Microsoft's Car.NET connects home, office and car by enabling information to be transferred among pagers, cellular phones, and desktop computers. It will also lockout certain functions while driving (e.g., typing or reading text messages). The system makes use of Microsoft Windows CE for Automotive 3.0 operating system. Ford and Qualcomm have collaborated in a new Telematics venture known as Wingcast. The company will develop and deliver a host of mobile communication services, including voice, entertainment, Internet access and safety services into cars and trucks, offering a hands-free, voice-activated interface inside vehicles, and via other hand-held devices while outside the vehicle. Wingcast is working with automotive OEMs to supply reference designs for the Telematics hardware interface as well as system integration for cars and trucks. Ford of Europe and Vondafone Group Pic are also partnering to provide in-vehicle Telematics services in Europe. The Focus is the first European Ford with a Telematics system featuring emergency and roadside assistance, traffic information, dynamic routing, and voice controlled services. Some new concepts and product designs are presented below; even though they represent prototype systems not currently available on the market, they provide a sense of one possible the direction the industry is heading.

BMW iDrive

Immersion and BMW have collaborated to develop the iDrive system featuring a single control dial mounted on the center console. iDrive consists of a computer that controls several hundred functions (including basic climate and stereo settings), a center-mounted LCD screen, and a console-mounted rotary pushbutton knob that works as the system's primary control. The driver slides the dial to choose between multiple control menus displayed on the in-dash LCD screen. The operating unit in the center console gives the driver direct access to many other driving functions and information and communication options.



The Controller can be moved in eight different directions, matching the eight items on the main menu. Rotating the dial moves it through menus and lists while pushing the dial axially selects a list item. All changes and selections made within the control menus are saved; each menu is presented in the same configuration as the last time it was used. The dial also returns automatically to its central position. The iDrive controller allows the driver to have instant control of every comfort element in the car, from the on-board navigation system to the air conditioner to the mobile telephone.

One unique aspect of the controller is that it provides tactile feedback, which changes depending on the currently active menu. The controller "clicks" through each item as the user scrolls through it. The manufacturers claim that the driver's sense of touch makes it possible to use the controller with minimal distraction from the road. The tactile feedback of the controller is powered by Touchsense™ technology from Immersion (www.immersion.com). Confirmation of the selected mode is displayed on a dash-mounted screen. Operating functions are also structured into three levels and prioritized on importance and frequency of use. Individual displays of the onboard computer, for example, can be configured so the most important information is in the driver's field of view in an effort to minimize distraction.

The BMW iDrive system includes a Siemens VDO Telematics link to the Internet enabling drivers to check the weather at their destination and call up addresses of destinations using a Wireless Access Protocol (WAP). Points of interest, such as hotels or restaurants, can be automatically programmed into the navigation system. The iDrive driver information system is being develop for the new BMW 7 Series.

A family of prototype systems from Johnson Controls also features large (7" diagonal) color LCD display with integrated, console-mounted knobs or steering-wheel-mounted buttons. Unlike many aftermarket devices, systems (such as Johnson Control's Harmony Infotainment) are integrated into the dashboard very early in the design process, and are engineered to be used as automotive infotainment systems. Designers claim that systems can be employed intuitively and with a minimum of distraction.

SUMMARY & CONCLUSIONS

An inventory of current in-vehicle technologies was conducted in order to measure and document the range of interface design characteristics of available Telematics devices. Aspects and dimensions that have implications for potential driver distraction were of particular interest. Information collected as part of this review will help NHTSA to identify what design features should be studied in future safety research that could help determine guidelines for equipment design and performance, as well as:

- Gauge the extent to which designers and developers are applying available guidelines and "best practices" gained through research and experience.
- Compare systems in terms of design approaches and architecture (highlighting good and poor interface design features),
- Identify areas where systems could potentially benefit from improved designs or guidance, and (where appropriate) possible safety implications of particular designs, and
- Identify industry trends and common practices in interface designs (are defacto standards emerging?)

The review was not intended to be exhaustive, but rather provide a diverse and representative range of system designs and configurations. Technology reviews were primarily limited to in-vehicle systems that are specifically designed for use in the driving environment. Portable, wireless devices which can be transported into vehicles and used while driving, but not specifically designed for this environment (e.g., cell phones, personal digital assistants) were selectively reviewed on a limited basis in order to serve as benchmark/comparison systems. The review included technologies used in passenger vehicles as well as commercial trucks, with both domestic and international systems canvassed. Reviews targeted systems that are currently available on the market. Operational aspects of the systems such as timing, processing speed, reliability, and accuracy of information were not directly assessed as part of the inventory; measurements focused on system interface characteristics as opposed to system performance characteristics.

Highlights and Key Findings

Devices tend to incorporate large numbers of features and options, as well as alternative methods for completing tasks. This characteristic was particularly evident for integrated devices, making it a potential challenge for drivers to learn all of the capabilities and features of a system. Most systems featured limited on-screen support relying on "quick start" guides, or voluminous manuals to document system features which consumers may or may not read. Formal training instructing drivers on how to operate devices was not widely available; although this aspect was not researched in-depth, commercial vehicle systems appeared to have more of an emphasis in this area.

Related to this is the amount and type of information presented to users. Navigation systems, for example, tended to provide large amounts of information, particularly map display screens, which included a variety of graphics, icons, and text-based elements. Map displays contained the most information (an average of over ten items), and generally served as the default guidance display (the one drivers would see first when operating the system). Some devices provided visually complex displays by redundantly coding information. The Mac VIP, for example, provided graphs and analog data together on the display. Because of their relatively small display areas, PDAs and cell phones pose particular problems. The amount of information presented on a display also contributed to the quality of the display, impacting font size, as well as the number of rows or information elements displayed in a single screen. Older drivers, in particular, may have difficulty interacting with and reading information on small display screens (like PDA-based devices), because of their small character sizes, distance from the screen, and generally large amount of information.

Most of the displays were easy to read and well designed in terms of their physical characteristics allowing drivers to perceive the displayed information. PDA and other communication devices drivers may bring into the vehicles were the exception. Aftermarket devices tended to have considerably more variation in their design and interface characteristics than comparable factory installed systems. As a group, OEM supplied navigation systems, for example, tended to have fewer controls, larger displays, and audio outputs which were integrated into the vehicle's exiting sound system providing for the option to mute stereo outputs when issuing navigation commands.

The majority of system displays were located in the center stack area of the vehicle cockpit where conventional radio and HVAC controls are traditionally found. A few systems located displays near the top of the dash closer to the driver's line of sight – a design which is consistent with existing guidelines. While this configuration may reduce the transition time needed to glance at the display, it may also create the potential for motion-induced distraction. That is, drivers may make more frequent, unguided or undirected glances at a display simply because display elements attract their attention. Map displays with moving elements pose this type of risk. Retractable in-dash display units also appear to be increasing in popularity – these were found among navigation as well as entertainment systems. All systems allowed displays to be easily viewed by a front seat passenger with controls accessible to allow interaction by passengers as well as the driver.

Despite human factors guidelines, several OEM and many aftermarket navigation systems do not restrict or lockout complex tasks (i.e., destination entry) when the vehicle is moving. All warn the driver against attempting to interact with the device while driving, but few actually physically restrict access to demanding functions when the vehicle is in motion. Nevertheless, many system do incorporate features that may minimize glance times to displays (and eyes-off-road time) and manage information flow, such as limiting the number of available menu options or rows of items on a display, and use of auditory outputs for routing information and system feedback. Systems also provide a wide variety of destination entry input methods; some requiring only several keystrokes to execute. Some system designs may encourage or facilitate the execution of complex and demanding tasks while driving. Systems that offer auditory feedback during data entry, for example, may allow drivers to keep their eyes on the road while manually interacting with the system (drivers can rely on the auditory feedback alone.) The Hertz NeverLost navigation system featured this type of design.

Trends & Common Practices in Interface Designs

One underlying design goal which appears to be emerging is to have fewer in-cab knobs, dials, switches, and buttons (simplify existing controls). Our sample suggests this design trend has not yet widely emerged into the marketplace (although many systems used a single dual control to execute many operations), but future system concepts and some prototype systems have embraced this philosophy. BMW's iDrive approach allows drivers to navigate through multiple displays using a mutlicontroller mounted centrally. The controller also features haptic feedback which designers argue can be used to distinguish among operations and functions. Research is needed to determine whether tactile feedback functions as an aid (enhancement) or a distraction to the driver.

Integration has been a common research theme and topic over the past several years, and there appears to be a general trend towards devices which integrate information, communication and entertainment functions in a single system. Integration takes different forms. At the most basic level, systems in our sample tended to demonstrate physical integration of displays and controls, as well as integration of functions within a system. Many Telematics devices, both present and future, may integrate functions sharing a common display while allowing drivers to control a variety of functions. Johnson Control's Harmony and BMW's iDrive are two examples. Cell phones are also transforming themselves into multi-functional devices, incorporating text messaging and e-mail features. These devices also provide access to a variety of services which can be accessed while driving through voice recognition technology, and provide weather, news and sports information.

The following features and characteristics were frequently noted in our sample of Telematics devices, and while they may not necessarily constitute industry "trends," they point to areas of "common" practice:

<u>Displays</u>

- Systems generally used color displays.
- Many systems reduced the usable display area by including header and footer information; thus, not all of the available display area was necessarily used to present information.
- There was no apparent standard configuration for displaying screen elements or for organizing on-screen items/controls for data entry. Consistency was not generally an issue within a given system, but no common framework emerged across manufacturers.
- No uniform or consistent pattern was observed in terms of how displays are organized. Data entry/inputs screens, for example, incorporated a wide variety of configurations and methods for spatially representing and organizing character sets. Maneuver lists displays also showed some variance in how they sequenced or ordered items with both top-down and bottom-up alternatives represented.
- The ability to display split-screen views was also a common feature in many navigation systems.
- Turn-by-turn displays were common in navigation systems; these also tended to present redundant audio instruction announcing the upcoming maneuver eliminating the need to glance at visual displays.
- No standard icons/graphics emerged; warning messages and vehicle position icons were generally more consistent in nature than other graphics.

<u>Controls</u>

- Most systems possessed dedicated hard controls for frequently used/accessed functions (e.g., repeat system message).
- Many systems used re-configurable keys/buttons whose function change depending on the application. Some systems also combined this design with dedicated hard controls for frequently accessed or important functions.

Auditory Displays/Interactions

- Manufacturers appeared to recognize that voice commands can be distracting or annoying, and at least in some cases, exercised care in selecting or designing for the type of transactions executed using voice commands. The Lexus navigation system, for example, limited the functions that were accessible in this manner.
- Several systems used a switch to activate their voice recognition system in an attempt to increase system reliability. These systems also tended to provide both auditory and visual feedback to confirm driver inputs and availability of the speech command.
- Some systems adopt a strategy to alert drivers through auditory tones/beeps in advance of the presentation of information, and/or changes in display status. This may limit the need to for drivers to continuously monitor the system, or repeat system messages.

Safety Features

- Warnings or cautions against interacting with systems while driving were common. This may represent an attempt by manufacturers to minimize legal risk associated with the use of in-vehicle Telematics devices. Nevertheless, perhaps the best and most effective way to minimize the risk would be to disable equipment when vehicles are in operation. The industry is also relying on voice-activated equipment to minimize risk.
- Some systems limit the depth of menus or number of rows of information drivers are required to navigate in order to acquire information (e.g., Mac VIP, Infinity navigation system, etc.).
- Many systems muted or reduced the volume of the radio/CD system when issuing auditory commands/messages/alerts. At least one navigation system manufacturer perceived this feature may annoy drivers and opted for a different approach.
- The ability to remotely program systems and download information into the vehicle unit is an innovative feature which could significantly reduce driver interactions with systems. The MVPc commercial vehicle system, for example, allowed fleet dispatchers to remotely program navigation system routes and instantly transmit the data to their drivers.

Operational Characteristics

- Systems supported multiple-input methods and approaches for completing tasks. All of the reviewed navigation systems, for example, supported at least 5 different methods for programming a destination. These alternatives impact the number of operations and button/key presses required to complete tasks.
- Touchscreen displays generally required fewer interactions than non-touch screen interfaces; these displays were common to both OEM and aftermarket systems. Touchscreen displays do, however, tend to have some disadvantages such as lack of tactile feedback.
- Systems provided for operation at night or low light conditions.
- Many navigation systems do not announce the street name of the upcoming maneuver/turn, despite the potential advantage that this type of information may provide (e.g., reduce wrong turn errors).
- Time-out functions were evident in some systems. These were used to pace driver voice command inputs as well as time the duration of displayed information.

- The majority of navigation systems used map-based information as the default both during pre-trip planning and active en-route navigation. Maps tend to contain vast amounts of information, and include dynamic elements which can potentially distract drivers. Map displays also may not be readily used or understood by a significant percentage of the population.

Finally, automotive suppliers and OEMs are doing more and more to accommodate consumers as they bring laptops, PDAs, and cell phones into their vehicles. The overall safety impact of this trend remains to be seen; however, there are number of strategies that may be used to limit or minimize distraction. Complex, overly demanding functions, or tasks unrelated to driving, for example, can be locked while driving. Functions can also be partially automated thereby reducing the task demands (e.g., speed dialing), and the format of displays structured to facilitate the task. It may be feasible, therefore, to integrate these type of devices (as well as increase the functionality of existing systems) while still maintaining acceptable safety margins as long as the system or device is well designed for use in automotive applications.

Recommendations for Future Work

One of the most significant challenges in implementing safe Telematics devices is understanding driver cognitive load, and determining what elements or design features contribute to distraction. The relationship between particular system design elements or configurations and distraction is not fully understood. Some basic human factors principles and guidelines do exist which can potentially reduce or minimize distraction associated with the design of a device or system, but these tend to address higher-level principles. Moreover, the impact of a particular strategy or design on distraction may be difficult to predict; some designs may appear to reduce task complexity or restrict information flow to drivers, but in fact may have opposite or unintended effects. Additional research is needed to assess design impacts on distraction; both overall effects as well as situations under which a design element may be distracting. Research examining the safety impacts must also consider driver use patterns (frequency of use, circumstances of use, etc.), recognizing that the quality and convenience of particular features and devices may influence their use. More work is also needed to advance the state of "driver assist" type systems, which monitor workload and adjust system capabilities accordingly.

Since driver discretion and judgment are central to the distraction issue, even well designed systems are not immune to distraction induced problems. System design is only part of the distraction issue. Potential distracters of many sorts are often present, but significant distraction does not always occur. One major determinant of risk and distraction is the driver – their experience, capabilities and skills. Willingness to engage and the relationship between system design and driver experience with the system is an area which needs additional research.

Finally, this effort represents a snapshot of HMI elements and industry practices for a small set of Telematics devices at a given point in time. It provides a benchmark. Future efforts should follow-up using the same approach, and a greater sample of devices, in order to more accurately gauge industry trends.

To-date, the focus of restrictions and lock-outs has been on destination entry tasks relying on visual-manual modes. There are other system tasks and operations that may be equally demanding (waypoint entry). Also, not all destination input methods are created equal; (our review found they can vary substantially in terms of the number of steps and button presses required to complete these types of interactions) some require more steps and button presses than others. Despite the tendency to view all destination entry tasks as equally complex, some use map-based entry, others can accept destination input by entering a phone number or recalling/accessing a previously entered destination – requiring relatively few steps/button presses.

Study Limitations

This inventory does not represent a usability assessment, nor does it constitute a formal evaluation of the distraction potential of particular devices. It provides basic information on a sample of available Telematics devices (focusing primarily on navigation systems) and can be used to make relative judgments and comparisons among systems as well as index general industry trends. Only a limited number of systems were reviewed, representing a convenience sample of systems, and is not necessarily fully representative of the range and types of available system designs. Navigation systems represent the single class of technologies for which the most extensive data was gathered. Also, the inventory did not examine the types of information processing requirements of systems or information displays. Display complexity is only one dimension that may contribute to distraction; task complexity is perhaps equally as important and can substantial impact how a driver uses displayed/presented information. Information content on the display alone therefore is not sufficient to determine distraction potential.

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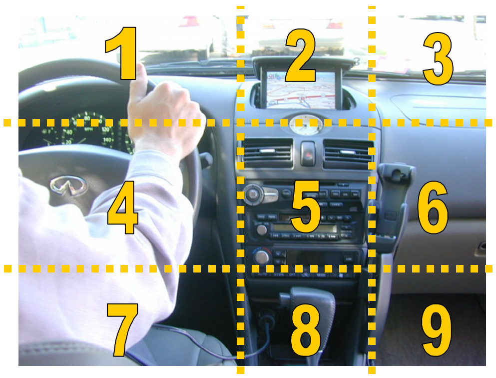
APPENDIX A

DATA DICTIONARY

VARIABLE NAME	DESCRIPTION	CODING LEVELS
<u>Basic Information</u>		
Device Name	Market Name of the Device	
Manufacturer	Manufacturer's Name	
Model	Model Number or Designation	
Availability	Origin (Point of Sale)	▪ Original Equipment Manufacturer (OEM) ▪ Aftermarket ▪ Fleet ▪ Consumer Device
Device Class	Indicates the General Category of Device (From Taxonomy)	▪ Navigation (ATIS, Route Guidance, etc) ▪ Communication (Pager, Cell Phone, etc) ▪ Productivity (Mobile PC) ▪ Entertainment (Games, Movies, etc) ▪ Safety (Safety/Security/Warning) ▪ MultiFunction ▪ HVAC ▪ Audio (Radio, CD, Cassette)
Device Dimensions	Physical Size (Dimensions) of the Device. Height x Width x Depth (cm)	
Number of Functions	Number of Available Functions	
Primary Functions	List of Device Functions	▪ Route Navigation/Guidance ▪ Voice Communications (telephone) ▪ Pager ▪ Personal Data Access (PDA) ▪ Aid Request & Mayday ▪ Emergency Roadside Assistance ▪ Mobile PC ▪ E-mail ▪ News & Information Links ▪ Internet Access/Surfing ▪ Telefax ▪ Audio System (Radio/CD) ▪ ATIS ▪ Motorist Services (and Concierge) ▪ Automated Tolls ▪ Yellow Pages (services/attractions directory) ▪ Vehicle Status (condition monitoring) ▪ Real-Time Traffic & Travel Advisories ▪ Driver Monitoring ▪ Collision Warning/Avoidance ▪ Driver Assistance (e.g., Parking Aid) ▪ Entertainment ▪ HVAC (Heating, Ventilation, Air Conditioning) ▪ Road Condition Information ▪ Remote Door Unlock ▪ Stolen Vehicle Tracking ▪ Obstacle/Pedestrian Detection

VARIABLE NAME	DESCRIPTION	CODING LEVELS
Cost	Retail List Price for Reviewed Model	▪ In US Dollars
Description	Basic Overview/Narrative of the Device	
Manual Available	Indication of Whether a Stand-Alone Manual is Included Along with the Device.	Yes/No
Number of Pages	Count of the Manual's Pages (or number or pages in the vehicle manual devoted to device).	Count
Training Course/Class	Indicates Whether Some Form of Training Course is Available.	Yes/No
Internal System Demo	Indicates Whether Some Form of Device Demo (internal to the product) is Available.	Yes/No
Reference/Instruction Card	Indicates Whether a Job Aid or Quick Reference Card is Available Outlining Product Use Information/Operating Instructions.	Yes/No
Training Video/CD	Indicates Whether a Video or CD is Available Outlining Product Use Information/Operating Instructions.	Yes/No
Device Number	Internal Project Reference Number Assigned to Device (Serves as Unique Device Identifier)	▪ 3 Digit Number ▪ 100 Series Navigation/Route Guidance/Traffic ▪ 200 Series Communication ▪ 300 Series Productivity/Mobile PC ▪ 400 Series Entertainment ▪ 500 Series Safety/Security/Warning ▪ 600 Series Multi-Function (Integrated) ▪ 700 Series HVAC ▪ 800 Series Audio System

Interface Characteristics		
Mounting Position 	Describes the Physical Location of the Device Unit and Display within the Vehicle.	▪ References a Section of a Generic Vehicle Cab Graphic. 1,2,3,4,5,6,7,8,9 Where 1= Top Left, 2= Top Center, 3 = Top Right, 4= Center Left, 5= Center Center, 6= Center Right, 7 = Botom Left, 8= Bottom Center, 9 = Bottom Right ▪ Possible areas defined include: **center stack** (area on the instrument panel where the radio, climate controls are usually located), **floor console** (space between driver and passenger seats), **cluster brow** (area on top of the IP directly over the steering wheel), center stack dash (dash area over the center stack).
Adjustable Position	Indicates Whether the Mounting Position can be Adjusted (Adjustable range for viewing by the driver).	Yes/No
Fixed	Indicates whether the mounting position is fixed.	Yes/No
Recommended Position	Indicates Whether the Manufacturer Recommends a Mounting Position for the Device (Applies to After-Market)	Yes/No
Vertical Viewing Angle	Vertical Location Relative to Driver Eye-Plane (device center)	Angle
Horizontal Viewing Angle	Horizontal Location Relative to Driver Eye-Plane (device center)	Angle
Obstructed View	Indicates Whether the Device Obscures Normal Vision (Blocks the Visual Field) Due to its Location	Yes/No. Details regarding obstruction if indicated. Direct View of the Roadway, Mirrors, or other Controls or Displays.
Controls		
Number of Hard Controls	Documents the Number of Physical Controls Present of the Device/Unit.	Count
Type of Control	Indicates the Range of Physical Controls Present on the Device/Unit	▪ Push Button ▪ Toggle Switch ▪ Rotary Knob ▪ Pull Knob ▪ Rocker Switch ▪ Touch Screen ▪ Lever ▪ Thumb-Wheel ▪ Hand-held Remote ▪ Stylus ▪ Joystick ▪ Bezel ▪ Hard Keyboard (and whether it is

		QWERTY) ▪ Soft Keyboard (and whether it is QWERTY)
Touch Screen	Indicates the Presence of a Touch Screen Interface	Yes/No
Hand-Held Remote	Indicates the Presence of a Remote Control Interface	Yes/No
Main Control	Indicates the Type of Control Serving as the Main Control (most frequently used control).	Selected from "type of control"
Smallest	The Name or Function of the Smallest Control and its Physical Dimensions in Centimeters.	Centimeters
Largest	The Name or Function of the Largest Control and its Physical Dimensions in Centimeters.	Centimeters
Min Control Spacing	Indicates the Closest Inter-Control Spacing in Centimeters. Measurements are Taken from the Mid-Points of the Most Closely Separated Controls.	Centimeters
Min Gap Spacing	Indicates the Closest Inter-Control Spacing in Centimeters. Measurements are Taken from the Edges of the Most Closely Separated Controls.	Centimeters
Multifunction	Indicates Whether One or More Controls Act to Manipulate Several Dimensions.	Yes/No
Steering Wheel Mounted	Indicates Whether One or More Controls are Mounted on the Steering Wheel.	Yes/No
Grouping	Indicates Whether Grouping Principles are Used in Control Layout.	Yes/No
Illuminated	Indicates Whether Controls are Backlit for Viewing at Night/Dark.	Yes/No
Visual Displays		
Visual Displays	Indicates the Presence of a Visual Display	Yes/No
Display Type	Indicates Basic Form of Display	▪ LCD ▪ Dot Matrix ▪ Head-Up- Display
Size	Size of the Display Screen (Diagonal, in cm).	In Centimeters
Height	Height of the Display	In Centimeters
Width	Width of the Display	In Centimeters
Integrated Display	Indicates Whether the Display and Controls are Manufactured as a Single Unit	Yes/No
Interchangeable Display	Indicates Whether the Reviewed Visual Display is the Only One Available/Compatible With the System	Yes/No
Display Legibility	Judgment Characterizing the Legibility of the Displayed Information (Factors contributing to judgment include contrast, text size, etc.).	▪ Excellent ▪ Good ▪ Fair ▪ Poor
Character Height, Width	Dimensions of the Typical Character/Text Item Displayed.	In Centimeters
Font Size	Point Size of the Displayed Font	Number
Rows	Indicates the Maximum Number of Rows or	Count

	Lines of Information Presented on the Display.	
Char/Row	Indicates the Maximum Number of Characters Presented Per Row on the Display.	Count
Words/Row	Indicates the Maximum Number of Words Presented Per Row on the Display.	Count
Graphics	Indicates Whether the Display Presents Graphics (Maps, Pictures, etc.).	Yes/No
Text	Indicates Whether the Display Presents Text Information.	Yes/No
Paragraph	Indicates Whether the Display Presents Text Information in Paragraph Form.	Yes/No
Icons	Indicates Whether the Display Presents Icons/Symbols.	Yes/No
Tables	Indicates Whether the Display Presents Information in Tabular Form.	Yes/No
Color Coding	Indicates Whether Displayed Information is Color Coded.	Yes/No
Grouping	Indicates Whether Displayed Information Takes Advantage of Grouping Principles.	Yes/No
Night/Day	Indicates Whether the System Offers an Altered Display Intended for Night Driving	Yes/No
Auditory Interface		
Auditory Display	Indicates the Presence of an Auditory Display.	Yes/No
Voice Recognition	Indicates Whether the Device Operates Through Speech Inputs (Voice Recognition).	Yes/No
Auditory Output	Indicates Whether the Device Provides Auditory Outputs.	Yes/No
Auditory Format	Indicates the Types of Auditory Outputs Provided by the Device (Synthesized Speech, Digitized Speech, Tone/Beeps).	Yes/No
Text to Speech	Indicates Whether the Device Has the Ability to Translate Text Information/Messages into Speech.	Yes/No
Guidance with Street Names	Indicates Whether Voice Guidance Specifies the Street Name or Number (or other relevant info) as well as Turn Direction. For Example, "In two miles, turn right onto Michigan Ave heading west."	Yes/No
Limited Road Name Speech Output	Indicates Whether Auditory Guidance Specifies Some Subset of the available Road Names /Numbers (using highway signing as a reference).	Yes/No
Complete Road Name Speech Output	Indicates Whether Auditory Guidance Specifies All Available Road Information (Names, Numbers, Heading, etc)	Yes/No
Max. Message Length	Indicates the Duration (in Seconds) of the Maximum Auditory Output.	Seconds
Number Commands	For Voice Recognition Systems, Indicates the Total Number of Commands The System Is Programmed to Accept (Command Library).	Count
Repeat Messages	Indicates Whether the System Includes	Yes/No

	Feature Which Allows Operator to Repeat Auditory Messages.	
Mutes Other Outputs	Indicates Whether the System Mutes Other Auditory Messages or Outputs In the Vehicle (e.g., Radio) When a Message is Delivered.	Yes/No
Automatic Volume Control	Indicates Whether the System Automatically Adjusts Its Volume to Counter Engine/Wind Noise	Yes/No
Ear-Phone Access	Indicates Whether an Ear-Phone Option is Available.	Yes/No
Clarity	Describes the level of Clarity/Intelligibility of the Auditory Display	▪ Excellent ▪ Good ▪ Fair ▪ Poor

Safety Features		
Warning Against Use While Driving	Indicates Whether a Warning is Provided to the Driver Cautioning Against Use While the Vehicle is in Motion.	Yes/No. Source of the Warning (Where and When the Warning is presented - manual, labels, start-up, operating)
Hands-Free	Indicates Whether the device can be used with Both Hands on the Steering Wheel (typically references an auditory interface using voice recognition). Hands-Free as opposed to hand-held unit. Some devices may be hands-free but not have voice activated controls (phone may be hands free after manual dialing).	Yes/No
Voice Activated Controls	Indicates Whether the Device can be Operated Via Voice/Speech Interface.	Yes/No
Can be Operated with 1 Hand	Indicates that the Device is Designed to be Operated With One Hand (Does not require two hands).	Yes/No
Manages Info Flow to Driver (Adaptive)	Indicates Whether the Device Includes Some Means of Restricting or Managing the Presentation of Information to the Driver When the Vehicle is in Motion. This is Done Real-Time, and Adaptively (e.g., based on driver workload, or road context)	Yes/No
Manages Info Flow to Driver (Non-Adaptive)	Indicates Whether the Device Includes Some Means of Restricting or Managing the Presentation of Information to the Driver When the Vehicle is in Motion. This Fixed as opposed to Adaptive.	Yes/No
Functions Lockout Out While Driving	Indicates Whether Driver is Prevented From Accessing Functions When the Vehicle is in Motion.	Yes/No
View Maps	Indicates Whether the Ability to View Maps is Disabled When the Vehicle is in Motion.	Yes/No
Destination Entry	Indicates Whether the Ability to Program a Destination is Disabled When the Vehicle is in Motion.	Yes/No
Destination Selection	Indicates Whether the Ability to Select a Destination From a List is Disabled When the Vehicle is in Motion.	
Modify Route/Detour	Indicates Whether the Ability to Alter a Route (to avoid traffic, etc.) is Disabled When the Vehicle is in Motion.	
Other Locked-Out Functions	Describes Other Functions the Driver is Prevented From Accessing When the Vehicle is in Motion (e.g., Screen Blanks Out).	List
Optional Locks	Indicates Whether the Function Locks are Option - Set by the User and Not Hardwired.	Yes/No
Display Blank While Driving	Indicates Whether the Display Screen Goes Blank When the Vehicle is in Motion.	Yes/No
Auto Re-Routing	Indicates Whether the System Automatically Re-computes a Route When a Deviation is Sensed.	Yes/No

General Interaction Dimensions		
Control Activation Feedback	Indicates Whether Driver is Provided Some form of Feedback After a Control Input. Includes Keying feedback to verify inputs and keypress to verify desired key activated.	Yes/No
System Status Feedback	Indicates Whether Driver is Provided Some form of Feedback When System is Processing Information.	Yes/No
Interaction by Passenger	Indicates Whether the Device Can be Configured for Use by the Front-Seat Passenger.	Yes/No
Highlighting	Indicates Whether Selected Objects on the Display are Highlighted.	Yes/No
Alert Tone	Indicates Whether an Auditory Tone is Used to Capture Driver's Attention.	Yes/No
Self-Paced	Indicates Whether Tasks are Self-Paced	Yes/No
Scrolling List	Indicates Whether the System Presents a Scrolling List of Menu Items.	Yes/No
Smart Spelling	Indicates Whether the System Only Allows the Selection of Letters which have the Potential to Spell a Word Existing in the Navigation Database	Yes/No
SR Compatibility	Indicates Whether the Controls are Designed to Match the Mental Model of their Use or Output	Yes/No
Auto Fill-In	Indicates Whether the System Will Finish Spelling a Word that it Recognizes From a Previous Entry or Database	Yes/No
Prompts Response	Indicates Whether the System Prompts the Operator When an Input is Required	Yes/No
Time-Out	Indicates Whether Tasks/Modes/Views are Timed-Out if not Completed or Inactive After a Designated Period of Time.	Yes/No
Confirmation of Speech Commands	After the Operator Enters a Speech Command, the System Repeats the Command Before Executing the Task	Yes/No
Presence of Ads/Distracting Items	Indicates Whether the Display Includes Advertisements or Peripheral Items (non-task related).	Yes/No
Dynamic Elements	Indicates Whether the Display Includes Dynamic Elements (Moving Map, Flashing Items, etc).	Yes/No
Max Depth Menu	Indicates the Maximum Number of Available High-Level Menus	Count
Max Number of Items in Menu	Indicates the Maximum Number of Items in a Menu.	Count
Restricts Input Options	Indicates Whether the Device Narrows Options or in Some Way Restricts Available Inputs.	Yes/No

Task Specific Interaction		
Sample Task	Identifies Common Tasks to be Performed by the Driver/User. The Set of Tasks to be Inventoried are Listed to the Right.	01 Destination Entry 02 Add/Modify Route 03 Cell Phone Dialing 04 Answer Cell Phone 05 Look-Up Phone Number 06 Accessing E-mail 07 Send E-mail
Method	References the Method or Start Point from Which the Task is Initiated/Performed. Tasks will be Completed Using Several Different Methods or Starting Points	01 Shortest Possible Entry Method 02 From Start-up (off position) 03 Destination Entry via Points of Interest (find Starbucks Coffee by name) 04 Destination Entry via Prev. Dest./Address Book 05 Destination Entry via Street Address (100 Main Street)
Number Steps/Operations	Indicates the Number of High-Level Operations or Goal-Oriented Steps Required to Complete the Task.	Count
Number Keystrokes	Indicates the Number of Button Presses/Keystrokes/Voice Commands Required to Complete the Task.	Count Note: Both scrolling and selecting are treated as separate actions. For example 2 "keystrokes" are recorded if an items is highlighted, then pusbutton pressed to select the item. The action of using a control to scroll down a list is only counted as a single action (e.g., scrolling down a list to the second item or the fifth item both count as a single "keystroke.")
Type Control	Indicates the main control type used to complete the specified task.	(refer to "Type of Control" for list) May also include voice commands.
Multiple Methods	Indicates Whether Different Methods are Available for Completing the Task.	Yes/No
Resume Without Interruption	Indicates Whether the Task Can be Resumed Following an Interruption.	Yes/No
Error Prevention	Indicates Whether the Device Includes Mechanisms to Prevent User Errors, and Describes the Form of Prevention.	Yes/No Description of Mechanism
Error Recovery	Indicates Whether the Device Includes Mechanisms to Recover from Errors, and Describes the Form of Recovery.	Yes/No Description of Mechanism
Escape	Aborts operation and returns user to main menu	Yes/No
Cancel	Aborts operation and returns user to the menu immediately above the canceled operation	Yes/No
Back	Aborts operation and returns user to the most recently accessed screen	Yes/No
Undo	Clears or reverses the most recent change/entry made by the user (e.g., delete entered characters).	Yes/No

System Architecture Information		
Operating System	Describes the Type of Operating System Used by the Device	▪ Microsoft Windows CE ▪ Palm OS
Blue Tooth (Wireless Comm)	Indicates Whether the Device is Blue Tooth Compatible, Enabling Wireless Communication Among Devices.	Yes/No
Add-On Capability	Indicates Whether the Device Can be Upgraded with Additional Capabilities.	Yes/No
Type	Specify Add-On Capability	Text

System Specific Data (Communication Devices)		
Speed Dial	Indicates Whether a Number Can be Dialed by Means Other Than Direct Phone Number Entry (e.g., address book, previous calls list)	Yes/No
Voice Activated Dialing	Indicates Whether the User Can Enter a Phone Number and Initiate a Call Using Only Voice Commands	Yes/No
Vibrate	Indicates Whether the Phone Can be Set to Vibrate When a Call is Incoming	Yes/No
Quiet Ringer		Yes/No
Multiple Key Answer	Indicates Whether There is More Than One Button That Can be Pressed to Receive a Call	Yes/No
Voice Mail/Answering Machine	Indicates Whether the Unanswered Callers Can Leave a Voice Message for the Recipient	Yes/No
WAP Services	Indicates the Ability to Access Web Sites Specifically Designed for Wireless Phone Use	Yes/No
Caller ID	Indicates Whether the Phone Displays the Name and/or Number of an Incoming Call	Yes/No
E-Mail/Text Messaging	Indicates System's Capability to Wirelessly Send and Receive Text Messages	Yes/No
Handwriting Recognition	Indicates Whether the Operator Can Enter Information by Printing with a Stylus	Yes/No
Auto Answer	Indicates Whether the Phone Can be Set to Receive Calls Without Operator Input	Yes/No
1-Button (Super) Dial	Indicates Whether a Number in Memory Can be Dialed with Only 1 Key Press or Press-and-Hold	Yes/No

System Specific Data (Navigation Systems)		
Dest. Entry Method	Indicates Range of Available Methods for Completing Destination Entry Task.	Preprogrammed List (Address Book) Street Address Intersection Freeway Entrance/Exit Phone Number Point of Interest Longitude/Latitude Map Town Center City Previous Destination
Map Orientation	Indicates Whether the Map Display is Ego-Centered (heading up) or Constant (north up)	North-Up Heading-Up
Map Perspective	Indicates Whether the Perspective of the Map Display is Similar to a Paper Map (top-down) or Angled Toward the Horizon (BirdView)	Top-Down (2-D) BirdView (3-D)
Number Views	Indicates the Number of Operating Mode Views and Lists the Specific Views Available (Map View, List View, Turn by Turn View).	Count Yes/No
Number of Info Elements	Identifies the Number of Information Elements or Basic Items Presented on the Display (e.g., Street Names, Distance to Turn, Cardinal Direction, etc.). This Information is Listed for Each Available Display View.	Count of Elements including: ▪ Road Map (including street identifiers) ▪ Enlarged Intersection Display ▪ Route Highway Shields/Markers/Icons ▪ Landmark/Service Icons ▪ Map Scale ▪ Vehicle Icon ▪ GPS Indicator ▪ Route Distance (Distance to Destination) ▪ Arrival Time/Travel Time to Destination ▪ Turn Arrows ▪ General Direction (Arrow) to Destination ▪ Time of Day (Clock) ▪ Cardinal Heading/Compass ▪ Vehicle Speed ▪ Distance to Turn (number and/or countdown bar) ▪ Current Position (street name) ▪ Next Turn (street name/number) ▪ Lat/Long Coordinates ▪ Scroll Bar (not soft control) ▪ Destination Address ▪ Soft Controls (each control)
Voice Turns	Indicates Whether Spoken Turn Instructions are Given When Approaching a Turn	Yes/No
Visual Turns	Indicates Whether a Turn is Visually Displayed When Approaching a Turn	Yes/No

Route Preview	Indicates Whether a Turn List or Map of the Entire Route Can Be Displayed Prior to Beginning Active Guidance.	Yes/No
Route Simulation	Indicates Whether Active Guidance (including visual and auditory displays, if available) Can be Simulated Prior to Beginning the Trip	Yes/No
Combined Views	Indicates Whether the Screen can Display Two or More Views Simultaneously (e.g., Map with Maneuver List - Split Screen)	Yes/No
Default View	Indicates the Default Type of View (Preset)	Map Maneuver List

APPENDIX B

SYSTEM THUMBNAIL DESCRIPTIONS

NAVIGATION

System: **Alpine NVE-N871A**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: A DVD-based route navigation system with remote control and separate 6.5" LCD color monitor (other display options available). The main unit may be installed under the front seat with interactions completed using the wireless remote. System features eight different methods for entering destinations (e.g., street address, intersection, point of interest, latitude/longitude, etc.) and route simulations and previews. See completed inventory for more details.

System: **Blaupunkt Travel Pilot DX-N**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: CD-ROM-based navigation system operated by handheld remote or optional steering wheel-mounted remote. Monitor can be used in conjunction with TV/video entertainment system or as a display for a back-up camera; both sold separately.

System: **Blaupunkt RNS-150**

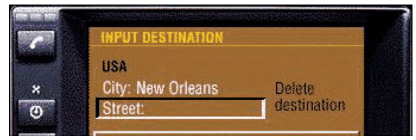
Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: Integrated radio/CD player and navigation system (dot matrix display). System features last 10 destination memory; simulation mode to illustrate route guidance; name of the road currently on and next road name on display; and a special destinations

display sorted according to distance. No map views, only turn-by-turn navigation. Automatically switches to night display when the vehicle's headlights are turned on.

System: **BMW Navigation System (Siemens VDO)**



Functions: Route Navigation/Guidance

Availability: BMW 7 Series

Description: Integrated system. A voice command option can be added allowing drivers to activate the navigation system, display a route map, change map scale, get information on current location and destination. The voice function does not allow drivers to enter destination addresses.

System: **Cadillac Navigation System**

Functions: Route Navigation/Guidance

Availability: 2002 Seville and Deville DHS and DTS

Description: Integrated system with 6.5" touch screen. Features 9 controls (five dedicated navigation controls along the left side of the unit, and four controls on the right side to operate the sound system), a DVD player which allows drivers to view movies when the vehicle is in park, and a voice recognition system. System automatically switches to a high contrast background for night viewing. Maps can be viewed "north-up" or from the driver's perspective.

System: **Clarion AutoPC 310c**

Functions: Route Navigation/Guidance
Audio System

Availability: Aftermarket

Description: AutoPC integrates car audio, computing functions, navigation and wireless communications through hands-free voice activation (recognizes more than 200 simple voice commands). System uses an open architecture platform powered by the Microsoft Windows CE operating system. Features text-to-speech applications, and can provide status information and assistance, such as turn-by-turn directions or E-mail alerts, through "speech synthesis" and text information presented on the unit's display.

System: **DestinAtor** by PowerLOC Technologies

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: Portable in-vehicle satellite navigation software for PDAs; the device is currently compatible with only the Compaq iPAQ(TM) Pocket PC. System provides users with displaying dynamic and interactive maps and real-time voice instructions and visual guidance throughout the trip. Automatically recalculates the route if a turn is missed. Mounts attaching to the automobile vent or windshield pedestal holder are available. Retail price $329 (not including PDA).

System: **Garmin StreetPilot III**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: Garmin's top-of-the-line portable GPS navigation system features a color display, visual/voice guidance, and a number of other guidance and display options. System is operated using integrated hard controls and comes with 1 regional CD-ROM map and dash-mount bracket.

System: **Hertz NeverLost (Magellan 750NAV)**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: Units available in Hertz rental vehicles, with over 7,500 units in the US. Integrated display/control unit with vehicle mounted stalk. Features turn-by-turn directions with voice prompts and visuals (3-d directional arrows), quickspell feature to minimize data entry by searching and displaying valid character combinations, and automatic re-routing when a turn is missed.

System: **Honda Navigation System**

Functions: Route Navigation/Guidance

Availability: 2000 Odyssey

Description: Honda Satellite-Linked Navigation System features a 4.6 GB DVD database, visual and auditory route guidance, different destination entry methods (including address intersection, telephone number, and map), and automatic re-routing and muting. The system can be operated using either touchscreen or integrated control inputs.

System: **Infinity Navigation System**

Functions: Route Navigation/Guidance

Availability: Infinity 2000 I30/Q45 and 2001 QX4

Description: The Infinity Q45 system featured a pop-up display which automatically deploys when the system is powered, and a separate control unit. The system features visual and audio route guidance, automatic re-routing when the vehicle is off course, and two map viewing options including a 3-dimensional birdview map which depicts an area from an elevated perspective. A touchscreen version of the system is listed under the Pathfinder.

System: **Jaguar S-Type Navigation System**

Functions: Route Navigation/Guidance

Availability: Jaguar S-Type 2001

Description: Features Visteon Voice Technology™, with a steering wheel-mounted "push to talk" switch. System acknowledges over 100 commands, offering hands-free voice control of the navigation system, phone, audio system, and climate controls. Continuous speech recognition - recognizes common, naturally spoken commands. Accepts user-defined personal vocabulary. Visteon Voice Technology™, also will be featured in the 2002 Infiniti Q45.

System: **Kenwood KNA-DV2100**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: DVD-based navigation system featuring a touchscreen interface and 2-D / 3-D map options. Shown with Kenwood LZ-800W widescreen mobile TV, which can also be used in conjunction with mobile entertainment systems.

System: **Lexus Navigation System**

Functions: Route Navigation/Guidance

Availability: 2001 LS 430

Description: System's database includes 53 point of interest categories, and offers eight different destination entry methods. Provides both visual maps and audio guidance announcing distance and turn directions. Control inputs can be accomplished via touchscreen, or use of a speech command (voice recognition) system. The speech command system includes 49 voice commands, and a switch to activate the voice recognition system.

System: **Magellan Pathmaster**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: Integrated display/control unit (4x4 inch color LCD display). Features turn-by-turn voice prompts, re-routing at the touch of a button, and a database with points of interest, gas stations, rest areas, shopping malls, etc. MSRP $1,995

System: **Mercedes Benz COMAND**

Functions: Route Navigation/Guidance

Availability: C20 Sport Wagon, 2000 S-class, 2000

CL-class, 2002 M-Class

Description: The Cockpit Management and Data (COMAND) System controls the vehicle's navigation, communication, and entertainment functions. It is used to activate the radio, cassette or the CD player, navigation system, internet access, and a voice-activated phone. Features an LCD screen with 32 hard controls. Operation of the screen-based controls is handled by a small knob that functions much like a computer mouse.

System: **Nissan Pathfinder Navigation System**

Functions: Route Navigation/Guidance

Availability:

Description: Similar to the I30/Q45 system described earlier in this section, but features a touch-screen interface. The system integrates HVAC and radio controls.

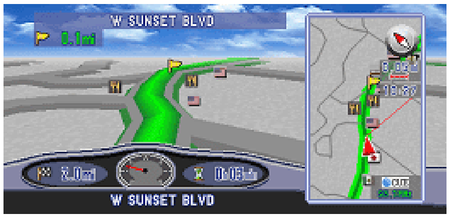
System: **Philips Carin 522 GPS**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: CD-ROM-based navigation system operated by handheld remote. System also provides trip information such as average speed, distance traveled, etc. Same system as the VDO Dayton MS 5000.

System: **Pioneer AVIC-9DVD**



Functions: Route Navigation/Guidance
News & Information Links (optional)
Audio System (optional)
Real-Time Traffic & Travel Advisories (optional)
Video Entertainment (optional)

Availability: Aftermarket

Description: DVD-based navigation system operated by handheld remote. Monitor can be used in conjunction with TV/video entertainment system or as a display for a back-up camera; both sold separately. Key features include a unique guidance display, voice recognition interface, and PC card slot for future upgrades.

System: **Pronounced Technologies AudioNav AN221**

Functions: Route Navigation/Guidance
Audio System

Availability: Aftermarket

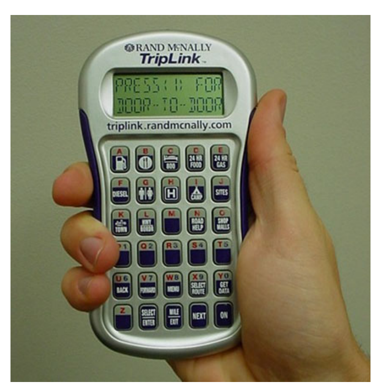
Description: A portable CD-ROM-based navigation system, unique because it relies solely on voice interaction. The user verbally prompts the system with a destination, including address, intersection, point of interest, and customized locations. Other features include alternate beginner and expert modes and rerouting capabilities. The audio CD player is also controlled by voice. An in-dash version with GPS is also available.

System: **Rand McNally TripLink**

Functions: Route Navigation/Guidance

Availability:

Description: A hand-held Advanced Traveler Information System (ATIS) device which provides text-based navigation information. The devices stores downloadable turn-by-turn driving



directions as well as provides information on motorist services (restaurants, hotels, gasoline stations, camping, etc.).

System: **TravRoute Co-Pilot 2001**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: Travroute offers a laptop and PDA version of their in-vehicle navigation system. CoPilot 2000 includes with route optimization, voice recognition, and nationwide coverage on one CD-ROM. Pocket Copilot is available for a wide range of PDA's (Cassiopeia, Compaq iPAQ, Jornada Palm, etc).

System: **Visteon NavMate**

Functions: Route Navigation/Guidance

Availability: Aftermarket

Description: System consists of an integrated unit with 3.2" display (2001 version has 3.5" display) and 13 hard controls. Four soft-touch buttons are backlit. Features turn-by-turn visual and voice-assisted route guidance, detour and automatic rerouting capability, and "Smart Speller" for easier and faster data entry, and the ability to "lay breadcrumbs" on the route's map, which allows drivers to quickly and accurately return to their starting point. Visteon also offers a portable system.

System: **Volvo Navigation System**

Functions: Route Navigation/Guidance

Availability: 2001 S80

Description: Features an in-dash, pop-up display.

Allows destination entry by street address, points of interest, personal address list, or phrase. Automatically re-routes, and mutes the radio during voice guidance. Also has a split-screen function. Supplied by Mitsubishi Electric.

COMMUNICATION DEVICES

System: **Ericsson R280LX**

Functions: Cell Phone

Availability: Currently Available

Description: A phone with some advanced features such as Internet and text messaging. Features many customizable options.

System: **Ericsson R380s Smartphone**

Functions: Cell Phone, PDA, E-mail, Internet

Availability: Currently Available

Description: An advanced mobile phone with added PDA functionality. With the flip closed, the device functions as a phone and is similar in operation to the R280LX model. With the flip open, the screen becomes much larger and a stylus is the primary interaction method. A number of other options become available, including e-mail, Internet, games, contact list, calendar, and notepad.

System: **Motorola V Series 120c Phone**

Functions: Cell Phone, Radio, Internet, Text Messaging, Sound Recorder

Availability: Currently Available

Description: A highly customizable phone with many advanced features including Internet, text messaging, voice notes, voice dialing, fax sending, FM radio, and software for 1-touch text input.

System: **Motorola StarTAC ST7760 Phone**

Functions: Cell Phone, Text Messaging

Availability: Currently Available

Description: A flip-phone with secondary button functions, voice mail, and text messaging (receive only).

System: **Qualcomm QCP-820 Cellular Phone**

Functions: Cell Phone

Availability: Currently Available

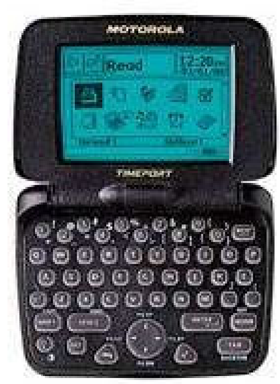
Description: A relatively basic mobile phone with a phone book, recent calls list, caller ID, and voice mail.

System: **Motorola Timeport P935 Pager**

Functions: Pager, PDA, E-mail

Availability: Currently Available

Description: A pager with additional PDA functions. The device flips open to reveal a hard QWERTY keyboard and 9-line display. Text messages can be sent and received. Additional features include a contact list, canned responses, alarm clock, calculator, jukebox, task list, memos, and fax sending. The P935 has an interface that mimics many features of PC operating systems.



System: **Motorola T900 Pager and e-mail**

Functions: Text Messaging

Availability: Currently Available

Description: A flip-open 2-way messaging device with available information subscription services. It features a QWERTY hard keyboard with backlit keys.

PRODUCTIVITY/MOBILE PC

System: **Cellport 3000**

Functions: Hands-Free Voice Communications

Availability: Aftermarket/OEM. System to be initially available in Ford vehicles

Description: The Cellport 3000 hands-free system provides a Universal Docking Station that accommodates cell phones of various makes and models. Drivers can dock cell phones to take advantage of hands-free operation. Provides voice activated features, including voice activated dialing, and voice dialing from your phone's speed dial directory (local phone book stores 23 entries).

System: **Delphi Communiport**

Functions: **Voice Communication & PDA Cradle**

Availability: Currently Available

Description: A device designed to cradle a PDA and a mobile phone that allows both devices to take input via voice recognition and give output using text-to-speech technology. It enables carry-on devices to be used hands free while driving.

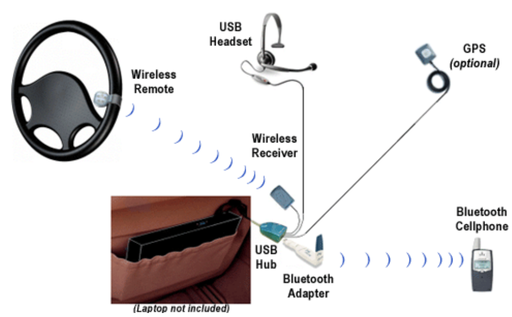
System: **Ericsson Mobile Companion MC218**

Functions: PC, Word Processing, Internet, E-mail, Fax, Games,

Availability: Currently Available

Description: A mobile computing solution with desktop interface. A large amount of options are presented to the user on the desktop, including 5 separate shortcut/function bars. Features include a large QWERTY keyboard, stylus input, and a large, backlit display. An Ericsson GSM phone can be docked with the MC218 to synchronize information and access phone features using the MC218.

System: **Mobile Aria**



Functions: Mobile PC (platform)

Availability: Aftermarket Services (4th Quarter 2001)

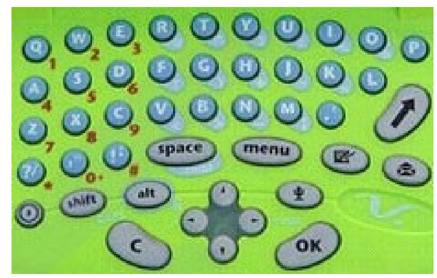
Description: Mobile Aria creates and delivers advanced Telematics services through a simple, voice-activated interface System using automatic speech recognition (ASR), text-to-speech (TTS), and Bluetooth peer-to-peer communications technology. MobileAria offers both hardware and services. Hardware consists of a True Hands Free™ kit with in-vehicle components (wireless steering wheel-mounted remote control, central unit, speaker/mic, and optional GPS receiver) and a Bluetooth cell phone and Bluetooth USB adapter for laptops. MobileAria functions via voice commands. System can read emails, and allow drivers to speak their replies, or respond with canned-text message. E-mails can be deleted, forwarded, and flagged with simple voice commands. Drivers can access Internet content such as Business, Sports, Entertainment, World News, and Local News.

System: **Motorola V100 Personal Communicator**

Functions: Voice Communications, Text Messaging, Wireless Internet,

Availability: Consumer Aftermarket

Description: A flip-open communication device which allows wireless voice and text communication, as well as Internet access. Voice recognition technology allows hands-free dialing, note taking, and menu access. Other features include a contact book and alarm clock. The device includes a QWERTY hard keyboard with an unusual layout.



System: **Nokia 9290 Communicator**

Functions: Cell Phone, Internet, E-mail, Fax, Word Processor, PDA, Multimedia

Availability: Pre-Launch

Description: A mobile office device with integrated cell phone and desktop applications. The 9290 functions strictly as a cell phone (with standard speakerphone option) when the device is closed. When the device is opened, it becomes a mobile office device with QWERTY hard keyboard, stylus input, and high-resolution color display. Features full PDA functionality, wireless Internet, e-mail, and office applications.

System: **Palm m500 Handheld**

Functions: PDA

Availability: Currently Available

Description: A customizable and expandable PDA with stylus input. In addition to organizer features, the m500 can run word processing, games, and other PC applications.

System: **Revolve RoadWriter**

Functions: Mobile PC (platform)

Availability: Aftermarket

Description: Provides a docking station and workspace for PDAs; intended for use in-vehicles. Includes a fixed keyboard (key spacing is 17mm center-to-center), nickel hydride batteries with charger, a 12-volt cigarette adapter, and two DB9 serial ports. Compatible with Palm III, Palm IIIc, Palm VII, Symbol SPT 1500, or TRGpro.

System: **Valde VehiclePC (VPC-2000)**

Functions: Route Navigation, Entertainment, Internet, Dispatch/Fleet Management

Availability: Aftermarket

Description: An onboard computer priced between $995 and $5000 depending on the options chosen. The system is configured for in-vehicle use with a touchscreen/keyboard interface and a durable, shock-absorbing chassis. The VPC-2000 has Windows 98 OS, GPS receiver, Intel Celeron or Pentium Processor, and DVD and MP3 capabilities. A 6.4” or 10.4” monitor must be purchased separately.

ENTERTAINMENT

System: **Audiovox Video In A Bag**

Functions: Entertainment

Availability: Aftermarket

Description:

System: **Honda Odyssey**

Functions: Entertainment

Availability: OEM

Description: This in-vehicle entertainment system is a dealer-installed option, featuring a floor-board console unit housing a video cassette player (VCP), a flip down 7" diagonal LCD screen mounted to the headliner, an infra-red remote control, and wireless headphones. The audio system is connected through the vehicle's speaker system. The VCP unit is located in the front-seat compartment below the main center stack and houses the media control panel (main controls including volume). This configuration restricts access to the unit by rear-seat occupants, and requires tapes to be inserted and ejected by front-seat occupants.

System:	**Johnson Controls AutoVision Rear Seat Entertainment System**
Functions:	Entertainment
Availability:	Johnson Controls (Supplier to OEM)
Description:	The AutoVision Rear Seat Entertainment system can be personalized to allow rear-seat passengers to select a wide range of entertainment and information options including video cassette players, removable DVD, Internet connections, online gaming, and music channel options. For vehicle manufacturers, AutoVision offers a wide range of integration options and accessories to meet the unique needs of consumers.

System:	**Steel Horse Universal Fit Entertainment Console**
Functions:	Entertainment
Availability:	Aftermarket
Description:	

System: **Visteon Rear Seat Entertainment System**

Functions: Entertainment

Availability: Aftermarket

Description: Two versions are available: an overhead mounted system for Sport Utility Vehicles and a console version for minivan applications. System comes equipped with a Nintendo game system and features a 6.4” LCD flip-up display, VHS video cassette player, television tuner, remote control, and parental control button. The audio flows through the vehicle’s speakers or headphones. The system is available as a factory-installed option in General Motors midsize Sport Utility Vehicles, or can be retrofitted using an aftermarket version.

MULTI-FUNCTION

System: **Joyride, Clarion**

Functions: Audio System, Route Guidance (optional), Rear-Seat DVD Entertainment (optional)

Availability: Currently Available

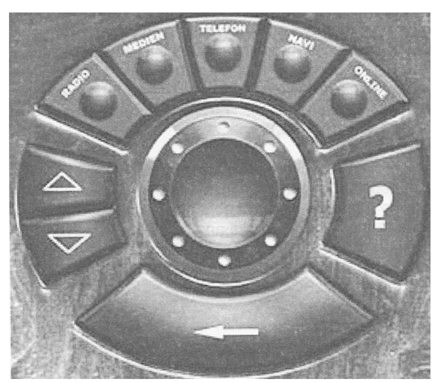
Description: An in-vehicle multimedia system with voice control functionality. The system is installed in the vehicle's dash with a small integrated color display, remote control and hard controls. Audio system has AM/FM radio, CD, and MP3 functionality. A larger display is available which allows for additional route guidance custom options (e.g., 3D map). Dual-zone capability allows front seat and rear seat occupants to access separate functions. DVD video is exclusive to rear seat passengers. The remote allows rear seat passengers to control DVD functions.

System: **CAA CarPC**

Functions: Route Navigation & Guidance, Audio System, Voice Communication, Entertainment, E-mail and Internet Access, and Vehicle Status.

Availability: An Advanced Prototype

Description: An advanced Driver Information System for cars and trucks. All functions accessed using a centralized set of controls. The system stresses interaction consistency.



System: **Communiport Infotainment PC from Delphi**

Functions: E-mail, Internet Access, Voice Communications, Vehicle Diagnostics, Audio System, Entertainment (MP3s, Movies, etc.)

Availability: Production expected in 2002. Cadillac has announced they will offer the system in high-end Cadillac's.

Description: The system integrates computing, wireless communications, and entertainment. Features Text-to-Speech, Voice Recognition, Integrated Cell phone, Voice Recording, and interaction with PDAs. Microsoft Windows CE operating system.

System: **Harmony Generation 1 (Johnson Controls)**

Functions: Multifunction. Infomatics

Availability: Prototype

Description: Johnson Controls is developing an integrated infotainment system intended to improve access to critical or useful information. The system features a combination of audio, multimedia and vehicle data aimed at entertaining and providing vehicle occupants with key information. Functions include: radio, satellite radio, CD/DVD/Removable Memory, MP3, HVAC, trip information, vehicle information, Navigation, RearVision™, and access to news, weather, financial services information, and the Internet.

System: **Motorola iRadio Telematics System**

Functions: Multifunction. Infomatics

Availability: Consumer Testing in 2001, expected market release in 2003.

Description: Combines entertainment, location-based information, navigation, emergency calling and communication. System includes voice recognition and text-to-speech technologies. Specific applications and services will vary by service provider and automobile manufacturers. Bluetooth technology to communicate with mobile devices such as pagers and Personal Digital Assistants (PDAs).

System: **OnStar, GM**

Functions: Safety and Security, Convenience, Routing, Conceirge.

Availability: Available on many GM Vehicles

Description: OnStar offers subscribers different services (e.g., emergency services, remote vehicle diagnostics, remote door unlock, routing support, concierge, etc.) all with real-time communications to a live operator. OnStar's interface features a three-button control unit (with LEDs) located on the instrument panel, rearview mirror, or overhead. Each button performs a different function: (1) answer or terminate a call, (2) initiate a call to an Onstar advisor, and (3) notify OnStar in the event of an emergency. Aside from the LEDs, no visual displays are used.

System: **Visteon ICES (Information, Communication, Entertainment, Safety & Security System)**

Functions: Route Navigation & Guidance, Internet Access, E-mail, Audio System, Voice Communications

Availability: Production expected in 2002.

Description: Similar functionality to Clarion's AutoPC. Boasts more natural language voice interaction technology. Features voice interactive software with text-to speech capability (see voice steering wheel mounted controls), and Microsoft Windows CE operating system.

Commercial Vehicle Systems

System: **CABIT**

Functions: Fleet Management (Messaging & Tracking)

Availability: Aftermarket (Commercial Vehicle)

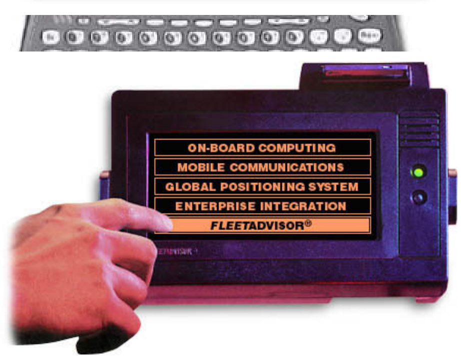
Description: Cabit OSB operates on Personal Digital Assistants (PDA's) like the Palm™ (as well as other computing devices) and provides real-time text messaging and communications. System features online mileage, routing, mapping, and logbook reports. Wireless, on-line services.

System: **Fleet Advisor from Qualcomm (previously Eaton Fleet Advisor)**

Functions: Mobile PC, Communication (Text Messaging), Trip Recording, Vehicle Status & Diagnostics

Availability: Currently Available (Commercial Vehicle)

Description: Fleet Advisor was recently acquired by Qualcomm from Eaton Corporation's Trucking Information services business unit. System combines wireless communications, on-board computing, and GPS. Features include real-time text messaging (macros and free form), trip recording (MPG, critical events, etc.), activity recording, DOT log processing and reporting functions. The high contrast M100 display uses touch screen technology, and the computer supports devices such as scanners, printers, GPS receivers, etc.



System: **Freightliner Driver Message Center**

Functions: Vehicle Status, Pager, Driver Assistance/Monitoring

Availability: Option on all Freightliner Century Class Trucks

Description: In-dash display with integrated controls. Message center provides engine status and diagnostic information, trip logs, and is capable of providing notification of incoming messages. System can also display warning messages from a roll stability advisor, if equipped, advising drivers of potential truck rollover risks.

System: **Freightliner Truck Productivity Computer (Truck PC), Developed by Delphi Automotive**

Functions: Mobile PC, Communications, Route Navigation, Vehicle Status and Diagnostics, Audio System, Trip Log, E-mail, Internet Access, Driver Assistance/Monitoring, Aid Request/Mayday

Availability: Production expected mid 2001. Available on all Class 3-8 Freightliner, Sterling, American LaFrance and Thomas Built vehicles.

Description: On-board computer with in-dash display and integrated controls. Features voice interactive software with text-to speech capability and Microsoft Windows CE operating system. System interfaces with numerous computer peripherals (i.e., keyboard, printer, hand-held PDA).

System: **Global Messenger**

Functions: Text Messaging

Availability: Aftermarket (Commercial Vehicle)

Description: The on-board communications display unit allows drivers to read and transmit preprogrammed text messages. System stores up to 50 pre-programmed messages (i.e., call in to dispatch, deliver load, etc.).

System: **HighwayMaster Series 5000**

Functions: Fleet Management (Data & Voice Communications, and Vehicle Tracking)

Availability: Currently Available (Commercial Vehicle)

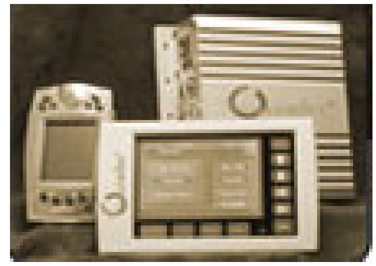
Description: Uses a wireless phone, data display, on-board microprocessor, and GPS. System features two-way messaging (free-form or macro-based messages) with recurring notification of messages waiting; auto-display; voice calls; and vehicle proximity and vehicle location tracking. An optional fax interface makes it possible to transmit and receive documents.

System: **Mac Truck VIP**

Functions: Vehicle Diagnostics
Availability: Currently Available

Description: OEM in-dash display center provides drivers with vehicle electronics data such as fuel mileage, trip data, and fault alerts. The display supports information in various formats including text, charts, and diagrams. Fetaures 10 lighted, dual-function pushbuttons and a main menu with 9 items. Over 50 menu screens are accessible; however, drivers are provided limited access to information while the vehicle is moving.

System: **Mobuis TTS Onboard Computer, by Cadec**



Functions: Vehicle Status, Route Navigation/Guidance,

Availability: Commercial Vehicle

Description: Onboard computer with LCD touch screen display for fleet management and communication. Interface uses drop-down lists and text messages when the vehicle is not in motion. Provides routing information, event notification, and delivery and pickup tracking. Graphically displays DOT logs. Portable version available. Windows CE operating environment.

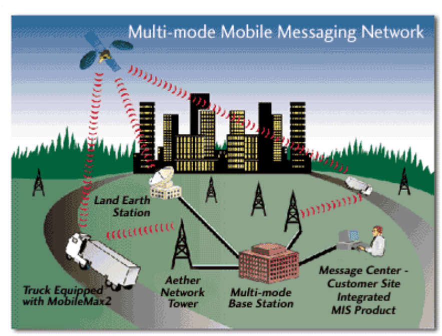
System: **MoniTrux by TruckScribers**

Functions: Fleet Management (Vehicle Tracking and Status Monitoring, and Pager)

Availability: Currently Available

Description: Links all trucks in the fleet via the internet and cell phone network. Features in-cab requests for driver to contact dispatcher or home, and five programmable buttons.

System: **Motient MobileMAX2**



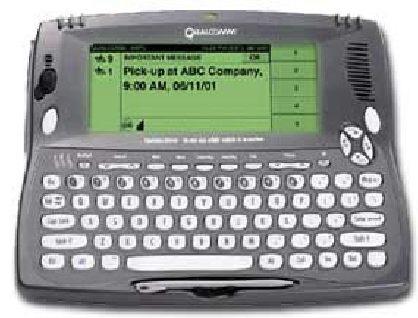
Functions:

Availability: Currently Available (Commercial Vehicle)

Description: MobileMAX2 is a mobile messaging service that features automatic check calls, dispatching, mileage tracking, load optimization, maintenance scheduling and shipment tracking. The in-cab keyboard display unit features built-in distress key, function keys, and a

PCNCIA card slot for updating applications. Architecture allows users to add accessory devices such as handheld units that can be used instead of or with a tethered keyboard display unit. The system also accommodates a wide variety of enhanced software for specific customer applications, and can support two-way communication.

System: **MVPc In-Vehicle Computer (from Qualcomm)**



Functions: Mobile PC, Communications

Availability: Currently Available

Description: Touch screen interface capability, and includes an integrated QWERTY keyboard and microphone and speaker. Features two way data communication with optional voice capabilities, vehicle tracking, and route planning and navigation. System interfaces with Qualcomm OmniTRACS and OmniExpress mobile communications systems. Uses Windows CE operating system to run custom or third party applications.

System: **PeopleNet Wireless Fleet Solutions**

Functions: Fleet Management (Messaging & Tracking)

Availability: Currently Available (Commercial Vehicle)

Description: An Internet-based fleet tracking and wireless communications (fleet management services) service with GPS satellite and two-way in-vehicle data and voice communications. In-Vehicle Base Unit transmits data and voice communications over the wireless network, and uses the Global Positioning System to monitor vehicle location. An in-cab message display is used to view and send data messages. Optional components include a Palm OS Handheld; Keyboard to compose all free-form data messages including e-mail messages; and Voice handset to place calls and access voice mail.

System: **Terion Mobile Messenger**

Functions: Fleet Management (Messaging and Tracking)

Availability: Currently Available

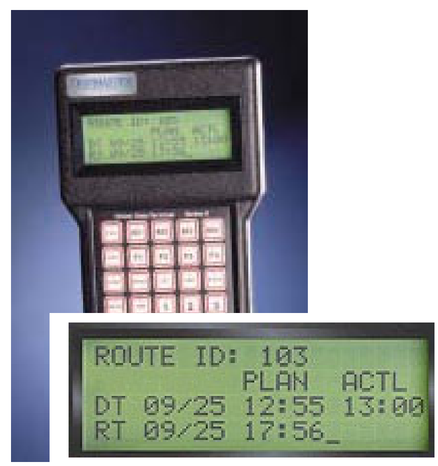
Description: The system (composed of a driver terminal, antenna and transceiver) offers two-way (e-mail style) text messaging and vehicle tracking. Driver terminal runs Terion's mobile software applications.

System: **Tripmaster Routes**

Functions: Mobile PC

Availability: Aftermarket, Fleet

Description: Intended to increase the productivity of professional drivers, Routes is a product that allows route information to be entered or imported and accessed by drivers. Information includes summary data of routes, data about upcoming stops, order information, and actions to be taken at each stop.



System: **XATA Driver Information System**

Functions: In-Vehicle Computer

Availability: Currently Available

Description: On-board information system integrates computing, real-time communications, GPS, and fleet management software. The driver computer uses a touch screen display which drivers can interact with at

all times. Features electronic DOT logs, fuel management, tachograph, trip planning and monitoring, onboard customized tables, GPS, two-way text messaging (free-form and pre-defined message sets), and automatic check calls. An electronic key stores information and transports data.

APPENDIX C

COMPLETED INVENTORY FORMS