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Human Factors Aspects of the Genesis Program

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Human Factors Aspects of the Genesis Program

Final Report

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Human Factors Aspects of The Genesis Program

Section 1. Introduction & Summary

Summary

The primary human factors concern addressed in this report is the use of GENESIS devices in the car in the Operational Test Evaluation. The implication is that drivers will be expected to attend to both GENESIS messages and the primary task of vehicle control. A driver's amount of attention is finite. When attention is divided between two (or more) tasks, there is less attention to devote to each task. If drivers are not fully attending to their driving, the chances that safety will be jeopardized are increased. Use of the auditory rather than the visual channel for presenting in-car information is considered. This is not a panacea and would add substantially to cost. We have two conclusions to offer related to this major human factors problem. The first is to assess the magnitude of the problem using vehicle simulation. This step would allow us to compare the use of GENESIS devices with the use of other in-car devices such as radios, cassette players and cellular telephones. The second conclusion is to emphatically instruct participants not to use the device when their workload is high. Taking this step recognizes that the GENESIS project is knowingly putting drivers at a higher risk of having an accident. Accidents involving participants could be blamed on GENESIS no matter what actually caused the accident. This would not add to the success of the project.

We also evaluated standard human factors concerns regarding GENESIS devices and their use. Of special interest here is the fact that the devices to be used, are designed primarily for home and office use and not for use in moving cars. Questions of legibility and readability, especially with regard to changing luminance conditions were discussed. Human factors standards are discussed but they are of only limited help since they were not specifically created to help with the in-car problem. Some general human factors considerations do apply. These are such concerns as literacy of the population of potential users, and readability and legibility of the message screens. The IBM-designed screens were evaluated and several suggestions for improvement were made. We also included a section of recommendations regarding safety and

another section on the training of GENESIS device users. In all the material presented here the overriding concern is the possibility that the use of the devices in a moving car may divert attention from driving.

Recommendations

We have only three recommendations, one general and two that are fairly specific:

- Throughout this report are discussions of human factors issues which will be important during the Operational Test Evaluation Phase. We recommend consideration of these issues by SAIC and HFRL during the planning for this phase.
- We recommend the evaluation of our suggestions for the improvement of the IBM screens by discussions between the screens creators at IBM and HFRL.
- We recommend a simulation study to precede the on-road tests. This study would validate safety aspects of the use of GENESIS devices while driving by comparison with the use of other in-car devices such as radios and cellular telephones.

Scientists', and others', recommendations are frequently in a form which suggests that more of the same should be done. Our recommendations here certainly have that flavor. Furthermore, since HFRL has a simulation facility, we may be tempted to solve too many problems through simulation experiments. While we recognize these biases, we believe that they can largely be discounted here.

Our recommendations initially require only our actions at HFRL. We will prepare a Statement of Work for SAIC in early January 1994. This SOW will include suggestions based on the first and third of the above recommendations. HFRL will contact IBM about the second recommendation.

Introduction

The work covered in this Final Report occurred between December 1, 1993 and December 24, 1993. An addendum to this report will be forwarded to Mn/DOT two weeks after we receive the prototypical Graphical User Interface (GUI) from JHK. The Human Factors Research Laboratory (HFRL) expects to receive the GUI Prototype from JHK sometime in January 1994. Most of the work, the first seven tasks, were requested by IBM. This was the same set of tasks that was forwarded to GENESIS-Mn/DOT in October or earlier by Frank Gozzo, IBM. HFRL may be requested to perform other tasks during the Operational Test Evaluation Program. Such tasks will be defined in conjunction with SAIC. HFRL has been asked by SAIC to submit a Statement of Work to them in January 1994.

HFRL Relationship to GENESIS Program

During the planning phases for GENESIS, HFRL offered to assist the GUIDESTAR Office of Mn/DOT by supplying human factors assistance with any or all aspects of the program. HFRL attended the Partners' meetings during the phase which ended with the publication of the "GENESIS Concept Definition And Preliminary System Design." HFRL continued to be represented at the Partners' meetings up to the present. HFRL is familiar with most technical aspects of the GENESIS Program and is acquainted with the Partners' representatives. This familiarity means that HFRL was able to begin to work effectively on GENESIS-related problems at short notice.

Another aspect of HFRL's relationship to the GENESIS Program is its past history of performing Mn/DOT sponsored research projects. Most of these projects, some of which ended in the recent past and others which are on-going, have dealt with issues which are directly or indirectly associated with the IVHS technologies which include the GENESIS technologies. As an example we are currently conducting human factors evaluations for the Trilogy Project (Radio Data Systems) whose objectives partially overlap with those of GENESIS.

Project Objectives

The specific objectives of this project are those stated in the tasks outlined below. These particular objectives all have to do with planning and preparing for the Operational Test Evaluation. An encompassing statement of the objectives for this project was: To seek and recommend corrections for human factor problems in GENESIS devices and their interfaces. That is, it will be much better to find and correct such problems now than during the Operational Test Evaluation.

Scope

This project was approximately three weeks duration. We were required to fit the time available to the work to be done in a manner usually referred to as Level of Effort. In another sense the scope of our work was primarily determined by the tasks requested by IBM. The tasks we did could be viewed as preparatory to the Operational Test Evaluation and as an aid in planning for that evaluation but not as a part of the actual on-road evaluation. We discussed that latter point and reached agreement with SAIC prior to submitting our proposal.

In-Car Use of GENESIS Devices

In the Travtek project, it was possible to implement lockouts on the device so that most functions were unavailable while the car was in motion. The car had to be placed in Park for the device to function. The GENESIS project has no plans to implement such lockouts. Given the variety of potential GENESIS devices, providing such lockouts, while technically possible, would not be feasible. The GENESIS users might be selectively diverting their attention away from the primary task of driving to the GENESIS devices. When considering that these devices could be as large as a laptop sitting in the passenger seat of the vehicle, a certain safety hazard has been created rather than avoided. Advocates of in-car devices might suggest that the GENESIS devices are no different then when a driver attempts to navigate using cumbersome paper maps. This is true but map-reading while driving is never recommended. Of prime importance is the suggestion and strong inference from manuals and operational testing, to use the devices only when not traveling or to use them as little as possible while behind the wheel. The location of GENESIS devices within the car will

be mostly a matter of user choice although the number of prospective locations is constrained by the need to read and manipulate the device from the drivers seat assuming that there are no passengers..

For the GENESIS Operational Test and Evaluation and subsequent general introduction of GENESIS, we might wish for a voluntary "lockout" by drivers. That is, drivers would not use their devices while the car was in motion. Effective means to achieve this abstinence have not been suggested.

Relationship to MITRE Guidelines¹

The MITRE guidelines for operational tests state that they are "conducted in the real world under live transportation conditions." However, these guidelines also state that they "serve as the transition between R&D and the full scale deployment of IVHS technologies, encompassing the broad range between these two steps." The work we have done falls in this "broad range."

Deliverables

The only deliverables for this project are this final report and the second report on the GUI evaluation.

Section 2. Tasks

Task 1. Evaluation of PDA User Interface Screens.

Task 1.1 Evaluation of Literacy Levels.

Newspaper accounts of the failure of our educational system to train adequately our students is a cause for concern in the GENESIS project. We read that most high school students have not mastered reading, that most cannot read maps or bus schedules and that only a few can name the states bordering their own. Such reports suggested that

¹Guidelines for IVHS Operational Test Evaluation Plans: Advanced Traveler Information Systems and Advanced Traffic Management Systems. Final Report for Project No. 3386J under Contract No. DTFH-91-C-00027, December 15, 1992.

we should be concerned with the ability of U.S. drivers to extract quickly and correctly the meaning of messages printed on their computer screens. On the other hand, it might be that only the literate segment of the population would be interested in owning a PDA device. If this is true, literacy is not an issue. However, since we have no evidence to support the supposition that only the literate will use GENESIS, we should consider the state of literacy in Minnesota (Operational Test Evaluation) and the U.S. in general for the broader adoption of GENESIS.

In the congressionally mandated series of studies² performed under the U.S. Department of Education, National Center for Educational Statistics as a part of the longitudinal National Assessment of Educational Progress (NAEP) is information on literacy which is relevant to the understanding of GENESIS-supplied information by the driving public.

The NAEP report divided students at three grade levels into categories. The grade levels were 4, 8, and 12. We will only consider 12th grade students in this report. The first set of descriptors were for the categories covering what experts in the field believed students *should* achieve for each grade level. These were referred to as Achievement Levels. The second set of descriptors were for what students at each grade level *actually* achieved. These were referred to as Anchoring Descriptions. Both Achievement Levels and their Anchoring Descriptions are defined below for only the 12th graders:

- Basic Achievement Level. Should be able to demonstrate an overall understanding and make some interpretation of text. Should be able to relate aspects of text to its overall meaning, make connections among and relate ideas in the text to their personal experiences and draw conclusion.
- Anchoring Description for Basic Level. Students could develop interpretations from a variety of texts. They understood overall arguments, recognized explicit aspects of text elements and supported global generalizations. They were able to

²NAEP Reading Report Card for The Nation And The States. (1992). Prepared by the Educational Testing Service under contract with the National Center for Educational Statistics, U.S. Department of Education, Washington, DC.

respond personally to texts, and use major document features to solve real world problems.

- Proficient Achievement Level. Should be able to show an overall understanding of the text which includes inferential as well as literal information. Should be able to extend the ideas of text by making inferences, drawing conclusions and making connections to their own personal experiences. Connections between inferences and the text should be clear, even when implicit.
- Anchoring Description for Proficient Level. Students integrated background experiences and knowledge with meaning from a variety of texts. They could interpret character's motives and differing points of view. They could identify text structure and apply document information to solve complex problems

There was a third level called Advanced. This level was an extension from Proficient. However, only 3 per cent of students attained this level. For this reason and since those who did achieve the Advanced Level would not have literacy problems, we will not discuss this level.

Table 1 shows summary data taken from the NAEP report for 12th graders.

Table 1
Reading Levels for U.S. 12th Graders

Unable to achieve Basic Level	25%
Basic Level but not Proficient Level	38%
Proficient Level but not Advanced Level	34%
Advanced Level	3%

The data in Table 1 strongly suggests that at least 25% of the U.S. driving population may have difficulty reading GENESIS display screens and messages with adequate understanding.

We might believe that anyone who is licensed to drive is literate and that everyone who drives is licensed. If we hold this belief we should moderate it by considering that

only little attainment in literacy is required to become licensed. Typically, those who are barely literate at the 12th grade do not become more so with time³. This segment of the population does not continue school. In discussing the literacy of licensed drivers, we should also consider the help an applicant might receive from a friend in completing drivers license application forms. We should also consider the fact that some drivers were never licensed and that some who once were are no longer. Another factor of concern is people for whom English is their second language and only a recent acquisition.

For many of these concerns, we must remember, that certain GENESIS messages lose value with time. That is, if a recent traffic incident is blocking a user's route, the opportunity to use an alternate route may require prompt action. If considerable time is spent in repeated glances at the display to try to interpret the message, the opportunity to take the alternate route could be lost. We can also surmise that safety is compromised proportionally to the length of time the driver spends in fixating the display rather than the outside roadway and traffic world. The extent to which this is true could be determined experimentally in driving simulation.

While we suspect that most drivers who are licensed are literate enough to benefit from GENESIS, we have no way at present of determining this fraction. Experts such as the previously cited Professor Rosemary Parks could help in better defining the impact of literacy levels on GENESIS. Such a study is, however, beyond the scope of this effort. Securing the help of Dr. Parks is a possibility and this could be done in conjunction with any additional human factors support beginning as early as January 1994.

Task 1.2 Evaluation of The Appropriateness of Information received by The Users And The Modes for Presenting Information to Users.

In this Subtask there are two separate issues. The first issue concerns the impact of the message on the traveler and the second the means by which information is received by the traveler.

³Personal communication from Rosemary Parks, PhD, University of Minnesota, College of Education, Department of Curriculum and Instruction. Dr. Parks is an expert in secondary school reading.

Of immediate relevance to the former issue is work which is in progress at the HFRL. We have completed a preliminary questionnaire-based study aimed at determining the correct structure for traffic messages. In this case "correct" means, determining the message structure which causes most travelers to behave in a consistent and rational manner. Rational here means behaving in a manner which would benefit the selfish interests of each individual and thus act in a way to reduce congestion for all travelers. For example in our pilot study of 64 participants we found a positive correlation between amount (and type) of information and traveler responses. That is, travelers were more likely to avoid congested areas when the message contained increasing amounts of information. Announcing "CONGESTION AHEAD" was inferior to "CONGESTION AHEAD -- 10 MINUTE DELAY" which was inferior to "CONGESTION AHEAD -- 10 MINUTE DELAY -- TAKE 169 TO HWY 55." In this study participants selected reasons why they made their choice to respond, completely or partially, to the information. Their reasons suggested that they were more confident that the information and advice was correct and timely, the more information and advice they received.

Partially related to the literacy issue, but also related to the shortage of display area, is the use of icons to replace text. In 1979 Potter, Kroll, and Harris⁴ conducted an experiment to test if people could understand and remember sentences composed of simple single words flashed on an oscilloscope screen at the rate of 12 words/second. They found that people could do this as well as they could with normal sentences. What was surprising was an auxiliary experiment where Potter substituted line drawings for the concrete nouns in the flashed sentence. This switch had very little effect on reading or comprehension of the sentence. This implies that pictures and words are read the same way. Earlier studies by Clark and Clark⁵, or Oldfield and Wingfield⁶ suggested that the effectiveness of pictures to replace words was dependent upon how

⁴Potter, M.C., Kroll, J., & Harris, C. (1979). Comprehension and memory in rapid sequential reading. In R.S. Nickerson (Ed.) Attention and Performance, VIII. Hillsdale, N.J.: Erlbaum.

⁵Clark, H.H., & Clark, E.V., (1968). Semantic distinctions and memory for complex sentences. Quarterly Journal of Experimental Psychology, 20, pp. 129 -138.

representative the picture was to its intended noun. Complexity or confounding icons reduced comprehension. Dewar⁷ in 1989 used a study to prove that simple graphic symbols used on traffic signs were more effective than words on signs. Symbols on signs were standard iconic representations of roadway conditions, warnings, or rules. If an icon was properly designed they were recognized or understood more quickly than word messages describing the same conditions.

The application to the GENESIS screens and menus could be the use of icons on the Main Screen to easily lead the novice user to the screen they want, or in designing buttons that convey meaning across all screens. For an example the Help button may be represented iconically as a Question Mark, the Cancel as an Eraser, or the Save button as a Bank Vault Door. By using these icons the designer can place these buttons where ever they want them and the user will notice quickly where they are on a screen.

In this way, the need for consistent placement of all recurring buttons on each screen is eliminated. The user is not required to read each button separately on every screen which can take extra time. The user simply glances at the screen and sees the needed icon.

Initial development of icons is extremely important because of the need for the icon to represent the idea and concept for which it stands. The more abstract a concept is, the harder it will be to find an icon for it. The final point made here is that screen resolution has an effect on icons and with the GENESIS devices the resolution may not be great enough to use complex icons, only the most basic or miniaturized version of the task concept to convey, may be available.

⁶Oldfield, R.C., & Wingfield, A. (1965). Response latencies in naming objects, Quarterly Journal of Experimental Psychology, 17, pp. 273 -281.

⁷Dewar, R. (1993). Hazardous Road Signs Ahead, Ergonomics and Design, July Issue., pp. 26-31.

Zaidel and Noy⁸ discussed advances in three types of drivers' displays: Integrated computer-based instrumentation, head-up displays, and auditory displays and controls. They point out problems with visual displays including virtual displays. These problems center on consideration of the rapid changes in accommodation required at different accommodating distances as well as shifts in the resting status of vergence. Night driving and aging add importance to these issues. The adoption of general purpose displays and controls that either are, or function like, menu driven computer screens with select and click operation will be more susceptible to human memory and cognitive limitations as well as to interruption effects. Zaidel and Noy state that there are no ergonomic criteria for deciding which functions should be integrated and which would be better left as dedicated instruments. In GENESIS we have committed to the use of a single, multi-purpose device. That is, while GENESIS has no plans for using the devices for the display of, for example, vehicle status information, we do expect users to run many non-traffic applications on their computers.

Zaidel and Noy also stated that the auditory mode is becoming more important for advanced driver displays and controls. However, they point out some of the negative implications of using speech in a vehicle's noisy environment and for the driving population with speech and language difficulties. They also point out that the auditory mode may be more intrusive than many would want. They concluded by calling attention to the rapid rate of evolutionary change in advanced driver technologies and the need for human factors to take best advantage of these changes.

A simulation study comparing four types of route guidance systems that was conducted recently at the University of California Davis, yielded some interesting results. They compared paper maps, head down electronic displays, head up display using an electronic map, and voice guidance with an electronic map. Perceptions and preferences, workload, and reaction time were measured. Subjective workload, user perceptions, and the number of guidance errors indicated that voice performed the best followed by head up, the head down, and finally paper map. As one might expect the maps requiring diverting attention from driving were the worst performers. Their reaction time study yielded inconsistent results except for the largest reaction times

⁸Zaidel, D.M. and Noy, Y.I. (1993). Ergonomic issues in the evolution of advanced driver interfaces. Paper presented at the 72nd Annual Meeting of The Transportation Research Board, January 1993, Washington, DC.

being associated with paper maps. This indicates that the safest and most effective systems are those closest to the driver's field of driving vision, with several modes of communication being used simultaneously. Combining voice with maps or using projected heads up displays reduced the workload on drivers and increased their subjective satisfaction.

Task 1.3 Evaluation of Messages for Legibility.

The purpose of this task is to evaluate the ability of the users to read the screens at reasonable distances and viewing angles. We were also interested in defining luminance conditions related to readability and the extent to which vision can be impaired without losing readability. Readability, according to Shurtleff⁹ "denotes the reading of words and text and refers specifically to the functional relationships existing between the properties of words and text and the observers' accuracy and/or speed in reading words or text." Legibility by contrast "denotes the identification of single symbols, and refers specifically to the functional relationships existing between the properties of individual symbols and the observers' accuracy and/or speed of identifying those symbols." Readability is discussed in the next section, 1.4.

The chief among the factors affecting legibility on any surface are luminance and luminance contrast, stroke width, symbol height-to-width ratio, and symbol height. Frequently in human factors we have attempted, successfully, to aid display *designers* and in turn this aids display users. However, for the GENESIS Project many of the displays are designed and sitting on store shelves awaiting use in a wide variety of applications including GENESIS. For GENESIS use at home or office we need have little concern about legibility. The legibility of small computers' displays will be satisfactory even if for some of the less expensive display implementations this satisfaction is marginal. An example of the latter would be a dimly back-lit liquid crystal display in a low illuminance environment. Conversely, if this same display was viewed with sunlight from a window falling on it, it would again not be adjudged satisfactory.

Since GENESIS intends drivers to use computers with displays that have no special features which allow them to adapt to a constantly changing luminance environment, we must expect some loss of legibility of displayed text. Elsewhere in this report we discuss the effects on safety of divided attention. Here, we are suggesting that luminance conditions in the car, from too bright to not bright enough, will exacerbate the effects of divided attention on safety. Drivers must not only spend time extracting the meaning (readability) of the displayed message (affected by literacy, age and the

⁹Shurtleff, D.A. (1980). How to Make Displays Legible. 156 pages. Published by Human Interfaces Design, La Mirada, CA.

other factors discussed above), but they must contend with the in-car factors which limit legibility.

We should inquire about the extent to which some set of luminance conditions degrades legibility which in turn degrades driving performance while performing particular driving maneuvers such as merging into high speed traffic, overtaking and passing a car or making a left turn at an urban intersection. (These maneuvers are among those causing most highway accidents.) Unfortunately, precise answers are not known. Because of their infrequency and the difficulty in ascribing causes, accidents are not at all good dependent variables. Often, we might be satisfied in comparing the degradation in driving performance due to reading a GENESIS display screen with say tuning a radio or dialing a cellular telephone. If, in simulation, performance degradation is no worse for GENESIS than for doing other secondary tasks, than we may feel more comfortable in having drivers use GENESIS while driving. However, if performance is much worse, we may want to consider other options before embarking on Operational Test Evaluation with in-car use of GENESIS. The fact is, that we do not know the extent to which the in-car use of GENESIS might jeopardize traffic safety.

The Shurtleff book cited above, discusses factors which affect legibility for over one hundred pages. However, nowhere, in that work is there a discussion of the legibility of a display placed on a car seat beside a driver. In this environment the most critical of the variables affecting display legibility is probably luminance. Imagine driving east on I-394, say 30 minutes after sunrise. The sun is in the driver's eyes but there is too little light on the display screen. If the driver turns north on say Highway 169, the sun, which this time of year is in the southern sky, may shine directly on the screen. Most of the contrast, both luminance and color, is lost and again the display may prove to be illegible. In both these cases the driver may elect to release the steering wheel with one hand and reach over and rotate the screen to a more favorable position *vis a vis* luminance conditions. The driver may now be able to see the screen by looking somewhat to the fore or aft directions. This in turn will increase parallax introducing a new factor for making the screen less legible.

Considerations such as our lack of hard knowledge and our reasoned guesses about potential traffic safety impacts are somewhat discomfoting. We do know that on occasion we drive into the sun while it is low on the horizon and that this may be a difficult driving task, especially in rush hour traffic. We can guess that drivers will try to solve the luminance problems posed above by holding the device closer to the

eyes than the arm's length distance to the passenger seat and to hold it at the most favorable angle for legibility with respect to the direction of the source of the ambient illuminance. Displays which have high luminance and high contrast settings are preferred as are displays with anti-reflective coatings.

Minimally acceptable contrast ratios for symbol identification (legibility) are in the range of 10:1 to 20:1 but these values are influenced by overall luminance, size of symbols, symbol blur, glare and many other factors which may or may not be present. Higher contrast ratios do not of themselves degrade legibility. However, at high contrast ratios other effects such as halation may take over thus reducing legibility. The effect of contrast on rate of symbol identification; that is, how fast a string of symbols can be read correctly is about the same as that for simple identification. Unfortunately, most computer (display) manufacturers assume reasonably good and reasonably constant viewing conditions. If the display is difficult to read, for example bright light shining on the display, it is the user's responsibility to remove the glare source. The small computers which are of interest for the GENESIS application do not have displays which will accommodate to the widely varying ambient luminance conditions.

Much the same can be said for other display factors regarding in-car use. For example, horizontal symbol spacing is usually around 10 per cent of symbol height. However, in difficult viewing conditions, spacing should be on the order of 25 per cent. Such customized display parameters are generally not available on the computers which GENESIS users will buy.

Symbol size and symbol aspect ratios (ratio of symbol height to symbol width) should be large; larger than most users would prefer for say word processing at their desks. Most displays have an aspect ratio of about 3:4, height-to-width. This should be satisfactory for GENESIS applications. Of greater concern is the total size of the display. We prefer that the driver obtain the maximum information possible in a single glance at the display. (We have already considered this in our discussion of icons.) There could be problems with small displays of say 8, 12-point characters by two lines. This would, at least occasionally, require scrolling which would in turn increase the time and complexity of the secondary task, unnecessarily jeopardizing traffic safety.

We of course hope that drivers do not attempt to use their GENESIS devices during times when traffic or other aspects of the environment are imposing a high workload on the driver. We lack systematic data on when drivers attempt to perform secondary tasks when driving. From anecdotal evidence related to accidents and perhaps from introspection, we know that drivers, at least infrequently but at their own discretion, attempt to do far more information processing than they can handle safely. We do know from simulation studies¹⁰ that when drivers were required to perform secondary tasks such as speaking on a dash-mounted cellular telephone, both primary task error (steering, measured by rms tracking error) and reaction time to brake lights increase. In this case the drivers, who were the subjects in the experiments, were not free to choose when they would perform the secondary task. Instead they were required to talk on the telephone at a cue from the experimenter.

Task 1.4 Evaluation of Usability/Readability .

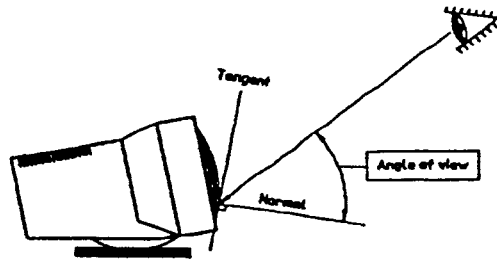
Introduction

The purpose of this task was to ensure that the user would be able to perform common functions easily, that foreseeable errors are anticipated and provided for and that the interface does not place excessive demands on human information processing capabilities.

Readability

Most Interfaces and systems provide the user with an unlimited number of fonts and size ranges. Anthropomorphic data has established that there are absolute limits to the perception by the eye of font sizes and types. These limits have been tested and correlated with user ease of comprehension. Fonts must fit into the normal angular field view of the eye:

¹⁰Hancock, P.A., Chrysler, S. and Stackhouse, S.P. (1992). Performing secondary tasks while driving. IVHS Annual Meeting Proceedings, Washington, D.C.



- A display should be legible from any angle of view up to at least 40 degrees from the normal viewing surface.
- Visual angle depends on the formula relating size and distance:

where $\vartheta = 2 \tan^{-1} [h / 2d]$

ϑ = Visual Angle
 h = Height of object
 d = distance to screen 11

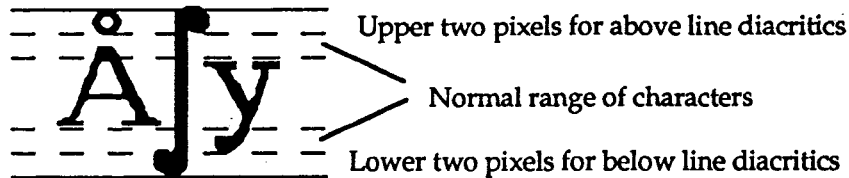
Text sizing and typography have been studied more than any other area of interface design. The following represent standards for text sizing and screen placement considerations.

- Text should be at least 3.5mm tall for optimum viewing at a 40 degree angle maximum, this corresponds to a minimum of 12 point type.
- The DIN (Duetsch Industrie Normen) specifies a minimum of 2.6 mm high based on a viewing distance of 500 mm and a range of 450 to 600 mm.
- If characters cannot be enlarged enough, one should increase the line spacing to increase readability.
- A 5 pixel by 7 pixel matrix is the minimum for alphanumeric and upper case characters
- Text should have no more than three different fonts.
- Text should never be in all uppercase form, it is more difficult to read than normal upper- and lower-case text.
- No more than 2 variances in differences of points should be used, with a wide range of points between them.

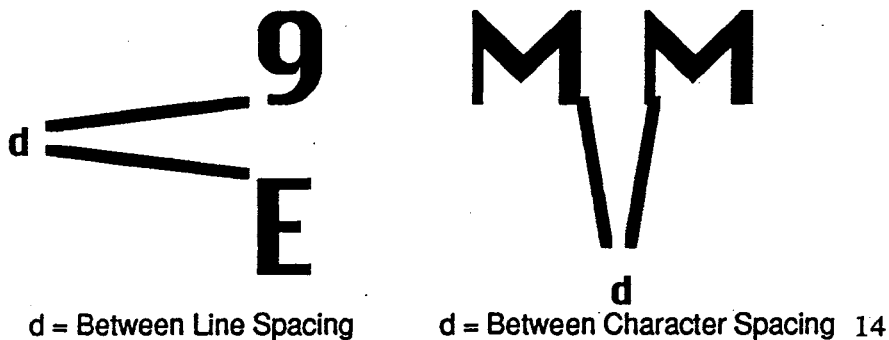
¹¹Alderson, G. & DeWolf, M. (1984)., Guide to Effective Screen Design. Computers in the Curriculum, Educational Computing Section, Chelsea College: London University.

For example: 10 point and 14 point. not 10 point and 11 point.¹²

- Because the Genesis system might evolve into foreign user markets it is important to allow at least two extra pixels for diacritics above and below the normal line of characters. (See diagram)¹³



- Between Line spacing should be at least one pixel. However, when large amounts of text reading are necessary this should be increased to two pixels.
- Between Character spacing should also be at least one pixel.



- Text should range to the left for easiest readability, Ranging to the right or centering leaves a jagged left edge which disrupts reading.
- Do not justify lines because this requires inconsistent spacing and hyphenation which is incompatible for low resolution systems.

¹²Rubinstein, R. and Hersh, H. (1984). The Human Factor: Designing Computer Systems for People. Burlington, Mass.: Digital Press.

¹³Apple Computer (1987). Human Interface Guidelines: The Apple Desktop Interface. Reading, MA.: Addison-Wesley Publishing Company. p 24.

¹⁴Alderson, G. & DeWolf, M. (1984)., Guide to Effective Screen Design. Computers in the Curriculum, Educational Computing Section, Chelsea College: London University.

- Line endings should coincide with grammatical conventions. Splitting words at the end of lines should be avoided
- Paragraphs should be indicated by an additional line break not an indentation of the line.¹⁵

IBM Screen Comments

IBM prepared the message screens which we have evaluated. These screens were obtained through the GENESIS Project Office. Of help in evaluating these screens is some of the information in the ITIS Bearer Independent Format for two-way messaging).¹⁶

Evaluation of the screens was undertaken using the examples provided in IBM Software Requirements Specifications Document # 191A4321-01. We have used IBM's section numbering to assist in identifying each screen through the use of common numbering. The user interface screens will be examined in order.

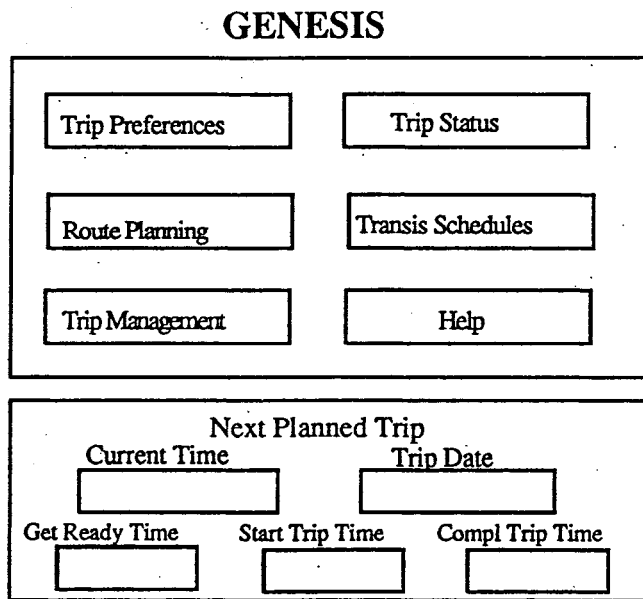
3.1.3.1 User Interface Screens.

3.1.2.1.1. Main Screen: The first screen is the device's Main Screen. It provides the five selection formats available: Trip Preferences, Route Planning, Trip Management, Trip Status, and Transit Schedules. It also includes the current trip settings that the user has previously programmed listing date and times. A current time clock and a help and quit button are located along the bottom. Is there a need for a quit button on this first screen? A quit would default to this same screen as it is the initial screen when the device is activated. Perhaps a button labeled Exit Genesis would be better than Quit. We believe that the help button should be located in the main selection area to emphasize it's availability to new and novice users. Most new users will not take time to carefully read instructions and a prominent help button, with pull down menu's for each selection, might prove extremely helpful. We can understand the help buttons current placement on the Main Screen is to correspond to it's placement on all of the

¹⁵Smith, S. L. and Mosier, J. N. (1986). Guidelines for Designing User Interface Software. Report ESD-TR-86-278, The MITRE Corporation, Bedford MA 01730.

¹⁶ITIS Bearer Independent Format, Version 3.1 (Two-Way Messaging), Draft 1, March 1993. Prepared by Castle Rock Consultants.

subsequent screens and this will aid the user with location of similar function buttons on each screen. However, the benefit of this early positioning may outweigh the position familiarity. The screen itself appears to waste space in the main selection area by including small buttons that are center justified. Changing this to six large buttons will facilitate readability, and ease of manipulation. It will be easier to see the buttons from a distance and to touch the proper buttons with either a pen or touch screen. Larger buttons might prove to be an important consideration for aged users who have limited visual capabilities and reduced hand-eye co-ordination. A possible re-arrangement of the screen might look like this:



3.1.3.1.2. The Trip Preferences screen: Here two main considerations are raised. The form fill-in format is adequate but in the future the interface will be on something as small as a PDA similar to Sharp's Wizard or Apple's Newton where form fill-in is most easily accomplished by an analog pointing device. Therefore, selectable buttons which list times by five minute intervals are more functional to the user. If all buttons elicit a pull down menu or show incremental changes it will facilitate using any pointing device and will not require keystroke entry. The second point is the left justification of the form fill-in questions. The intent here is for all fill-in spaces to match up, however, this gives a ragged appearance to the screen layout due to the structure and length of the questions. There is a large amount of room on this screen to better explain each question to get the best answer. Perhaps this is an unimportant point except for aesthetics, however a slight adjustment to visual presentation can

make a large difference in user satisfaction. Again the buttons along the bottom edge of the screen for Help, Cancel Changes, Save, and Main Screen could be larger.

3.1.2.1.3. Route Selection: This screen provides a good menu driven way to scroll between all stored routes. The Copy button does not appear to have any relevant function here. Where do you copy the Selected route to? Whatever you select goes to the route planning screen so there appears to be no usage for a copy function. Consistency of buttons is important here because the previous screen had the buttons arranged Help, Cancel, Save, while this screen arranges them as Help, Update, Delete. It is important to keep same function buttons in the same general areas. Cancel is a negative or take away action and is the second button of the previous screen. The second button on the Route screen is a positive Update button. The third button is the positive Save button on the Trip Preference Screen while the third is the negative Delete action on the Route Screen. People can be easily confused and will select the same button position that they saved with on the previous screen, thus deleting whatever route they have selected.

3.1.3.1.4 Route Planning: This screen provides easy use and understanding with only minor revisions suggested. The Preferred Major Route screen can be as long as the Starting Point, Destination and Preferred Travel areas. It has the space available so list 3 or 4 preferred routes at once. This will allow quicker scanning and scrolling. Similarly, the Route section at the bottom can display the entire route not just the enter and exit roads already entered. For instance the Route could say.

Route:

<p>You have Selected: Home to Work by I-494 Entering at Carlson Exiting at York</p>

If there is available screen space it should be filled with enough redundant and complete information as possible.

Again the Save button is in a different location than previous screens.

3.1.3.1.5. Trip Selection: This screen resembles the Routes Screen (3.1.3.1.3.) only there is an absence of a Copy button.

3.1.3.1.6. Trip Management: Here there is an abundance of information where several of the previous format suggestions should be applied. The screen looks somewhat cluttered and formidable. There is some left justification and indentation in the bottom third of the screen. The buttons could line up vertically instead of displacing buttons 3 and 4 to the right. The buttons need selectability, and the negative and positive action buttons are switched from the previous two screens. The Save is now the third button and the Cancel is the second.

When this screen is active are the alternative routes automatically displayed or are they selected? It would appear that the user can select which alternatives to use. (the buttons have selectability). A far more efficient method would be to have the preferred route up as it will be after the user selects it from the Trips Screen (3.1.3.1.5) and then the two quickest alternatives should automatically default according to travel times. This way the user will have his preferred route showing and if an alternative is found by the system to have a shorter travel time and it is displayed the user can quickly choose it. We realize that this is a programming screen with the majority of users selecting new and then setting their preferred and alternative routes. However, any measure of intelligence that can be added to the system, as in being able to help the user select the quickest alternatives, can greatly improve efficiency and reduce training. The users can enter their preferred routes and alternatives and later select these as the only choices. It would require a very powerful interface and system to help the user select routes by listing as many alternatives as possible and giving the user as many choices as they might ever need. This might allow for the greatest reduction in potential congestion but would this feature be used?. This also would be an excellent window of opportunity to show an alternative mode; that is a Bus or HOV alternative. The second alternative could be a bus route that is moving more efficiently than traffic. A separate pop-up menu could be shown which states that traffic is delayed well past the selection default from trip preferences that asked what time you were willing to start earlier to get ready for trip. The solution could be bus schedules or use of car pools and HOV lanes.

What is the difference between Travel Time for your preferred route and the Estimated Time from _____ to _____ in minutes? We assume this could be a way to indicate to the user what the individual travel times are for sections of their trip (from Carlson to Ford exit and from Ford to I-35 W). However, it is hard to find a use for these estimated times when we can see total travel times for our trips and alternatives.

Why must the user reselect their Time to Get Ready for Trips and earliest start times? They should have been set during the trip preferences section. A screen conservation idea might be a button that asks if these times need to be updated for this individual trip.

For instance a question can ask:

**Do you need to update your
time to get ready?**

<input type="radio"/> Yes
<input type="radio"/> No

If yes is selected then a pop up menu would appear with the necessary questions.

3.1.3.1.7 Trip Status: This screen needs to emphasize the far right side buttons . These are the functions that the user is going to select here. By the time they get to this screen they are ready to start their trip and have all ready chosen their preferred and alternative routes. A smaller abbreviated version of the route screen space could be used and the Start, Cancel, Resume, Pause, etc., buttons can all be enlarged. Another suggestion would be to remove this area all together and display the trip and selected route and if and when the route appears to take to much travel time the user can select Change Route which pops up the previous trip management screen where they can select an alternative.

The Trip Date, Get Ready Time, Start Trip Time, and Complete Trip indicators are not necessary as the user has selected this screen because they have been awakened, they know what day it is, and they are ready to start their trip. This is redundant unnecessary information. They do not need this information because they are past these event times.

A refined screen might resemble this:

Trip Status

Trip	
<input type="text"/>	<input type="text"/>
Route	Travel Time
<input type="text"/>	<input type="text"/>
<input type="button" value="Start Trip"/>	<input type="button" value="Cancel Trip"/>
<input type="button" value="Pause Trip"/>	<input type="button" value="Resume Trip"/>
<input type="button" value="Trip Finished"/>	<input type="button" value="Change Route"/>

For the Operational Test Evaluation, knowledge of trip durations or even actual trip completion times compared to desired trip completion times, would be important dependent variables. If these screens could be used to stimulate the user to enter trip start and complete times, less important data would be lost than would be the case if we simply rely on the users' memories.

3.1.3.1.8. Change Routes: This menu seems redundant because the same task can be completed with the Trip Management screen (3.1.3.1.6.). The only refinement would be to have the P/A function be two channel selectable. P and A would be displayed and you could touch either when the original routes are highlighted.

<input type="radio"/> Pref.
<input type="radio"/> Alt.

You would select whether the highlighted route should be changed to the other or not.

This should be a small window that has just one selection button and one route listed which can be used to scrolled through the alternatives.

3.1.3.1.9 Transit Schedules: This is a well designed screen. We might only note that the Transit Fare Information does not vary that much and should not require a large area. More area might be devoted to the schedule section which people will read.

General Suggestion:

- 1.) Make all buttons selectable so that any analog pointing device can be used at any button or Form Fill-in space.
- 2.) Use consistency in button placement so that like action buttons or same function buttons are on the same place on every screen.
- 3.) Increase the use of pop up menus that are activated by one screen and don't require switching to another. For instance, the Change Route screen could be a small pop up screen you would select the new preferred route, and it returns to the same position on the screen you started at.
- 4.) Increase on screen help by making the Help button very prominent.
- 5.) How does the user know they have entered everything correctly? When they switch back to the main screen there should be an acknowledgment of previous screen completion. Perhaps those choices made could become darkened and the next screen to be selected could be highlighted.
- 6.) On screen statements such as "If you are finished return to Main Screen" could appear when the screen is completely filled.

Functional Analysis

First we will examine the novice who is beginning to use the device for the first time. Since Trip Preferences are at the top they select it. They are now looking at the trip preference screen (3.1.3.1.2)

Time I need to get ready for a trip _____minutes.

- 1.) What trip am I getting ready for? a dinner? work? Different situations require different preparation time
- 2.) Does this mean average time or absolute time? If this is in Trip Preferences, should I put in my average morning time before I leave or should I put in the maximum I have ever taken to leave no room for error?

How much earlier I would be willing to start getting ready for a trip _____minutes.

- 1.) What time of day is this? If in the afternoon, perhaps two hours. If in the morning, when I need sleep, perhaps 10 minutes. Each trip will have different parameters.

2.) It is not clear as to if this means earlier than what I have previously entered as time to get ready or does this mean the total time including the time to get ready.

How often do I take a Trip?

1.) Most people will answer..., Everyday. They will not be thinking of specific individual trips at this point.

How much time I would have to save before switching to an alternative route. _____ minutes.

1.) Again people need to be thinking of individual trips, I might want as little as five minutes if I am going to work and I don't want to be late.

Cancel Changes Button: I haven't entered anything before so why would I make changes? More appropriate wording might be, Erase Selections, or Clear Entries.

Now what do I do..., Save? Go to the Main Screen? Prompting when the user has filled in the final question might say " Save your entries now or Clear for new preferences" after save it should automatically return to main screen, or ask user if they are ready to select routes push Main Screen.

Having returned to the Main menu, the user selects Route Planning and sees a blank screen with Routes and the word "New" (3.1.3.1.3)

1.) If no routes are stored the screen should say, "Select new to begin programming routes." It will not say this after first route is saved.

Previous suggestions for the route screen were discussed in section 1.0

After "New" is selected the user is moved to the Route Planning screen (3.1.3.1.4).

1.) When new the Route Description Box should say "type in name of route here".

Selecting starting and destination points.

1.) When other is selected why isn't it a fill-in box so that the user remembers the exact points they selected. "Other" is a huge category to be used by salesmen and delivery persons who have regular stops. This can be put into the title of the route, but to increase satisfaction there should be more information than is stored in the PDA and less that people must remember.

2.) There is no way to tell the system which way I am going on this road until I select the enter exit points. Direction that the user is traveling is important here since some exits are only northbound and some are only southbound. To proceed with the enter / exit points it is important to know which way the traveler is headed to provide the proper entrances and exits to select in pull down menu.

Enter / Exit points

1.) It will be important to have each form fill-in to have an exhaustive list of only the viable possibilities for each preferred major route selected. A pop up menu should list all choices for the direction traveled and not list every exit in the freeway system.

2.) The system assumes that if an exit point is another preferred route, then it should switch to that preferred route. This might be extremely confusing to the user, or at least frustrating if they are entering something and suddenly it switches the exit point to an entrance point without a warning. A message should appear telling the user that they have selected another preferred route and ask if they want to continue not cancel their previous route.

Estimated Times

1.) These should be written to say from home to the selected entrance or exit points. This will avoid confusion.

When complete, prompt the user to save all data, then return to the Main Screen.

The user now selects Trip Management.

The first screen seen is the Trips (3.1.3.1.5) which will be blank except for "New"

1.) Same suggestions as for 3.1.3.1.3. the Route Screen

2.) If the user selects a trip then the screen should progress to the Trip Status Screen (3.1.3.1.7) because this would be the logical progression. The user has chosen a trip; now lets start it or edit it.

After selecting new, users are moved to the Trip Management Screen (3.1.3.1.6). and the users are expected to enter their preferred routes.

1.) Does this mean the title of a previously entered route? does this mean the same I-494 that I just entered in route planning? There will be a significant amount of confusion here. The GENESIS system will probably default to the route entered just previously in the route planning screen. This will be fine but where do the alternates come from. We assumed that users are expected to select a preferred route that they previously entered and that they want to take. They are also assumed to have to select the alternates. They will do this based on travel times noted and by selecting the "view advisories" to note any congestion. It needs to be clear if a user can enter his normal route under preferred and if everything will set itself up by default after that. If users select their home to work preferred route, does a list of other alternatives appear in the next boxes?

2.) Users who enter their home to work route will not take the time to enter any alternates, they will expect the system to do that. It would take to much time to enter every different variation on how someone gets to work. One of us has nine completely different routes to get to the University based upon condition on each and on traffic variables. The point being that some type of automation or help is necessary here. It will also be important to keep the scrolling list for Preferred and alternates small. If a user selects their preferred route only viable alternatives should be listed.

How often do I take this trip?

1.) This is a very important question to the user as this sets them into thinking about specific trips, not preferences. Try to place this early so that users are thinking of their specific routes and trips.

The bottom half of the screen will fill in according to preferences and the selected route.

1.) Can these values be changed, for instance start trip time. If users can change these, they might set up an impossible travel schedule. These buttons should be non-entry with only the "Time I need to get ready" and "how much earlier" boxes being filled, with corrections in all parameters made by the system. We will assume this is how it will work.

There is a Start Trip button here suggesting to the user that once they push this they are done. Is this the case? Perhaps this should move them to the Trip Status screen automatically.

1.) A message saying "Your route is planned push Start to begin trip, Save to save entries, or Main Screen" will help users know what they want to do next.

2.) It appears to be an odd place to start a trip on this screen. It might be better to go to the Main Screen and have a Start button there.

The next selection on the Main Menu is the Trip Status screen (3.1.3.1.7) If you selected a trip from the Trip Screen menu, this should appear in the trip window with the preferred and alternate routes displayed. It should never appear blank nor have any trips that do not have pre-determined associated routes.

1.) An important idea here is to have selective highlighting. As the screen is filled with trip information the right side buttons should be highlighted with only the active buttons showing. For example you must start a trip before resuming a trip, pausing trip, or canceling the trip which would be possible. Only the Start Trip and the Change Route buttons should be active and highlighted. After the trip has been initiated, then the Cancel, and Pause buttons should be highlighted. After Pause is initiated only the Resume button should be highlighted and active.

2.) The change route selection and subsequent screen could be modified as described in Task One or by selecting Change Route the Preferred window will change to a selectable button with all stored preferred routes. This way no 3.1.3.1.8. screen is necessary.

3.) When Trip Complete is selected the screen should return to the main menu automatically and a further button push on the Main Screen button would be unnecessary.

The final selectable button on the main screen is for Transit Schedule information. This screen (3.1.3.1.9) has a good interface where users select the routes from a selectable button and then specify the transit stop they want, the time period of the day and the direction traveled.

1.) The first question raised here is what is the function of the View Schedule button? Does this display the entire route in a novel format? Does it show the route map or enlarge the schedule screen to full display capacity? Is it a way to see the schedule selected if there is more than one schedule displayed? If the user has chosen the Route (by number or description), the Transit stops, the time period and direction, there should be only one schedule displayed and why would one need to view it? This seems to have no function or to redundantly present information. It is understood that real time information is being broadcast and this screen would show bus locations and their estimated arrival times to the stop users have selected. If this is the case, remove the Transit fare information window and expand the schedule information portion:

Schedule

The next 16A bus will arrive at your selected stop in _____ Minutes.

It is followed by another 16A bus in _____ Minutes.

A 5B bus that travels to _____ and that you can transfer to a _____ bus that will take you to _____ will arrive at your stop in _____ Minutes

2.) Why is there a large Transit Fare Information screen. All buses cost \$1.00 with a .25¢ surcharge for peak hours or express times. There are special classes of users with reduced rates, but all users should know the basic cost of their bus trip.

Overall Suggestions:

- 1.) There are possibly too many menus, perhaps several can be incorporated as pop up or pull down menus without the need to return to the Main Screen each time.
- 2.) Defaults must use intelligence to select the users most commonly chosen routes or if a user just programmed a trip, the trip status should default to the most recently programmed trip. People are more likely to program one trip at a time right before they need to go on that trip.
- 3.) Several references are made to the device telling the user that there is a delay and that the device is retrieving schedules or information. Feedback here is very important to user satisfaction. If they are told to wait for two minutes they are more patient than if told simply to wait. A clock or hourglass counting down time helps the users feel that they are involved while waiting. Feedback provides a simple deterrent to frustration from users feeling that they are forgotten.
- 4.) Currently the user is required to make several selections based on memory or exactly developed plans of route and trip destinations. Most users will need as much on-screen help as possible. This can be in the form of selectable windows and buttons which list the applicable choices, or by offering choices or help from pop up screens and pull down menus. The user can not possibly be expected to remember all the choices.
- 5.) Users will expect the system to know what they are thinking. A user might not remember the exit to go to work and some form of address entry for work might be required which could be searched and possible exits selected. Likewise the person may not remember all routes they have taken, but by entering their enter and exit position the system could search for the common routes that fit this profile.

Task 2. Determination of Maximum Weights, Sizes and In-Car Locations for PCDs.

Pagers

Since Pagers are small, light weight and already in wide use, it is reasonable to assume that their size and weight is satisfactory for the population of pager users. The limitations of pagers for the GENESIS application has little to do with weight and in spite of the small display size, they can perform their role for displaying limited traffic information. Thus, we devoted our attention in this report to the issues of larger devices such as laptops, notebooks, Newtons and Wizards. The readability of these devices was considered in a previous task.

Size and Weight of PDAs

There is an axiom in GENESIS that people will purchase computer/communication devices to serve many functions and not solely to receive transportation information. This implies that a device which could be ideal for serving GENESIS purposes, would not necessarily serve the broader functions required by the user population. This observation implies, in turn, that the evaluation of devices to serve the GENESIS functions¹⁷ must consider the multiple uses for which the devices were purchased. Therefore, we need only consider whether a given device can meet GENESIS requirements and not whether there is an excess of capability over minimum GENESIS needs. We know that more capable devices tend to be larger. An important device attribute that affects readability is display size. In Table 2 we see that there is a loose correlation between display size and device weight.

¹⁷GENESIS, System Function Allocation, November 29, 1993. Prepared for GENESIS Partners by Paul Hoffman, BRW.

Table 2
Weight and Screen Size of Prospective Devices¹⁸

	<u>Weight (lbs.)</u>	<u>Screen Diagonal (in.)</u>	<u>Cost (\$)</u>
----- PDA Hardware -----			
Amstrad Pen Pad	0.88	4.4	399
Apple Computers Inc. Apple Newton	0.91	4.75	699-949
AST Research Inc. GRID PalmPAD	2.9	6.5	2495
Dauphin Technology Desktop DTR-1	2.5	6.0	2495
Fujitsu Personal Systems 325 Point	1.6	7.25	2295
Tandy Z-PDA	1.6	7.25	699
----- Pen-Based Portables -----			
AST Research Grid Convertible	6	9.5	2995
EO Personal Communicator	2.2	7.5	1999-4000
IBM ThinkPad 710T	5.73	9.5	
MicroSlate Datellite 400L	5.5-7	9.5	5295
NEC VersaPad	4.2	9.4	3000
NEC UltraLite Versa Family	6.28	9.4	4269
PI Systems Infolio 160	3.44	9.5	2249
----- Keyboard-Based Portables -----			
Altima Traveler	3.9	8	
Toshiba T4500C	8.4	8.5	
ZEOS Contenda	3.9	7.4	

In Table 2 we also note a correlation between device size and cost. Screen diagonals of 9.5 inches accompany heavier as well as more costly devices. The IBM ThinkPad is approximately six times heavier than the Apple Newton but the ThinkPad has nearly five times the display area of the Newton. In light of the readability analysis in Task 1.3, the usability analysis in Task 1.4 and the safety comments in Task 3., we suggest that the larger displays will improve readability, usability and safety.

¹⁸The data in this table was taken from the PDA Hardware Comparison Table by Luanne M. Yuricek; IBM Federal Systems Company; October 28, 1993

When considering size and weight it is appropriate to consider potential impacts on people with disabilities. This includes older people with diminished strength due to aging and to common debilitating diseases such as arthritis. We have discussed this with Dr. Michael Wade, Head of the Division of Kinesiology at the University of Minnesota. We have also discussed this concern with three physicians in group practices. The consensus on this issue is that if a person is physically capable, even with electromechanical aids, of driving a car, then they are also capable of moving a ten pound box from home to car and car to office. Thus, this class of potential users is not excluded from the benefits of GENESIS because of size or weight considerations.

Location of Vehicle Controls and Displays

A study by Laux and Mayer¹⁹ looked at the effect of the location of controls and displays on the driving task. While their study was concerned with conventional controls and displays in cars, some of their findings apply to the use of PDAs in cars.

One of these findings was that drivers, even in unfamiliar cars, have expectations about the locations of displays and controls which aid in finding them while driving. Since GENESIS devices can be placed anywhere in the car, the beneficial effects of locational expectations will be reduced. Although there were no differences in locational expectancies between younger and older drivers, the older drivers did take longer to find controls placed in unfamiliar locations. They found that different display and control layouts imposed different attentional loads²⁰ on drivers as they searched for controls and displays while driving and this finding was especially prominent for older drivers.

The Laux and Mayer study clearly showed the advantages of having standard (familiar and expected) locations for displays and controls. We cannot expect that all GENESIS users will always locate their devices in the same location. We can also expect that a device placed on a car seat will move in accordance with the forces acting on it. This will not be an advantage for GENESIS users.

¹⁹Laux, L.F. and Mayer, D. (1991). Locating vehicle controls and displays: Effects of expectancy and age. Report sponsored by AAA Foundation for Traffic Safety, Washington, DC.

In a follow-up study Mayer and Laux²¹ studied the use of in-car displays by older drivers. In this study different types of displays and the use of color in displays was tested. This study essentially confirmed previous findings that older drivers have more trouble in dividing their attention and that they have slower response times in both acquiring information from displays and in responding to it.

Task 3. Safety Recommendation for Operational Test.

Introduction

The safety recommendations which follow concern both the ground rules for the Operational Test Evaluation of the PDA as well as the broader safety issues related to GENESIS. Although fewer people will be involved, safety during the Operational Test Evaluation Phase is a serious concern. While we cannot violate the laws of chance, we can make sure that we are not unduly increasing the likelihood of accidents. Simulation prior to full on-road testing is a step which should be considered. If, for example three out of the first five "GENESIS" cars should be in accidents, even accidents having nothing to do with GENESIS and entirely the other driver's fault, the GENESIS Project could come to an untimely end. This would be particularly true if there was personal injury. A prudent, although time-consuming approach, would involve simulation/off-road testing prior to the Operational Test Evaluation on-road testing.

Safety and Human Factors Guidelines

The National Working Group on IVHS Safety and Human Factors issued a report which specifically included safety concerns for implementations of ATIS.²² Some of the issues and recommendations identified by this working group have high relevance to GENESIS human factors. These are summarized in the following:

²⁰See the Task 3. subsection on attentional demands while driving.

²¹Mayer, D. and Laux, L.F. (1992). Evaluating vehicle displays for older drivers. Report sponsored by the AAA Foundation for Traffic Safety, Washington, DC.

- Environmental complexity (includes road configuration, signing, weather, and traffic) and information needs, singly and combined, place overlapping demands on attention, memory and decision-making for the driving task.
- We need better models of:
 - self, vehicle, environment and driving task (a mental model).
 - mental workload including spare information processing capacity.
- We lack understanding of drivers' cognitive and sensory-motor responses to highway incidents and unsafe maneuvering by other drivers.
- We must try to identify the best displays and controls to accommodate individual and group differences.
- We need to know the range of drivers' capabilities and limitations with respect to IVHS technology. The standard driver must be specified based on research results and not speculation.
- Among the many functions to be specified are: navigation, route planning and advice, emergency services, elected versus mandatory information, and driver priorities.
- We must determine sensory display modes (visual, auditory, text, graphic symbol, and HUD). Information from visual displays should be aggregated for successive glances. We should separate information which can be safely presented while driving from the complete set of needed information. Timing of information presentation might involve a consideration of speed, traffic density, headway, weather and driver characteristics such as age and ability.
- We must determine means for data entry and function selection (hard keys, soft keys, voice recognition, cursor control).
- We should strive to develop human factors guidelines for displays and controls for the multiple IVHS functions and for their integration.
- Data bases need significant improvement both in content and means of access, not only for researchers and designers but by the user population as well.
- We need to develop models which will help us to evaluate potential IVHS technology improvements.

In the latter regard, Levison at BBN Systems and Technologies, working with Paul Green at the University of Michigan Transportation Research Institute (UMTRI) and

²²IVHS Safety and Human Factors Considerations. Thomas Sheridan was the Group Leader for the ATIS Section. Sponsored by IVHS America. Report No. IVHS-AMER-ATMS-92-1, May 1992.

the U.S. DOT is developing a simulation model for driver's use of information received in the car.²³ If this model was complete, the GENESIS program could exercise the model based on the Preliminary Design and the work done since, particularly the Function Allocation. The model results could then be validated quickly in vehicle simulation and test-track or small scale on-road tests. Armed with these results and following the changes suggested by them, GENESIS could begin the Operation Test Evaluation Phase with greater confidence of success.

Older drivers and to a lesser extent younger drivers have visual deficits which may decrease the usefulness of GENESIS for them. The most serious losses of visual function consequent on aging are decreasing contrast sensitivity and loss of dynamic visual acuity. A decrease in the size of the visual fields also occurs on aging.²⁴ Both of these visual functions are important to safe driving yet they are not measured at drivers license examining stations. This, of course, means that there are many drivers with these and other visual impairments. Effects on display readability in this regard were noted above. In this section we are concerned with display size.

Although dynamic visual acuity has no direct role to play in reading the displayed messages, contrast sensitivity does. If ambient luminance is low or if the total luminance flux from the display is low, or if luminance contrast is low, or if any combination of these conditions pertains, then users will have difficulty reading messages on even the larger of the displays listed above. These observations hold for all users, and not just for older travelers. The situation is, however more difficult for older travelers. Furthermore, although visual functions such as dynamic visual acuity are not directly related to reading displayed messages, they may have a deleterious effect on safety and usability which may be aggravated by smaller display sizes. Below we discuss attentional issues which underlie the mechanism for this effect.

Populations at Risk

²³Levison, W.H. (1993) A simulation model for the use of in-vehicle information systems. Present at the TRB 1993 Annual Meeting.

²⁴Sylyk, J.P., Severing, K., and Fishman, G.A.. (1991) Peripheral visual field loss and driving performance. Washington, DC: AAA Foundation for Traffic Safety.

In the discussions above we have mentioned potential problems which various user groups might have with GENESIS. We have discussed travelers for whom English is not their first language; older travelers; travelers with visual deficits; travelers with physical disabilities and travelers with reading problems. In all instances we have concluded that if the problem is of a magnitude such that a license is still issued, then GENESIS creates no more of a problem for these travelers than for any other travelers. On the other hand, if the traveler is not licensed or is intoxicated with any drug including alcohol, GENESIS is not likely to play a role and even if the driver attempts to use GENESIS, safety may not be degraded much further.

We can conclude that GENESIS might decrease traveler safety. The extent of this decrease is important to know. This question is best answered in driving simulation experiments.

Divided Attention Issues in Driving

One of the critical problems of driving in an IVHS environment is the question of distributed attention. It is clear that the present trend for increased information in the driving environment (both inside with map navigation and personal devices) and outside (via variable message signs) places greater attentional demands on the driver. Also, we are aware that division of attention among multiple tasks leads to degradation of primary (steering) performance, especially in high demand (i.e., high traffic) conditions. The seminal work of Ivan Brown²⁵ at the Applied Psychology Unit in Cambridge, England attests to these performance changes. What is as yet unknown is the relationship between the division of attention and safety in terms of collision avoidance. We *do* know that attention is implicated far more in driving safety than is simple visual function. If divided attention was only related to the visual channel, then this would be a strong reason for using auditory displays. However, attention can be diverted from the primary task by auditory as well as visual displays.²⁶ This accounts for the poor relation between visual function as measured in driver screening and licensing tests and subsequent driving accident records. As divided

²⁵For example, Brown, I.D and Poulton, E.C. (1961). Measuring the spare mental capacity of car drivers by a subsidiary task. *Ergonomics*: 4, 35-40.

²⁶Brown, I.D. (1962). Measuring the "spare mental capacity" of car drivers by subsidiary auditory task. *Ergonomics* 5, 247-250.

attention is clearly a critical factor in safety, it is central to an understanding of how in-vehicle intelligent-traveler communication devices can be used.

Recent demonstration projects (such as Travtek or EC PROMETHEUS) provided displays within the vehicle, but required the driver to redirect vision away from the path of progress to assimilate information. The Travtek Advanced Traveler Interface System demonstration used a synthesized voice to present information to the driver.²⁷ The Travtek team concluded that voice was a desirable component for ATIS systems. In Travtek, safety was the putative reason why the driver could not reprogram the route guidance of the vehicle while in motion. However, as the driver was able to change displays (e.g., to time and date), and was able to reprogram routes if they had left their preset route, then distraction is a problem. In fact, in driving the vehicle it was frequently the case that the display became the center of attention and primary demands such as headway and velocity control were neglected with problematic results²⁸.

Attention takes a finite time to switch. Models of driver capability show that intermittent sampling of the forward view does provide the capability for vehicle control. The control problems arise in unusual or emergency conditions. Quite simply, this is why we can tune present head-down radio displays without a collision each time. However, increasing the time attention is spent looking inside the vehicle increases proportionately the opportunity for collision.

One potential solution offered for this switching dilemma is the use of heads-up displays in which information is presented on or in front of the windshield. Such vehicles are already in operation²⁹, although the information they display is non-vital and therefore represents a technical rather than human factors approach. There are,

²⁷Means, L.G., Carpenter, J.T., Szczublewski, F.E., Fleischman, R.N., Dingus, T.A., and Krage, M.K. (1992). Design of the Travtek auditory interface. General Motors Research Publication, Warren, MI.

²⁸McKnight, A.J. and McKnight, A.S. (1992) The effect of in-vehicle navigation information systems upon driver attention. Report on a grant from AAA Foundation for Traffic Safety, Washington, DC.

however, problems with heads-up displays in terms of "where" to present the information in terms of focus of the driver. If the displays are focused on the windshield, then attentional capture can leave the driver as blind as if they were looking in a different direction. This capturing effect is especially true if the driver is fatigued. There remains the time, in this case, to switch attention via switching of focus. If displays are focused at infinity then drivers must distinguish information from a constantly changing and probably cluttered background and this can become as demanding an attentional task as the inside-outside switching it was intended to alleviate. In short, information presentation within the vehicle is a trade-off with attention directed toward vehicle control. We must use our understanding of attention switching to distill superior design for communication messaging and interface designs for in-vehicle communication devices. The safety impact of these differing configurations under various levels of attentional demand as represented by higher or lower density traffic conditions should be evaluated. The initial evaluation should probably precede the on-road Operation Test Evaluation.

Reaction Time And Sight Distance

Reaction time research has identified many types of reaction times. Of special interest here is Perceptual Reaction Time.³⁰ PRT is the time it takes the driver to respond to a new piece of information. This is not just the time detect the presence of new information but the time to understand it and then respond to it. For car driving this time is 2.5 to 3.2 seconds depending on which investigator or organization is making the estimate. The point here is that at a PRT of 3.0 seconds and a speed of 55mph, a driver will travel about 220 feet before applying the brake. This is more than 10 car lengths which is much greater than the usual following distance, even in fairly heavy but flowing traffic.

AASHTO states that the minimum sight distance should be enough to enable a vehicle to stop before hitting a stationary object in its path. Decision sight distance, also according to AASHTO, is the distance required for a driver to detect a difficult-to-

²⁹The Volvo-Dynaguide graphical and text display which is part of the Trilogy project, is on a flexible stalk and can be located at the height of the windshield

³⁰Dewar, R. Hazardous road signs ahead. Ergonomics in Design, July 1993, pp 26-31.

perceive information source and then complete the required maneuver safely and efficiently. Just as PRT is much greater than simple visual motor reaction time, decision sight distance is greater than minimum sight distance.

The above distances and times are influenced by many environmental variables as well as operator skill, attentiveness, fatigue, age and physical ability. The issue here is the extent to which the use of GENESIS by the intended population, driving in the wide range of driving environments, contributes to the duration of reaction times and the length of sight distances. Based on the kind of information available, we can guess at the impact of GENESIS, however, only with empirical studies can we validate these guesses.

National Highway Traffic Safety Administration (NHTSA) Guidelines

We asked NHTSA for help in identifying human factors guidelines which applied to the GENESIS Project. Specifically we asked for guidelines covering the in-car use of small computers compatible with the GENESIS concept. NHTSA could offer no direct help. They suggested we consult guidelines related to cockpit human factors. We did consult the main human factors standard relating to displays and controls for cockpits.³¹ We judged that cockpit tasks are too different from the tasks involved in driving and using GENESIS devices. By in large it is more difficult and dangerous to drive a car in rush hour traffic than it is to fly from Minneapolis to Chicago.

In the cockpit at other than low altitude, the task analogous to steering is relatively simple. The trade-off is between heavy traffic, slick roadways, etc. and the need in the cockpit to control altitude. Instrument Flight Rules (IFR) landings, even at zero-zero visibility, while difficult, are very different from car driving. During IFR landings the pilots visual attention is fixed on displays and need not be shared between displays and out-the-window views. Landing on aircraft carriers is different than driving because it is such a practiced maneuver with little variability and done in the absence of

³¹Woodson, W.E. and Coburn, C. (1980). Recommended modifications to MIL-STD-1472B; Selected sections on controls, displays and related hardware. U.S. Army Missile Command, Addendum to Technical Report RS-CR-80-2, 249 pages.

traffic. In short Mil-Std-1472 offers little of value for the GENESIS problems of concern in this report.

Task 4. Human Factors Standards

Standards are valuable when they apply exactly or very closely to the case at hand. If, however, the standards do not apply, they should not be used. There are many cases when we would like to apply rigorously standards which are rigorously defined. This saves time since the problem was previously considered by a group of knowledgeable people who after much study and debate, defined a standard answer to a standard problem. Not all standards, however, are completely rigorous. It is instructive to consider briefly the difference in the nature of different kinds of standards by contrasting standards for parts used in the manufacture of say military and space hardware to human factors standards. If designers seek a fastener, they can consult standards for fasteners, discover the relevant attributes for fasteners and then usually find a standard part which has the desired attributes. As a side benefit, the part will cost much less than a customized version. In this case the circumstances which created the need for the fastener were nearly invariant. The designers needed to fasten one particular thing to another equally specified thing. These things and the circumstances in which they would be used were the invariant quantities. Human factors standards on the other hand, deal with people who are far from invariant. Human factors standards may also be required to deal with changing environments. Standard parts such as fasteners may be required to function in extremes of say temperature or pressure but they are insensitive to ordinary variables such as time of day, amount of available light, amount of training, and so on. People are sensitive to such environmental factors.

There are human factors or human engineering standards which relate but do not exactly conform to the use of GENESIS devices in the car. Standard devices which will be (or have been) purchased by GENESIS users can all be readily used in home and office. This aspect of their use poses no problems. It is the in-car use of these devices that has the potential for creating problems for users.

Published standards of which we are aware, do not specify devices for in-car use under all environmental and population variables. Instead, published standards treat more nominal environmental and population conditions and segments. As suggested

before in this report, we must trust the judgment of drivers not to use the device when workload is already high.

Standards can indicate baselines which show how far from "ideal" GENESIS conditions might be. For example in a study performed for the U.S. Airforce, Correll³², prepared the following data for a video monitor display specification.

Minimum Conventional Criteria

1. Symbol Set.

94 alphanumeric and special symbols of the ASCII 96 7-bit code table.

2. Symbol Format - Minimum.

63 characters per row

16 rows

3. Symbol Height - Minimum

3.5 mm

4. Symbol Definition - Minimum

5x7

5. Symbol Luminance - Minimum

25 ftL

6. Symbol Contrast Ratio - Minimum

4:1 with ambient illumination in range of 75-100 fc.

7. Percent Active Area - Minimum

0.75

8. Screen Orientation and Position.

³²Correll, E.L. (1979) Human engineering specification for legibility of alphanumeric symbology on video monitor displays. Defense and Civil Institute of Environmental Medicine Report 79X01, Downsview, Ontario, Canada.

The line of sight from the eyes of the viewer having 50th percentile eye height to the center of the screen for a viewing distance of 60 cm should be within 10-20 degrees below the horizontal line from the viewer's eyes; the plane of the screen should be within plus or minus 5 degrees of the plane normal to the viewer's line of sight.

9. Contrast Enhancement - Minimum

Anti-reflective treatment of screen surface.

10. User Controls - Minimum

Symbol luminance

11. Chromaticity

Green or white only.

Legibility Performance Criteria

1. Minimum Acceptable Corrected Reading Rate

CRR = 120 symbols per minute

2. Maximum acceptable reading error

RE = 3%

3. Maximum Acceptable Reading Error per Symbol

RES = 0.45%

4. Maximum Acceptable Confusion Error

CES = 0.30%

In the 1970s IBM published guidelines for visual display terminals. These guidelines are now in their 3rd edition.³³ This 65 page guideline covers the human optical system, visual display considerations, keyboards, workstation configurations, lighting, and acoustic noise. While all these topics are of great interest to GENESIS, none of the information applies directly to the range of ambient conditions in the driving environment.

³³Human Factors of Workstations with Visual Displays. (1984). IBM, San Jose, CA.

In another guideline which provides baseline information which cannot be applied directly to the GENESIS environment Shackel³⁴ shows reading rates which apply in the laboratory or classroom but not necessarily for a driver in a car. For example for silent reading for most literate adults, the range found was 250 - 350 words per minute (wpm) whereas for listening the comparable rate was 120-150 wpm.

Perhaps we should not assume that these rates apply for drivers who are reading or listening. In fact listening rates might well be comparable to or even exceed reading rates when driving workload is high. Thus design specifications need to be developed for car drivers. Either that or we can assume that performing certain GENESIS related tasks while driving is no worse than performing tasks which have not been shown to contribute to decreasing traffic safety.

In the Human Factors Design Handbook³⁵ Woodson has a chapter on special workplaces which includes a section on vehicle operator work stations. This chapter presents information on automobile design from the standpoint of the driver. Neither this chapter nor the lengthy chapter on visual displays directly applies to GENESIS. There are two reasons for this. The first is that participants in the Operational Test Evaluation will use commercially available devices which cannot be redesigned to suit GENESIS. This is not a serious drawback since these devices are usually well-designed for their intended uses. The second problem is that using these devices while they are on a car seat or hand-held, while driving, was not one of their intended uses. This problem may or may not be a drawback. It is definitely a drawback if it leads to unsafe driving practices. However, if drivers use these devices when the driving workload is low, the benefits may well outweigh the risks.

Woodson does list and discuss very general principles. Some of these principles are:

³⁴Shackel, B. (1979). The ergonomics of the man-computer interface. pp 299-324. In Man/Computer Communication, Vol 2., Infotech International Limited. Maidenhead, Berkshire, England.

³⁵Woodson, W.E. (1981) Human Factors Design Handbook. McGraw Hill Book Co., New York, 1047 pages.

- Use the simplest display concept commensurate with information transfer needs;
- Use the least precise display format commensurate with readout accuracy;
- Use the most natural or expected display format;
- Use the most effective display technique;
- Optimize visibility, conspicuousness, legibility and interpretability.

These are excellent design principles. Yet with the possible exception of adding auditory displays, they do not relate directly to GENESIS for the reasons listed above.

While the above standards do not directly relate to GENESIS, they can be used as guides for potential improvement in the use of display devices in the GENESIS context. That is, Woodson's principles (above) may compel us to ask questions about means for beneficially modifying the in-car environment so that the use of displays could be brought more in line with the principles. This stands in contrast to efforts to redesign the devices themselves.

In an SAE publication³⁶ there is a discussion of dual task performance and workload that is relevant to GENESIS. The authors make the point that if tasks competing for our attention depend on different resources, then task interference may be minimal. Unfortunately, in GENESIS both the driving and device reading tasks depend on the same resource; visual information processing. However, overall workload might be reduced by the addition of an auditory display. The authors cite work which supports this idea. The idea supported is that inter-modality response competition is reduced compared to using two single modality responses. However, the authors also point out pitfalls in the use of auditory displays:

- Certain kinds of tasks are not compatible with auditory display, especially tasks with spatial analog representations such as maps.
- While verbal messages are more compatibly presented via speech than print, the transience of speech suggest that a "visual echo" might be needed.
- If off-loading the visual channel requires parallel processing in the auditory channel, there no gain and perhaps a loss in information received.

³⁶Stokes, A., Wickens, C. and Kite, K. (1990) Display Technology, Human Factors Concepts. Society of Automotive Engineers, Inc., Warrendale, PA. 171 pages.

For GENESIS the implication of the above is that the auditory mode of information presentation should be in addition to and not a replacement for the visual mode.

Task 5. Define Training Requirements for Participants in The Operational Test Evaluation.

The first principle of training is that all potential test participants and any other personnel to use the devices in a vehicle, must be fully trained and familiar with the functions and safety requirements before ever stepping into a car. The training process should be exhaustive and require full competence in operating under all situations before on road testing should occur. The potential participants should be cautioned on in-traffic usage and encouraged to complete all programming and route determination prior to starting trips. From an operational test perspective the most important consideration is test participant safety. During training is the time to establish habits and usage rules which discourage unsafe operation.

The MITRE Corporation's Guidelines For Operational Test Evaluation Plans³⁷ stipulates that documentation of all training criteria should be complete and explicitly defined. This includes reference to meeting the criteria for proper selection of a representative sample of users. This means that careful planning must be done to include age groups, gender, and driving experience. This might require oversampling of specific groups (e.g., older drivers) to meet the criteria for generalization to the driving population. What this implies to training is that operation test personnel must be proficient in training all segments of the population with a potential emphasis on an older population and those unfamiliar with basic computer functions.

Before starting any evaluation the operational test staff must be fully trained in all configurations of the system, the data collection tasks to be completed by them, database management and analysis techniques, and person to person interaction training so that they may go out and train the potential test participants.

³⁷MITRE Corporation, (1993). Guidelines for Operational Test Evaluation Plans: Advanced Traveler Information Systems and Advanced Traffic Management Systems. WP 92W0000230S.

All participants should be trained before working with the GENESIS software in ways to evaluate the effectiveness and worth of the system. This allows a consistent reporting in the evaluation phase. The evaluation phase should include measures of user acceptance reflected in their attitudes and frequency of use. This will require an evaluation of the relationship between the system and the traveler behavior. This will be best accomplished by well trained participants.

Participants should be screened during training as to their willingness to participate and to keep accurate records. The test evaluation depends upon well trained and cooperative participants. If during the test participants do not use their devices or do not keep records the test evaluation will be insufficient for data analysis.

Task 6. Communication to Coordinate Efforts with SAIC, IBM, JHK, and Ray Starr.

The first communications specifically relevant to this study occurred during the GENESIS meeting at the end of November 1993. Frank Gozzo from IBM had prepared a list of prospective tasks which HFRL might do. These tasks, not surprisingly, primarily concerned human factors issues associated with the use of PDAs. This list of tasks had previously been submitted to Ray Starr at the GENESIS Program Office. Frank Gozzo and Stirling Stackhouse reviewed these tasks. All tasks were deemed important, within the realm of human factors and within the capabilities of HFRL.

A second discussion at the same GENESIS meeting took place between Robert Rausch from JHK and Stirling Stackhouse. JHK is using a Small Talk based rapid prototyping tool to create the graphical user interface for the fixed end. HFRL agreed to do a standard human factors analysis of a run-time version of this interface when it is completed in January 1994.

In early December Vaughan Inman from SAIC visited HFRL for an afternoon. We discussed two topics. The first was the then current version of the HFRL Statement of Work (SOW) for this study. No tasks for HFRL that were not related to the Operational Test Evaluation emerged from discussion of this first topic. The second topic was potential HFRL contributions to the Operational Test Evaluation. In a subsequent telephone conversation, HFRL agreed to send a draft version of a SOW to SAIC in mid-January 1994.

In early December 1993, HFRL prepared and submitted a SOW to Ray Starr for the work reported here. Ray suggested modifications to this SOW. These modifications

mainly dealt with work that was more relevant to Operational Test Evaluation than to the issues discussed in this report. These tasks were part of the request by IBM. Postponement to January would delay IBM's mobile-end work.

This report was forwarded to SAIC, IBM, JHK and Ray Starr on December 24, 1993. If HFRL receives comments on this report it will incorporate them and reissue this report.

