

Report of IVHS System Architecture Workshop

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Introduction

Bernard A. Galler

The IVHS System Architecture Workshop was supported by a grant from the University of Michigan College of Engineering, and co-sponsored by the IVHS AMERICA System Architecture Committee. It was held on the campus of the University of Michigan on October 24-25, 1991, and included 54 participants from 8 countries.

The general purpose of the workshop was to promote international harmony through science and technology, and the specific mechanism employed was to organize the meeting around five topics arising from current system architecture discussions. These topics might be regarded as meta-questions about the nature of system architectures to be developed over the coming years:

- (1) Is it desirable, or even possible, to aim for common functional requirements for an ATIS system for the entire world? For Europe, Japan, and North America, where do most of the current actions occur? Given the different cultures, geography, demography, perceived user requirements, and so on, in these diverse areas, is it realistic to aim at common interfaces?
- (2) Is it feasible to take a normative forecasting approach to aim for common functional requirements for an ATIS system on the basis of alternative future IVHS scenarios? Given the comprehensive and uncertain IVHS of the future, of which ATIS is a part, is it practical to design system architectures now that can accommodate most if not all of the future functions?
- (3) How necessary is it to achieve compatibility over time? That is, if expanding subsets of ATIS features are introduced which expand IVHS capabilities, how necessary is it that earlier versions continue to function as they did, under new, presumably more capable regimes?
- (4) Is it possible to agree on a process which would lead to an accepted set of functional requirements for a geographic region to be determined under (1) above? How should this process avoid the obvious conflicts of interest that come from existing products already in the field?

(5) What is the appropriate level of compatibility; i.e., can interfaces be specified at some level of abstraction among components of an ATIS system so that any concrete implementation which is consistent with the prescribed interfaces, but which may differ radically within each component from any other system, is acceptable as satisfying the agreed upon "standards"? How can the "hooks" be provided for other subareas of IVHS?

Position papers were solicited in each of the five areas, and one afternoon of the workshop was devoted to breakout sessions where the authors of the papers (with one replacement) were available as resource people. Questions were posed to each of the breakout sessions to help them focus in more detail on the topics they were considering. (The groups meeting on questions 2) and 3) met together, since they decided that they had a great deal in common. Both of their questions dealt with compatibility over time in the IVHS context.) Then the entire group reconvened in a plenary session to see what consensus could be achieved on recommendations to IVHS AMERICA and the rest of the IVHS community. While the emphasis was on Advanced Traveler Information Systems (ATIS), there was recognition and discussion regarding other areas of IVHS activity, such as ATMS, AVCS, APTS, and CVO.

The participants were invited according to a deliberate plan to include representatives of thirteen constituencies. These constituencies were spelled out in the proposal for the workshop which appears as Appendix A to this report. Included were such groups as IVHS experts from various geographic areas, national, state, and local government experts, equipment vendors, and consultants.

Each breakout session had a facilitator and a recorder. The facilitator then prepared a summary of the session discussion for presentation to the following day's plenary session. These summaries were subsequently expanded for inclusion in this report. Although the final session followed the presentations of the summaries at the workshop, the report on the final session by Prof. Kan Chen is presented here first, since it sums up the overall discussion, and in some sense is the *final word* of the workshop.

We hope that the areas of consensus, and there were several important ones, will influence the thinking of the global IVHS community toward better cooperation and more extensive exchange of information.

Conclusions and Recommendations

Kan Chen

In general, the workshop participants felt good about the experience of having worked together for two days on a wide range of issues surrounding system architecture of IVHS. Although many issues are yet to be resolved, the participants have found areas of agreement based on which concerted actions may be suggested. This section summarizes these areas of general agreement and some of the recommendations for future actions, as discussed at the closing plenary session of the workshop. Since the System Architecture Committee of IVHS AMERICA has endorsed the workshop, many of the specific recommendations have been targeted for that Committee. However, most of the following conclusions and recommendations should be of value to all the IVHS programs around the world, and to the IVHS community at large.

1. Specification of functional requirements is the first logical step toward the development of any system architecture. Originally it appeared that different cultural backgrounds of different countries might lead to different functional requirements, and might thus become the root cause of potential international conflicts in IVHS system architecture development. Discussion at the workshop revealed that IVHS: functional requirements are fairly common among all countries. The differentiation among countries is more sensitive at the level of strategy, which sets priorities and desirable time sequence in fulfilling the various IVHS functional requirements.
2. One possible implication of the above insight is that, while the IVHS system architectures in various countries may be different in the near future as they try to accommodate different functional requirements of high priority, they need not be fundamentally different in the long run if all countries try to accommodate the entire set of IVHS functional requirements. Another implication is that a list of functional requirements for IVHS system architecture design is operationally meaningful only if the list is prioritized. Such prioritization should also be useful for corporate strategy and product planning in the private sector.
3. System architecture is still a nebulous concept that has been ill-defined, and the diverse backgrounds of the workshop participants

- only exacerbated the difficulty in their discussion due to a lack of common terminology, or a common understanding of the same terms. There is a consensus, however, that system architecture should emphasize structure at the system level, not the physical level. Although system architecture is not synonymous with system design, it would be desirable for system architects to have done some concrete design work before they try to abstract the relevant architectural concept. The workshop participants have discussed both technical and organizational implications of IVHS system architecture. It would be helpful if they would separate the two discussions. It was agreed that, to help future discussions, formal international terminology standards (in the form of a common glossary) should be developed and agreed upon.
4. There was a consensus that temporal compatibility of IVHS system architecture, especially on the side of the highway infrastructure, should be achieved, even at some cost. As have been detailed in another section, both forward compatibility (to accommodate future needs) and backward compatibility (to accommodate older systems) should be achieved.
 5. There was also a general consensus that a high-level architecture model should be sought, spanning the maximum range of IVHS functionality; that is, across ATMS, ATIS, and AVCS. However, at a more specific level, an important issue has remained unresolved; namely, should we allow (and even encourage) separate parallel development of system architectures for ATMS/ATIS and for AVCS in the immediate future, or should we insist that comprehensive IVHS technologies be developed to span all three categories of and parallel development, as system architectures for ATMS/ATIS field tests have in fact been designed without much serious effort to assure their forward compatibility with AVCS requirements. It appears that this trend will continue unless researchers working on AVCS can demonstrate in the near future how different system architectures for ATMS/ATIS may have different capacities to accommodate AVCS functional requirements.
 6. In order to make smooth and rapid progress, the work on IVHS system architecture should try to incorporate and take advantage of existing architectural constructs as much as possible. However, it should be remembered that (a) none of the existing constructs fully satisfies the comprehensive needs of IVHS, and that such constructs

as OSI and GOSIP have been developed for digital communications only; and (b) communication is only one aspect, albeit a very important aspect, of IVHS. Thus, while they must not be ignored and can serve useful purposes, the existing architectural constructs, neither individually nor in aggregate, can be applied directly to IVHS without further adaptation and development.

7. Given the premises that IVHS system architecture must incorporate many existing architectural constructs, and that system architecture touches all IVHS technologies as they are linked together to perform total system functions, the system architecture process must facilitate many people in a diversity of organizations to play complementary roles, which could be both parallel and subsequent, in the overall process. Acknowledgedly an initial part of this process has been set in motion by IVHS AMERICA's System Architecture Committee, and by MITRE Corporation which has provided system engineering support for the U.S. federal IVHS program, but much more effort is needed to target additional steps to fit more people and more organizations, including those engaged in the growing number of IVHS field tests, into a larger process.
8. Two glaring gaps in the current IVHS system architecture process are (a) incorporation of functional requirements from IVHS programs and organizations outside of North America, and (b) coupling to, and inputs from, the ultimate users. To close the first gap, it was suggested that IVHS AMERICA headquarters should seek and establish formal policy agreements from relevant European and Japanese authorities to obtain documents on functional requirements and other related reports which have been issued by DRIVE/SECFO and Prometheus in Europe, and by VICS, SSVS and other programs in Japan. These agreements will not replace, but will facilitate, access to the information by professional individuals. Once the documents have been obtained by IVHS AMERICA, they should be made known to interested individuals through the Clearinghouse Subcommittee and the monthly newsletter of IVHS AMERICA. After the documents have been made available, there should be feedback to the European and Japanese authorities regarding the value of the materials in order to reinforce additional information sharing.
9. As to the second gap -- the lack of coupling to the ultimate users -- it was pointed out that while such organizations as American Automobile Association (AAA) and American Truck Association (ATA) have been playing useful surrogate roles, they cannot provide

the genuine, diverse, and in-depth perspectives of the ultimate users. On the other hand, the ultimate users may not have the interest and background to provide inputs and reactions to a new field like IVHS. A couple of suggestions were made to strengthen user ties. One suggestion was for IVHS AMERICA to direct all of its committees to involve ultimate users, or at least their surrogates. Another was to systematically organize or maintain contact with those ultimate users involved in the increasing number of IVHS field tests, and engage them in future IVHS system architecture discussions.

10. Given the centrality of system architecture in IVHS, it was recommended that the Coordinating Council of IVHS AMERICA should use system architecture, perhaps along with evaluation, as the hub of the coordination process. This may also apply to that part of the IVHS strategic planning process which tries to link the various parts of IVHS functions and technologies. The opinion was expressed that the current size of the Coordinating Council is too large to perform substantive coordination. It seems that the Council itself needs a coordinating group, which could use system architecture as a vehicle for substantive coordination.
11. The notion of supporting the development of a number of IVHS system architectures has been advanced by the IVHS AMERICA System Architecture Committee. While the notion has obvious merits, concerns were expressed regarding both the need for defining metrics for system performance and the need for defining the criteria for choosing competing teams. It would be desirable, and important, to have common tools and environments for comparative testing and evaluation of competing system architectures. This leads to the desirability of using common simulation packages and common testbed environments to do comparative evaluation of competing architectures. For simulation, it would be desirable to have common computer packages for high-level simulation (such as the one under development by MITRE for measuring system effectiveness), medium-level simulation (such as the one used by DRIVE to compare communication system requirements and performance), and low-level simulation (such as the microscopic traffic simulation developed by the Ontario Ministry of Transportation and Queen's University). The multiple testbeds of real traffic environments should be flexible enough to simulate future environments.
12. The participants felt that their experience in the workshop was particularly valuable because of the international and substantive

emphases. The question was raised near the end as to whether a sequel to this workshop would be worthwhile. One suggestion was to encourage a similar workshop (not necessarily on the subject of system architecture but related to IVHS) to be conducted just before or after the 1992 Vehicle Navigation and Information Systems Conference in Oslo, Norway, September 2-4. Perhaps a European university should take the lead in organizing that workshop (following Jim Neisch's recommendation to let the universities around the world facilitate the movement of international cooperation in IVHS). However, the future workshop, like this one, should be fully coordinated with IVHS AMERICA. Another suggestion was for all the IVHS AMERICA technical committees to consider using the workshop format to facilitate substantive discussions in some of their future meetings. This would make better use of the professional expertise of the technical committee members to collaborate in IVHS development.

Questions for the Breakout Sessions

Bernard A. Galler

(1) Geographic compatibility

- Is it desirable to have common functional requirements across geographic areas with possibly different cultures?
- Is it realistic to expect to achieve such compatibility, given diverse cultures, geography, demography, perceived user requirements, etc.?
- How would one achieve consensus as to what compatibility means?
- How would one achieve consensus on common functional requirements?
- Would it ever be possible to mandate compliance?

(2) Future IVHS Scenarios

- Is it feasible to take a normative forecasting approach to aim for common functional requirements for an ATIS system on the basis of alternative future IVHS scenarios?
- Is it practical to design system architectures now that can accommodate most if not all of the future functions?
- Is it possible to predict future scenarios with any confidence?
- Should current system architectures be restricted because of future possibilities, when normal obsolescence might remove barriers to accommodating future scenarios without such intervention?
- Can we predict that the public will buy into future scenarios? Do we have to predict that successfully?

(3) Compatibility over time

- Is it necessary to have compatibility over time?

- Won't normal obsolescence take care of incompatibilities?
- What about vehicles with older, less capable systems? Should they continue to function under new regimes? As well?
- What should the normal turnover period be? When is it safe to assume that an older architecture or technology is safely retired?
- Is there an obligation to guarantee that older systems continue to work when new systems are installed?
- What public policy questions are raised here? Is it simply a market question?

(4) The process

- Is it possible to agree on a process which will lead to an accepted system architecture?
- Can we expect that the process about to be launched by the IVHS America System Architecture Committee will be successful?
- How can the potential conflicts of interest be avoided? What about products already in the field?
- Are there de facto standards already that will not go away?
- Will everyone buy in at the end of the process?
- Is it possible/desirable for different industrial groups and/or universities to agree to concentrate on different parts of the IVHS spectrum so as to avoid duplication of effort at this stage of IVHS's growth cycle?

(5) Level of abstraction

- Is it possible to find the appropriate level of abstraction for describing interfaces?

- Is it realistic to assume that technologies will be able to change drastically on either side of such an interface without causing disruptions?
- Will it really be possible to maintain standard interfaces in the face of new technologies in the future?
- Should these interfaces, if they can be identified, be mandatory?
- What role should government play in establishing standard interfaces?

REPORT OF THE "GEOGRAPHIC COMPATIBILITY" GROUP 1

1. **LAUNCHING QUESTIONS:** The workshop organizers proposed the following questions to indicate the scope and thrust for this group:
 - 1) Is it desirable to have common functional requirements across geographic areas with possibly different cultures?
 - 2) Is it realistic to expect to achieve such compatibility, given diverse cultures, geography, demography, perceived user requirements, past history of IVHS development, etc.?
 - 3) How would one achieve consensus as to what compatibility means?
 - 4) How would one achieve consensus on common functional requirements?
 - 5) Would it ever be possible to mandate compliance?

2. **REPORT OVERVIEW:** The group discussion divided into two parts:
 - 1) an organizing (path-finding) exploration-type discussion, culminating in the decision to organize our considerations and conclusions by: Goals/Objectives; Strategies; and Functional Requirements.
 - 2) deciding which of the Goals, Strategies, and Requirements are sensitive to geographic and regional (and cultural) differences, and why.

A major section of this report will be devoted to each of the above parts, followed by a Conclusions section.

It should be noted that compatibility across countries and regions must include the "physical layer" as well as higher layers. But whenever our group encountered a physical layer item, we stopped that discussion, believing that was "engineering design" rather than architecture.

3. **EXPLORATORY DISCUSSIONS:** The meeting began by first viewing the launching questions. An early question was posed: "What Systems Architecture and Standards Progress has occurred in Europe, Japan, and the USA?" This question launched an exploratory type session which, upon review, divided into three categories:

- 1) IVHS experiences and consensus (or not) in Europe---from the deeply experienced European representative.
- 2) Interleaved comments about experiences and attitudes in Japan--these were more limited since the representative has been in the U.S. for the past 4.5 years.
- 3) Interleaved comments about attitudes and conditions in the U.S.--from either of the U.S. members.

This section will collect the comments/items under each of the three categories.

3.1 Report from Europe:

Particular countries have unique problems: i.e., Sweden has weather problems different from other European countries.

While there is no consensus on a finished architecture, there is a recognizable consensus in Europe on the RDS Standard and the Traffic Message Channel (TMC) pre-standard, which has been agreed-to by Great Britain, France, Germany and Sweden. TMC is now being tested, and is expected to be available in 2 to 3 years.

The logic for starting with RDS-TMC is that one does not need much infrastructure (it uses existing FM stations). Debate does exist about the limited capacity of RDS. However, if one notes that predictable items such as the recurring traffic volumes and the urban street maps can be placed a priori in the vehicle, the small capacity one-way RDS link can be used solely for the unpredictable (exception) events. Also, these facts are not sensitive to geographic differences. Thus, while some still contend that the RDS link is "too weak", many believe it will be adequate.

Many people contend that RDS is "too weak" (capacity too small) and recommend use of beacons; at one stage, it was stipulated that if beacons are installed at public expense the system must provide societal as opposed to user goals.

It was noted that, to make progress, one needs to gather together "all the actors" in the Transportation Plan, and that this was done in Europe. Sometimes public authorities are not technically up-to-date; such gatherings should not overlook the starting step of improving conventional control (of

traffic lights) strategies, and the integration of adjoining systems. When designing a system, "one sees the control system first"; then one sees the architecture.

It was stressed that looking at the situation in a comprehensive manner, including the Land-Use plans in a metropolitan area, is required. Progress IVHS requires working with the public authorities; it is not a self-organizing activity.

In Europe, it is widely agreed that stressing "Park and Ride" is the right approach to congestion; providing mobility is not an overriding goal (as it is in the U.S.)

Congestion-acceptance varies from region to region; in Italy one can see drivers reading the newspaper as they are delayed in congestion.

A study showed that an emergency calling system has a negligible cost-benefit performance (from the societal point of view), yet is highly desired by almost everyone.

3.2 Comments about Japan:

Japan and Europe, relative to the U.S., places societal goals higher than user (driver) goals. Thus, rapid transit is used much more by commuters (than in the U.S.). Busses may have their own communication capability, to deal with congestion. Many car owners use them only on holidays (or weekends).

Japan's cities (also Europe's) existed a long time before the car arrived (in the U.S., many city plans assumed the car's presence).

It was contended that it is "comfort" that is the strongest determinant in deciding whether a driver will choose to move to a rapid transit facility as an urban area is approached.

There are no street names in Japan; thus any route guidance system will differ from that in the U.S. and Europe.

The "gadget/toy" aspect seems unusually important in Japan; a single young male may have substantial discretionary spending ability, but with no house purchase, spends heavily on a car and TV. This is one contributor to the sales of navigators; while currently not extremely useful, they will "someday be useful".

3.3 U.S.-based Comments

It was contended, more than once, that the architecture will involve a set of "core functions" that are independent of geography and cultural boundaries, and that such core functions, which emphasize giving the drivers information and letting them choose which way is best, should be the starting point for our architecture discussions (at this point we began the list of functions shown in Fig. 3). Other functions have more speculative value, and may be privatized. (There appear to be a growing number of people who predict a staged process, where we will start with more basic functions and evolve to include more advanced ones).

The U.S. emphasizes users (drivers), as opposed to Societal, needs. "Mobility" appears to be written into the Constitution, as well as personal freedom.

In U.S. urban areas, it is now very costly to lay new highways (i.e. I-66 in Washington area; I-696 in S.E. Michigan)

IVHS is "not for lost tourists"; rather it is for commuters.

Congestion has now become a highly-ranked problem in citizen surveys, to which the legislators are responding.

The U.S. seems uniquely tolerant of drunk-driving (??).

The above exploratory discussion culminated in the suggestion that we pursue geographic (and regional) compatibility in terms of the three... separate items: Goals/Objectives; Strategies; and Functional Requirements.

4. **FOCUSSED DISCUSSIONS:** The last half of the working time was spent deliberating and constructing the relative sensitivity to geographic compatibility of the three areas just mentioned, with the results shown in Figs 1 through 3. Note that most of the goals are expected to be similar from region to region.

Fig. 1 indicates the goals believed to be insensitive to region, as well as those which are expected to be sensitive. When goals are in conflict, as in Mobility versus Environmental Health, the goal of a country is likely to be relatable to its level of industrial development.

Figure 1 GOALS AND OBJECTIVES

GEOGRAPHICAL/CULTURAL INSENSITIVE:

Safety

Environmental Health

Efficiency

- Travel Time
- Fuel
- Road Maintenance

User Comfort

Protect Privacy

GEOGRAPHICAL/CULTURAL SENSITIVE:

Relative Importance of user versus societal goals

Value of vehicular mobility versus mass transit

User purchase motives (e.g. Japan - purchase priorities)

Both the articulated and the unarticulated goals of a country will inevitably result in a Strategy, which may range from highly controlled by the government and authorities to laissez-faire. Fig.2 lists the determinants of strategies which are expected to be and those which are expected to be sensitive. Note that the vast majority of strategy-determinants are expected to be sensitive to regions and countries. This is perhaps the most important result of our session: the largest source of differences in different countries will occur in the strategies, and not the goals or the functions themselves.

Fig. 3. lists all of the functions that were considered during this session, and all were judged to be insensitive to region or country. Thus, it is emphasized again that it is the strategies, and somewhat less the goals, which can be expected to differ between regions. The functions themselves are not expected to differ at the architecture level, although they may possibly differ at the physical layer (design) level.

5. **CONCLUSIONS/RECOMMENDATIONS:** We recommend that any future considerations of the role of compatibility across regions be done in the separable terms of Goals/Objectives, Strategies, and Functions. The separation of these items will improve the ability to assess the future with respect to the differences that are likely to result in the different regions and countries.

For the goals, the issue of Societal versus User (Driver) goals are expected to differ in the different regions; the different stages of industrial development and the different physical and cultural heritages will also produce different goals. We conclude that the most differences will occur in the Strategies adopted by the various countries/regions due to the differences in the determinants listed. We expect that the functions themselves will have practically no geographic sensitivity.

We note that both the Goals and the Strategies of any region are of course dependent upon the introduction of any new significant event (like the gas shortage that occurred in 1973).

We recommend that the discussions and conclusions here be extended to include the physical layer (design) level, since it also is influential in compatibility across regions.

Finally, we note that the answer to the first two launching questions is "yes", based on the above. The last three questions appear to refer to the design

Figure 2 STRATEGY DETERMINANTS

INSENSITIVE:

Multi-modal Coordination

SENSITIVE:

Role of Litigation

Global versus Local Optimization

Acceptance of Technology

Acceptance of Authority

Master Plans for Urban Development

- Physical Plant
- Road Network
- Required Coordination

Acceptance of Congestion

Relative Contribution of IVHS to Congestion Resolution

- Road Construction
- Decrease Demand
- Pricing

Figure 3 FUNCTIONS

Congestion Information of Real-Time Unpredictable Events

Automatic Toll Billing/Debiting

Commercial Fleet Management

Traffic Surveillance

Incident Management

Route Guidance Information for Local Applications

Safe Driving

- Road and Environment Monitoring
- Proper Vehicle Operation
- Distance Warning and Control
- Intelligent Cruising
- Intelligent Manuevering

Portable 911

Yellow Pages

Traffic Management System (Control)

level, and therefore go beyond the architecture level limitation of this session.

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Joint Report from the Future IVHS Scenarios Group 2 & Compatibility Over Time Group 3

As the titles of these two groups indicate, this joint session focused on the future of IVHS, with particular emphasis devoted to forecasting new developments and needs in Advanced Traveler Information Systems (ATIS) and to addressing the issue of the compatibility over time of IVHS systems and products, especially ATIS.

Defining System Architecture

To set the table for discussion, the session began with a detailed discussion of the definition of "system architecture," and three candidate definitions were offered:

- (1) a generalized functional decomposition of system components aimed at describing what each component must do and not how it should do it;
- (2) a top-level, broad-strokes system design, and
- (3) a diagram of system interconnections, showing which components interface with which other components.

After much debate, the participants were unable to reach agreement on a correct or best definition, though they were able to specify some dimensions of a system architecture. These dimensions include providing for information flow within the system, controlling this information flow (e.g., determining flow rates and protocols), dividing the system into functional units that perform specific operations, and, not to be forgotten, allowing for the successful completion of some goal, such as providing navigation information to the driver of an automobile.

The participants also agreed that it would be both feasible and useful for the IVHS community to engage in a normative process of developing functional requirements for ATIS, provided that designers and engineers solicit and consider consumers' opinions and concerns. Nonetheless, the group recognizes that it is difficult to predict accurately the future development of any sociotechnological system, including IVHS. Among this assembled group of experts, for example, only 57% were confident that they could predict 80% of the functional characteristics that will be available in ATIS during the years 2000-2010. As for forecasting when

particular features would be deployed during this same period, none of the participants was confident of forecasting correct dates within a five-year window.

Plausible ATIS Futures

Therefore, recognizing what cannot be done, the participants moved on to a discussion of what is possible and concluded that it is feasible to design system architectures now that can accommodate most -- perhaps all -- of the ATIS functions that will be deployed through 2010. With this in mind, the participants next engaged in their own forecasting and developed a number of seemingly plausible IVHS futures, notably the following:

- (1) an ATIS that closely resembles that which is presented in the Mobility 2000 Final Report;
- (2) an ATIS that closely resembles that outlined in the IVHS AMERICA Strategic Plan;
- (3) an ATIS modeled on that being used in the Prometheus project; and;
- (4) an ATIS that resembles one or more of the wondrous visions of science-fiction writers, such as Isaac Asimov.

Temporal Compatibility

Compatibility over time of IVHS would appear to be an important issue to all involved in IVHS efforts. Business, for example, wants the unfettered latitude to pursue innovation and to market better products -- imperatives in a competitive consumer market. Consumers, on the other hand, want some guarantee or mandate that purchased ATIS will remain useful for some time to come and not require regular replacement, perhaps at a considerable cost. Given the potential for disagreement and controversy surrounding this issue, the participants of this joint session attempted to outline, in general terms, a reasonable compromise between the two extremes -- a compromise capable of fostering innovation, but not hostile to the notion of retaining compatibility between different generations of ATIS.

Forward Compatibility

First, the participants considered the issue of forward compatibility: in short, will an ATIS purchased today have the capability of interfacing with future ATIS components? The general consensus of the committee was that near-term, deployed architectures should have the ability to accommodate foreseeable future needs; in seeking to place a limit on how far into the future is reasonably foreseeable, ten years was a figure agreed to by the majority. In addition, the participants agreed that this goal should be met even if it entails some additional (not technologically essential in the short term) costs, e.g., providing support for options that do not currently exist, but that may soon exist.

Backward Compatibility

In addressing the issue of backward compatibility, the participants agreed that new systems should accommodate analogous features of older systems for at least the half-life of these older systems. If, however, it becomes extremely cheap to replace or upgrade older systems, then this requirement for backward compatibility should be relaxed in order to promote technological advance and, presumably, improved systems. At least one participant suggested that it may be better to subsidize upgrades or replacements for lower-income consumers than to block deployment of beneficial innovations; in this area, public policy clearly will play a large role in influencing the future development of IVHS.

Architecture Stability

Beyond the issues of forward and backward compatibility, the participants also agreed that once a system architecture is settled upon, committed to, and promulgated by those in the IVHS community, incompatible change should be very difficult to make, thus creating a stable architecture around which to design and create improved versions of existing features. Such a constraining atmosphere should not, however, restrict the development and deployment of new features, which may require architectures and systems greatly or wholly incompatible with those previously deployed.

Questions Needing Attention

In addition to the issues and questions debated and discussed by the participants, several areas requiring serious attention also were identified; among these are:

- (1) delineating the differences between a system architecture and a system design;
- (2) measuring and evaluating differences and potential conflicts between the goals and actions of individual consumers and society as a whole;
- (3) establishing a mechanism for addressing new events and developments within and affecting IVHS system architecture;
- (4) guarding against the temptation to oversell the potential benefits of IVHS; and
- (5) investigating the costs and benefits of portable 911 emergency service.

Conclusions

Debating and brainstorming together, the Future IVHS Scenarios Group and the Compatibility-Over-Time Group raised many crucial issues and concerns and outlined several areas of agreement and, at least, one area of protracted disagreement. The disagreement, mentioned several times already, concerns defining what constitutes a system architecture. Importantly, however, the group reached a consensus that forecasting common functional requirements is both a feasible and useful activity and that compatibility over time should be expected, at least in regard to features and functions that are foreseeable at this time.

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Report from the Process Breakout Group 4

This material summarizes the views of the breakout group that addressed the process of developing a systems architecture.

1) Definition of the term "Systems Architecture"

The discussion revealed that a very generalized level of systems architecture is needed to assure rapid, extensive, and secure deployment of IVHS in North America. Such an architecture will establish a set of conventions under which many, many different types of IVHS systems can be deployed in the future, ranging in functionality from ATMS through the ATIS, AVCS, APTS, CVO etc. regions of application as expressed by Mobility 2000. This architectural construct will support alternative system designs which may or may not be interoperable with one another. Wide applicability of the systems architecture is needed to enable broadly functional IVHS that can be tailored to applications and markets as needed, while still achieving an internal orderliness in the design for communication, networking, distribution of processing, data structures, and so on.

In an ATIS context, for example, the systems architecture would support any of a variety of communication media such as IR beacons, RF data broadcasts, digital cellular radio, etc. in a manner which molds each system according to the internal conventions but does not render them uniform in the simplest sense, or omni-operable. Clearly, an IR transceiver will not communicate with an RF infrastructure. Thus, *it is not the plan to use the systems architecture conventions to assure interoperability* of mobile equipment across all infrastructures. Rather, the architecture establishes that any complying system configuration would be extendable and buildable in the future by virtue of its conformance to certain conventions. And a high level of transferability of subsystem modules, components, and software would result.

True interoperability (i.e., where any equipped car will function on any road) must be attained by means of policies and presumably standards that serve to target specific system configurations for adoption. The FHWA, for example, could promote such an adoption policy and "enforce" it to a certain degree by making the provision of federal funds contingent upon adoption of the standard system configuration. Thus, interoperability of certain mobile and infrastructure equipment is achieved by standardizing upon configurational details, rather than by means of the architecture design, per se. Other system configurations which do not

"interoperate" with, say, nationally standardized equipment may also be very desirable for local or specialized application—and the architecture would support them.

The group did not attempt to define the content of this broad, high-level systems architecture, but rather agreed upon the goal of seeking an architecture having the generality implied above.

2) The Knowledge base for creating Systems Architecture

The task of creating a systems architecture for IVHS is a daunting one. The group noted that the fantastic complexity of the technical/legal/institutional/socioeconomic context for IVHS tends to humble those concerned with its systems architecture. Two specific responses to this state of humility seem reasonable. Namely, (1) there is a need to proceed with a variety of focussed studies on plausible IVHS system concepts so as to better acquaint individuals and organizations with factors that must be addressed in an overarching systems architecture, and (2) there is value in carefully examining existing constructs that have been already created for steering open system design and rendering broadly useful conventions for information systems.

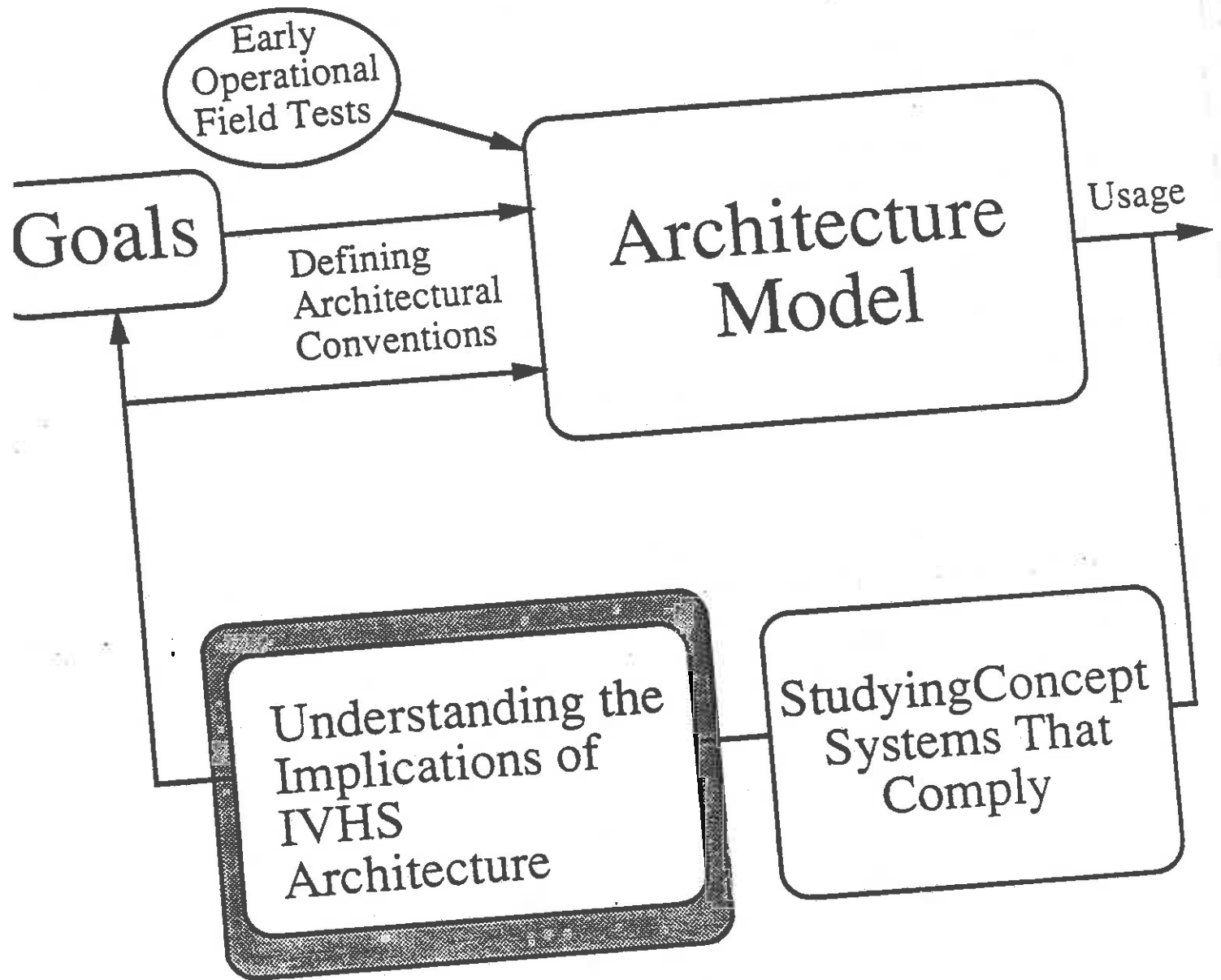
Focussed Studies

Relative to item (1), the group recognized the value of pending efforts by Mitre and by the Systems Architecture Committee of IVHS America to flesh out specific IVHS architecture concepts (each of which is presumably a system configuration for delivering a defined set of functions to the user.) The value, here, is in "learning by doing." The premise is that a great deal needs to be learned by those who will guide the drafting of a high level architecture convention. In the process of such focussed learning projects, the rest of the IVHS community should not become alarmed that the entire scope of interest in IVHS has been reduced to that functionality which is currently being studied. Rather, it recognizes that human knowledge is generally built up through a process of enlargement—basic arithmetic precedes fractions, then algebra, then trigonometry, then calculus. Of course it's also true that if the only focussed study of IVHS is confined to one or two narrow ranges of application, the IVHS community may become nervous that a functionally-limited architecture is in the making.

An illustration of the learning process is shown in Figure 1. The intention is to develop a sound "architecture model" which will serve as the high-level convention upon which all IVHS system designs are based. This

Figure 1

The process of Developing IVHS Architecture



model is "jump-started," so to speak, by the results of early field tests and research studies as well as by broad goals which are set by the community of stakeholders. At some point, a rough form of the model enables the definition of concept systems whose focussed study leads to a better understanding of the implications of systems architecture. Working through a feedback path, such understanding serves to refine both the goals and the model, itself. As time goes on, the warrant for operational field tests and studies that lie outside of the path (i.e., involving systems that do not "comply" with the evolving model) diminishes, such that most further development of the architecture model occurs within the loop.

Existing Constructs

With the explosion of information systems over the last thirty years, a large effort has already been applied to the development of conventions upon which communications, processing, networks, and data systems can be generically ordered. In one sense, such conventions serve to "manage the synergy" occurring across many organizations and applications so that the technology market grows expansively and efficiently. Recognizing that the world of information systems, altogether, is enormously larger than the world of IVHS, it will benefit the IVHS architecture effort to carefully study the conventions created by the information systems community. Relative to communications functions, the group acknowledges the OSI conventions and the governmental specification called GOSIP. For the ordering of distributed processing systems, the ODP convention is also seen as a prime resource. Assuming that such existing conventions are substantially transferable to IVHS, they should be given first consideration in developing an IVHS architecture model.

3) The Long Term Goal Toward Which the Architecture Model Must Contribute

Over the long run, we wish to foster a transition from "no IVHS" to "lots of IVHS" in North America. Our long term goal, therefore, is the achievement of the lots-of-IVHS implementation. Along the way, the development of an IVHS architecture model will play a significant role. But many other roles and interactions are also recognized, as sketched in Figure 2. The figure is not meant to portray a serial process but does illustrate that the architecture issue stands as one item within a host of highly interconnected steps and phases. For example, the achievement of a booming IVHS market will require activities such as:

- Coalition-Building
- Development of Specific Technologies
- Creation of Public Awareness

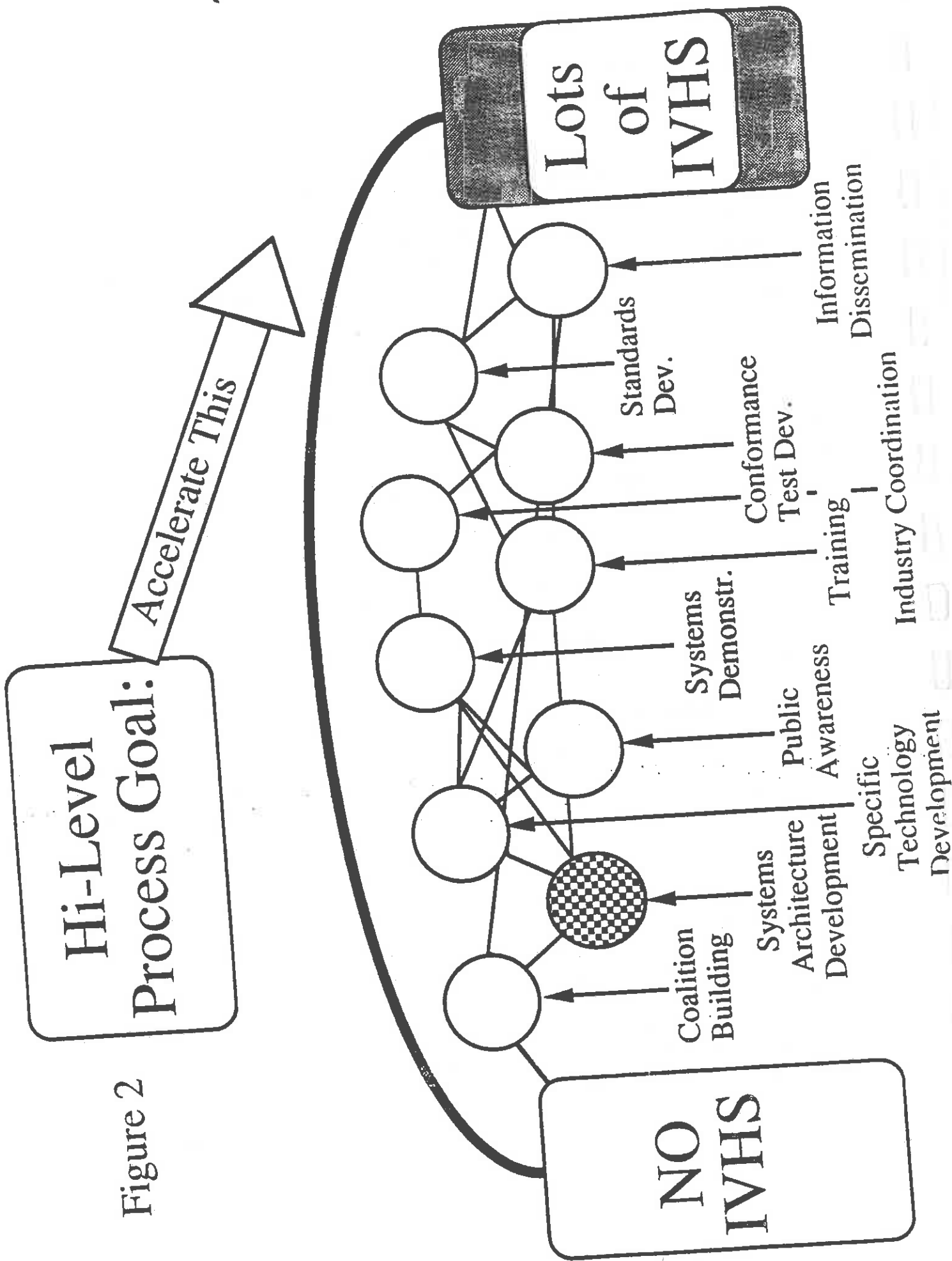


Figure 2

Demonstration of System Concepts
Training of Professionals and Tradespersons
Coordination of the Multi-source Industry
Development of Standards
Development of Conformance Tests
Dissemination of Information

While the list is not intended to be inclusive, it suggests that the development of a systems architecture will not proceed in a vacuum. In fact, it must reflect, both in its substance and its process the overarching "process goal" toward which it and all other IVHS activities tend: namely, acceleration into the IVHS era of ground transportation. Since many of the steps involve the same organizations and individuals, the movement will benefit if the development of systems architecture engages the parties that will be impacted by its contents in various downstream stages. In the selection of teams, for example, that will focus on concept systems during the next year or two, it would be prudent to preferentially consider those parties that have long-term roles to play.

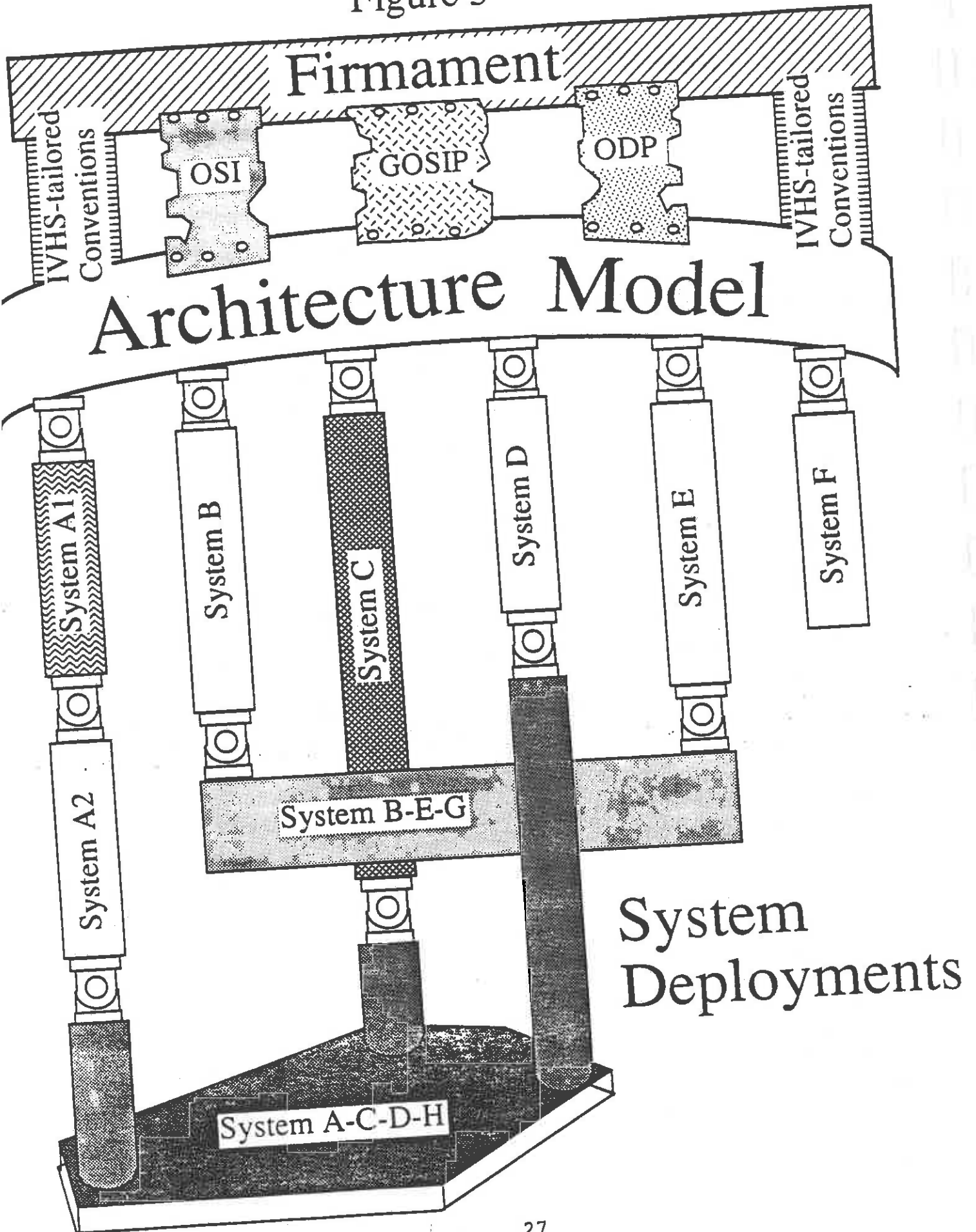
4) Assessment of "User Needs"

It was recognized that definition of a systems architecture requires the identification of user needs as the fundamental basis for setting goals. While user needs are more or less known in a qualitative sense, little or no work has been done to define user needs in a quantitative way. Further, it appears that proper description of user needs requires that IVHS functions addressing those needs be envisioned in advance such that user needs can be expressed in terms that are germane to their resolution through IVHS technology. Such an exercise has been conducted by the European community and reported in a SEFCO document entitled, "Functional Requirements." The group recommended that this document be studied in order to guide a corresponding effort to define user needs and functional requirements for IVHS in North America.

5) Macro View of Systems Architecture

Figure 3 is intended to illustrate a macro view of the "architectural model" which the group hopes to promote. The figure portrays the model, itself, as an overarching structure from which hang individual "system deployments" that actually provide service to road users. Individual systems become connected to the architecture model when they are designed in conformance with all of its conventions, thus warranting certification or "pedigree" under the IVHS Architecture Model. These

Figure 3



systems can be deployed as "stand-alone" packages (as in System F) or can be extended (as in Systems A1 and A2) and even bridged (as in Systems B-E-G and A-C-D-H) by virtue of a certain internal orderliness assured by the architecture model.

System "F" in the figure could be thought of, for example, as a form of Mayday system that employs a paging-type transmission. Such a system might be built to conform to the Architecture Model in order to benefit from conventions in defining, processing, and communicating data—even though the system might exist as a stand-alone deployment, not readily linked to other systems.

An illustrative scenario for System "B-E-G" can be offered using an analogy to the Japanese AMTICS and RACS packages. Namely, if a beacon-based RACS system (B) and an RF broadcast-type AMTICS system (E) were built to conform with the overarching architecture model, they could be later combined into one (G) type of bridging deployment by which a vehicle is seamlessly guided across beacon-only and broadcast-only territory. The dual functionality would be made possible due to the conventions afforded by the architecture model. Although the cross-link feature would require that vehicles employ dual communications equipment as well as other hardware and software supporting the hand-off between areas of beacon and broadcast coverage, the inherent build-ability is assured by means of the central architecture. While such cross-linking more or less describes the current Japanese effort under the VICS program, the architecture envisioned for North America would transcend the domain of this example and embrace a still broader range of systems and functions. One challenging task that lies ahead is to stake out this broader range, whatever it is.

The figure also indicates that the architecture model, itself, is connected to the "firmament" by elements that have been adapted from existing constructs such as OSI, GOSIP, and ODP, and by means of some conventions which will be tailored especially to meet IVHS needs. The adapted provisions are illustrated as somewhat raggedy since it's expected that some liberty must be taken to fit existing conventions to IVHS. The firmament represents the established practices of the information and communications systems community and the pervasive commercial base that supports it. Suspending all of the IVHS architectural enterprise upon this firmament confirms that the IVHS endeavor truly grows out of the state of practice already established by industries engaged in telecommunications, commercial and military aviation, computing, and so on.

6) Using Systems Architecture as a Coordination Point for IVHS America

Per a suggestion attributed to Mr. Gabe Heti of the Ontario Ministry of Transportation at the VNIS meeting, Figure 4 portrays an approach by which the work of technical committees in IVHS America may be loosely coordinated on the basis of their interaction with the systems architecture process. In this sense the provision of user needs and functional requirements as a basis for defining systems architecture, for example, derives from and feeds back to the "user/application" groups. The cross-cutting groups that deal with legal, institutional, benefits/evaluation & costs, and human factors & safety concerns serve to modify the approach to systems architecture in order that it square with human and socioeconomic realities. The prescriptions of systems architecture, together with the more targeted design work on system configurations, leads to the definition of standards.

While the group came to no consensus on the specific suggestion characterized by Figure 4, there was agreement that a unifying theme for IVHS coordination is definitely needed and that systems architecture may serve as a candidate theme.

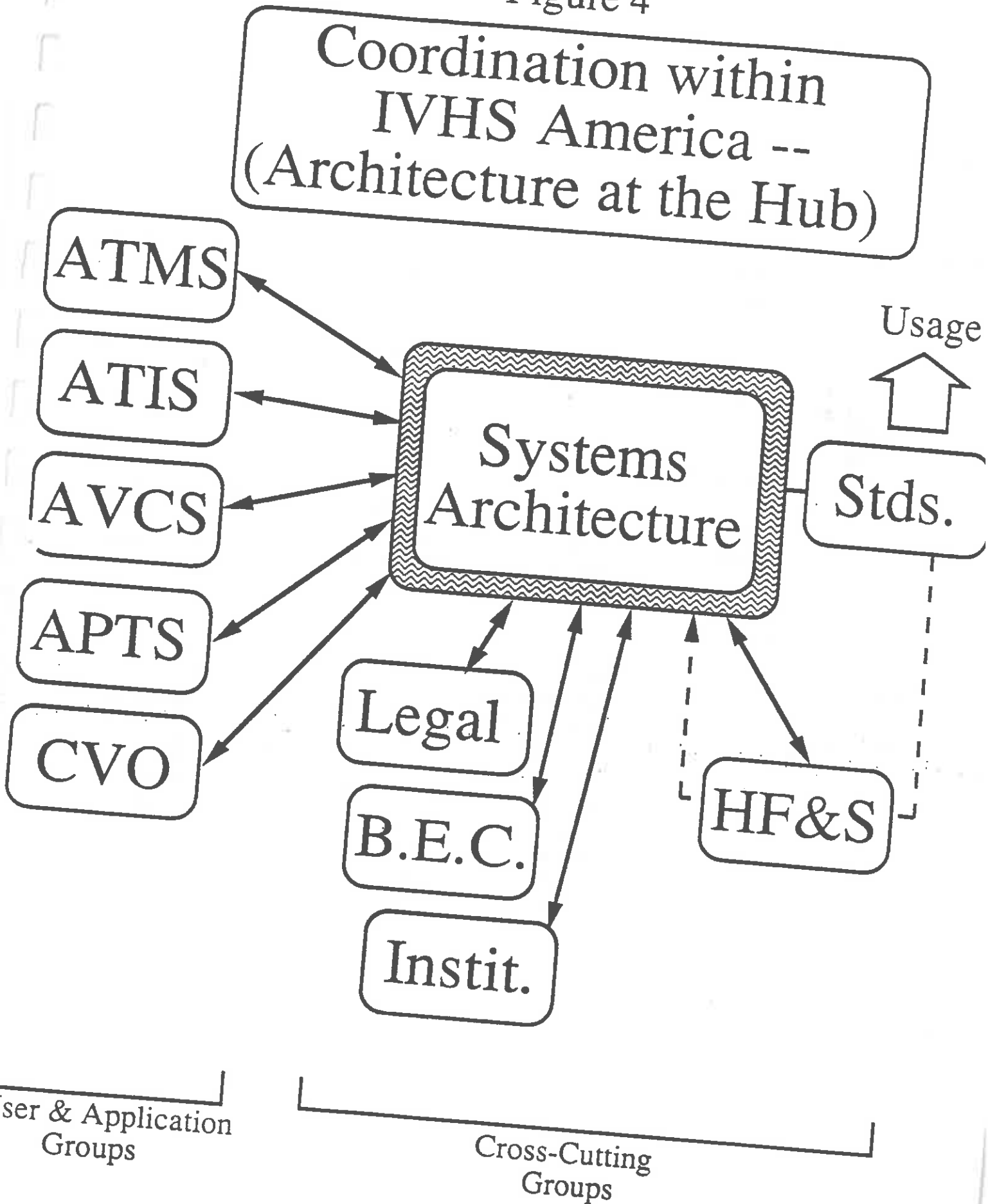
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Figure 4



Summary of the Session on Levels of Abstraction Group 5

Questions posed by the Workshop Organizers to this group:

- Is it possible to find the appropriate level of abstraction for describing interfaces?
- Is it realistic to assume that technologies will be able to change drastically on either side of such an interface without causing disruptions?
- Should these interfaces, if they can be identified, be mandatory?
- What role should government play in establishing standard interfaces?
- Does the appropriate level of abstraction depend on allocation of the frequency spectrum (or different frequency bands for IVHS), and on the choice between generic system architectures (e.g., vehicle-based versus infrastructure-based route guidance)?

(In the discussion, it was decided that the last question, as it related to frequency spectrum, was more properly the province of Group 1, especially since there was more expertise there, so it was not considered here.)

There was a lengthy discussion as to (1) what is meant by an architecture, and (2) how would one in fact "deliver" an architecture. What would one use as the description of an architecture? The group distinguished the following types of architecture descriptions: functional, physical, and "protocols." There was general agreement that we were not here considering physical descriptions of architectures.

It was suggested that to arrive at an architecture, one would move more or less in sequence (but more likely, iteratively) through the following stages:

- Service and system engineering objectives -->
- Overall integration framework (i.e., interfaces) -->
- Functional specifications -->
- Protocols for information flow across boundaries

and the last three stages would represent the deliverables, i.e., the description of the architecture.

The analogy was suggested of electronic mail moving across networks. There it was clear that cooperating networks had to provide gateways, or bridges, in order to allow communication between participants on different networks, and the interfaces had to be defined clearly. In order to provide such definitions, it was necessary to agree on the functions which each network promised to provide, and the protocols which each would use to specify which services it would be requesting on individual messages that crossed between the networks. These protocols had to embrace expected services, as well as the format of electronic mail addresses, and so on. Each network could provide many more services to its own members, but it would be understood that only certain services would be provided by other networks, and the gateways would only guarantee those services when passing information through from one network to another. In addition, it was noted that protocols for describing information service elements (i.e., specific functions to be provided) can be independent from the protocols for information flow (i.e., routing information, etc.)

It was generally agreed, then, that a similar situation applied to the evolution of IVHS interfaces; e.g., when new standards or protocols would be introduced in the future, existing products might need gateways, or bridges, to interface with other, possibly new components. In other words, while compatibility with products already in the field must be taken into consideration when deciding on interfaces, if the benefits warrant it, changes could be made. On the other hand, the ease with which bridges can be created to minimize the effects of such changes should also be taken into account.

The discussion then moved to an attempt to identify the interfaces that one would expect to define in an IVHS architecture. One example of part of the discussion will help clarify the resulting list of possible interfaces: One could consider the infrastructure to be everything external to the vehicle. Immediately one imagines a central Traffic Advisory Center (TAC). What about the roadside component? What about users at home communicating with both vehicles and the infrastructure? A person might

want to provide advice to a driver about a congestion report, or ask a question about congestion in a communication to the TAC. What about the operator of a fleet of vehicles? Do we provide explicitly for the interface between that operator and other components?

It is clear from that part of the discussion that there will be many interfaces in the overall system. The general principles that this group agreed to use were that (1) we were concerned primarily with the driver/vehicle/infrastructure system, and not sources of input (helicopters, police radios, etc.) or consumers of output (radio stations, etc.), although these were important constituents of the eventual overall system, and (2) it was better to identify at least one or two levels of interfaces below the obvious first level, such as driver - infrastructure, since identical or vacuous interfaces and components could be collapsed later, but it would be harder to break them out at a later time. Thus, the interface between a roadside component and the TAC should be explicitly included. In fact, the group ended up including local, regional, and central components of the infrastructure. Finally, there was an interface identified for a "user," possibly at home, communicating with the infrastructure, presumably the central TAC, but not necessarily. The list that resulted from such considerations was:

- 1. user - infrastructure
- 2. driver - vehicle
- 3. vehicle - infrastructure
- 4. vehicle - vehicle
- 5. infrastructure - infrastructure
- 6. operator - infrastructure
- 7. infrastructure: central - infrastructure: regional
- 8. infrastructure: regional - infrastructure: local

Moving to the level of abstraction for such interfaces, it was suggested, with general agreement, that the appropriate level of abstraction would allow the substitution of a new system component (with or without new technology) for an existing component of a system as long as the new component satisfied the interface description and protocols. In this sense, it had to be "plug-compatible."

There was agreement that it should be possible to define interfaces with the appropriate level of abstraction.

The group turned to consideration of the process under way by the IVHS System Architecture committee to generate a system architecture.

There was agreement that the resulting architecture should be strongly endorsed by industry and government, leading to guidelines. Together with what has been learned from ongoing field tests and products already in the marketplace by then, we can expect rapid convergence to accepted standards.

In the area of safety and limited resources (such as frequency spectrum), we can expect eventual mandatory standards, but there was strong resistance to having other aspects of the architecture become mandatory. The position of the group was that *there should be clearly defined guidelines for the industry and the public if we are to avoid arbitrary mandatory requirements. One can arrive at standards voluntarily without making them mandatory.*

The discussion then turned to how such conventions and standards would evolve. Again, there was general agreement that there has to be a free flow of information to accomplish this. In particular, data from field tests, and the methodology of evaluation of these field tests, must be made comparable, globally. There was strong support for the statement that testbeds should be developed for the evaluation of performance and other characteristics of various pilot systems in common environments.

It was suggested that Figure 1 of Huber's position paper for this session would serve as a useful logical framework in arriving at a system architecture, although it was recognized that the emphasis there was on communications, and other aspects of the framework would have to be fleshed out as well.

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A Proposal for an IVHS System Architecture Workshop
(endorsed by IVHS America System Architecture Committee,
and supported by a grant from IMRA America)

Bernard A. Galler and Kan Chen
Department of Electrical Engineering & Computer Science
University of Michigan

June 26, 1991

Introduction

In recent years we have seen increasing interest in Intelligent Vehicle-Highway systems (IVHS). Experimental, and even production, IVHS systems have begun to appear in Europe and Japan, and some systems are being developed in the North America now as well. Comparison of these systems reveals that each provides important features recognized as part of the "IVHS problem," but none solves the entire problem, whatever that is. What the problem is that needs eventually to be solved is, of course, part of the current dilemma.

Unfortunately, as a variety of partial solutions come into being, each introduces some incompatibility with the others. If we envision an overall solution some day, we also see the need for compatibility at some level, so that travelers moving from one geographic region to another will be able to benefit from the availability of IVHS resources in those regions without undue cost or delay. Unless some attention is paid to the problems of compatibility, early enough to reduce the costs of retrofitting systems because of possible later agreement on "standards," these costs could undercut all later efforts to achieve meaningful compatibility.

The workshop proposed here will explore the problems and opportunities toward achieving compatibility at least in the area of Advanced Traveler Information Systems (ATIS). If some agreements can be reached in this area, while taking into account interfaces with other aspects of IVHS, perhaps further efforts, both within the ATIS domain and in the wider IVHS domain would be made easier and more productive in the future.

There was agreement that the resulting architecture should be strongly endorsed by industry and government, leading to guidelines. Together with what has been learned from ongoing field tests and products already in the marketplace by then, we can expect rapid convergence to accepted standards.

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The Workshop

The purpose of the workshop would be to explore the feasibility of achieving some level of agreement on functional requirements in the ATIS domain. Specific questions to be discussed would be:

- (1) Is it desirable, or even possible, to aim for common functional requirements for an ATIS system for the entire world? For Europe, Japan, and North America, where do most of the current actions occur? Given the different cultures, geography, demography, perceived user requirements, and so on, in these diverse areas, is it realistic to aim at common interfaces?
- (2) Is it feasible to take a normative forecasting approach to aim for common functional requirements for an ATIS system on the basis of alternative future IVHS scenarios? Given the comprehensive and uncertain IVHS of the future, of which ATIS is a part, is it practical to design system architectures now that can accommodate most if not all of the future functions?
- (3) How necessary is it to achieve compatibility over time? That is, if expanding subsets of ATIS features are introduced which expand IVHS capabilities, how necessary is it that earlier versions continue to function as they did, under new, presumably more capable regimes?
- (4) Is it possible to agree on a process which would lead to an accepted set of functional requirements for a geographic region (to be determined under (1) above)? How should this process avoid the obvious conflicts of interest that come from existing products already in the field?
- (5) What is the appropriate level of compatibility; i.e., can interfaces be specified at some level of abstraction among components of an ATIS system so that any concrete implementation which is consistent with the prescribed interfaces, but which may differ radically within each component from any other system, is acceptable as satisfying the agreed upon "standards"? How can the "hooks" be provided for other subareas of IVHS?

We note that many of the topics listed above were discussed in the excellent paper by N. D. C. Wall and D. H. Williams, "DRIVE

Integrated Communications Infrastructure," presented recently at the DRIVE meeting in Brussels. We would recommend to each of the writers that the concepts presented in this paper serve as an example, if not the basis, for their position papers. This will give the workshop an immediate focus for discussion, whether the ideas and recommendations in that paper are adopted or not.

Organization of the workshop

A Program Committee has been established, consisting of Bernard A. Galler (chairman) and Kan Chen of the University of Michigan, Jack Kay (JKH & Associates), Robert Parsons (Parsons & Associates), Nigel Wall (British Telecom Research Labs), and Hironao Kawashima (Keio University). This committee will plan, organize, and conduct the workshop with the assistance of a Local Arrangements Committee. It is the responsibility of the Program Committee to determine the participant list for the workshop, and the writers of the position papers.

About 50 experts will be invited to attend the workshop, at a location convenient and accessible to them. The workshop will last two days, and will be based on invited position papers on each of the five topics outlined above. If there might be more than one view on a specific topic because of identifiable constituencies, more than one author may be invited to write on a specific issue.

The position papers will be distributed to expected attendees in advance for their consideration, and at the workshop there will be a plenary session to introduce all of them and answer preliminary questions. Then the group will break into parallel sessions to discuss each of the topics. On the second day, the groups will present their conclusions, their areas of disagreement, and their recommendations for further activity, for example, by the System Architecture Working Group of IVHS America.

Summaries of the presentations will be prepared by specially designated observers, for publication as a monograph, to be available to the interested public. The monograph will contain the original position papers, plus summaries of the discussions arising from them, and the group's recommendations for the future.

Representation

There should be at least some representation from each of the following constituencies to provide multiple perspectives during the parallel discussions of the principal topics outlined above. The relevant constituencies are:

- 1) European IVHS experts
- 2) Asia-Pacific IVHS experts
- 3) North American IVHS experts
- 4) U.S. Department of Transportation
- 5) State and local departments of transportation
- 6) Academic and non-profit institutions
- 7) Transportation vehicle vendors
- 8) Communications equipment and systems vendors
- 9) Experts on legal, sociological, and political IVHS matters
- 10) Public transit
- 11) Heavy vehicle (commercial) experts
- 12) IVHS America System Architecture Working Group representatives
- 13) Consultants

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 Marlin Ristenbatt - EECS
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 Kevin Balke - Texas AM
 Michael Bolton - AATA
 E. Ryerson Case - Canada
 Ian Catling - Ian Catling
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 James Chadwick - MITRE
 Clay Collier - NavTech
 Peter Davies - Castle Rock
 Michael Dearing - IMRA
 Leo DeFrain - MDOT
 Mahn Ahn Do - Nanyang Tech.
 Ronald Fisher - UMTA
 Ghassan Freij - DRIVE SECFO
 Stig Franzen - Saab
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*Some inaccuracies may occur.

Factors Bearing on the Issue of International Compatibility for Intelligent Vehicle/Highway Systems

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Introduction

Intelligent Vehicle/Highway Systems (IVHS) are being defined, designed and implemented in several areas of the world. In North America, Western Europe and Japan there are programs underway in varying stages of development. A great deal of research has been done in these three regions, leading to a better understanding of the system requirements, technical challenges and possible benefits associated with IVHS.

Although the United States had an active "smart car/smart highways" program underway in the 1960s, it failed to mature largely because it pre-dated the microprocessor era and the technology was unavailable to provide the functionalities necessary. Western Europe and Japan began work on IVHS in the 1980s, and undertook a large volume of research into IVHS technology areas. Both Western Europe and Japan have produced operational systems, though neither has implemented what could truly be called a fully operational wide-scale IVHS.

Within the past three years, the United States has re-kindled its interest in IVHS. In addition to the initiation of several ambitious demonstration projects in this country and Canada, work has begun on a plan to define, design and implement IVHS in North America. Under the leadership of the Federal Highway Administration, supported by a broadly constituted advisory organization - IVHS America, this work includes the development of a system architecture, the drafting of functional requirements and standards, and the structuring of a cooperative research and development (R&D) program that includes participation by all levels of government, as well as industry and universities.

For a variety of reasons, neither the European nor the Japanese IVHS programs widely shared the results of their earlier work with the North American countries. Although there are recent signs that this unfortunate situation may be changing, it remains difficult for researchers in this country to gain access to detailed information about foreign programs. It is apparent that a spirit of three-way cooperation will have to develop if there is to be international standardization for IVHS.

Despite the foregoing, the question of the feasibility, need or even desirability of aiming for commonality among the functional requirements in international IVHS programs is still

an open one. These three regions of the world are dramatically different in their cultural, geographic and demographic characteristics. Are they so different that the basic IVHS functions and their implementations will require separate solutions? If the IVHS implementations are different among regions, can common interfaces still be defined to facilitate the development of system components for international sale?

This paper presents a discussion of some of these issues

The Role of IVHS Functional Requirements

The definition of the functional requirements for IVHS in North America is far from complete. However, as the result of the activities of Mobility 2000, IVHS America technical committees, and various demonstration programs, a reasonably complete set of requirements is emerging. These requirements fit into a system architecture, the details of which are currently the focus of intense work.

In order to be able to accommodate the rapid rate at which technology advances and the new functional requirements that will develop as the public begins to use the systems, IVHS will have to be built around a very flexible and open system architecture. This same flexibility could be used as the basis for enabling possibilities for international coordination of functional requirements.

Barriers and Facilitators to the International Coordination of Functional Requirements

The barriers and facilitators associated with successful coordination of functional requirements for IVHS as a whole, or for any system subset like ATIS, fall into four categories: economic, geographic, demographic and cultural.

Economic Barriers and Facilitators

Whether an individual will invest in IVHS technology or not is a function of two factors: cost and benefit. At the extreme ends of the two factors (either very low or high cost, or overwhelming benefit), anomalies do occur, but in nearly all cases, the cost/benefit ratio has to fall within a range that is itself dependent on economics. However, the relationship for

IVHS technologies is not as simple as just standard of living per capita income.

As an example of the effect that regional economics has on IVHS, consider the fact that automobile manufacturers in the United States universally agree that there is a limit of around 300 for the cost of new systems in cars. It is sometimes characterized as "anything that costs more than air conditioning is not going to make it as a high-market-penetration item". Also consider that air conditioning has quantifiable, immediate and certain benefits. IVHS will have to establish itself in a similar manner to be equally successful in the marketplace.

The dollar limit in this country is derived from the fact that, for the majority of Americans, their car is their *second*-largest capital investment after their home. People in this country who would not hesitate to spend \$25,000 for an addition to their house would not spend the same amount on car add-ons. In fact, most wouldn't spend that much on the whole car, although that is getting steadily harder to do).

In Japan, however, the real estate market is so out of reach for a vast portion of the middle class, that *their* largest capital expenditure is their car. As a result, we have seen significant sales in Japan of IVHS systems that cost more than \$5,000. For that kind of money, though, the buyer expects to get a very high level of functionality - all of the "whistles and bells" that technology can provide.

Western Europe represents an amalgam of the two previous examples in many respects. Housing is less available to the middle class in some countries in Western Europe than it is in the United States, but it is still much more accessible than it is in Japan. As a result, there are probably not enough people in Western Europe who will spend "more than air conditioning" for IVHS systems to make that option viable.

Certainly, raw purchasing power will have an effect on the success of IVHS by country. The United States has a Gross National Product that is about equal to all of Western Europe, and almost double that of Japan. See Table 1.

Table 1. Gross National Product by Country
(billions)

United States	4,863.7
Japan	2,576.5
Germany	1,338.3
France	898.7
Italy	765.3
United Kingdom	738.0
Canada	390.1
Spain	301.8
Belgium	112.0

Considered in the light of balance-of-trade issues and general economic health, however, GNP doesn't translate directly into purchasing power, but it is an indicator. [The per capita incomes for the United States, Germany and Japan (1984) were \$21,800; \$10,000; and \$10,700 respectively, with the latter two increasing at twice the U.S. rate.] This has an interesting effect on the cost/benefit ratio discussed above. There is a cost, that is a function of personal income, beyond which an individual will not buy a product, regardless of the benefit it promises to deliver. Since that cost varies with country, it follows that the amount of functionality that can be affordably put into an IVHS system will vary as well.

Another economic factor is the price of fuel. According to a recent International Energy Agency Report, the price for a gallon of unleaded gasoline varies from \$1.15 in the United States to \$4.46 in Italy. The price in other countries is shown in the Table below.

Table 2. Price of Gasoline
(dollars/gallon)

United States	1.15
Germany	3.03
Spain	3.09
United Kingdom	3.23
France	3.47
Japan	3.49
Italy	4.46
[Western Europe - average]	3.46

With nearly a 4:1 range in the price of gasoline, the proposed fuel-saving features of IVHS offer widely varying incentives to would-be buyers of systems. As the benefits from IVHS relate to reduced vehicle operating costs, an Italian would probably be willing to spend more on (but also expect more from) IVHS features that offered fuel savings than would an American.

The size of the market for IVHS systems is a significant price determinant as well. As of the end of 1988 (the most recent figures available for all countries), the United States, with over 184 million, has more registered motor vehicles than Western Europe and Japan combined. (See Table 3.)

**Table 3. Registered Motor Vehicles by Country
(Millions)**

United States	184.4
Germany	34.4
Japan	29.8
France	26.9
Italy	26.3
United Kingdom	19.2
Canada	15.4
Spain	12.1
Belgium	3.8

It is apparent that economy of scale will have a large effect on the ultimate price of IVHS, if good market penetration can be arranged. Suppliers are going to do better tailoring their systems to the requirements of the United States or major European markets and hoping that other countries will accept similar functionality, than they will targeting a high-end Japanese market with no penetration in the United States or Western Europe because of the high cost. As a result, the idea of international functional requirements, except, perhaps at the most basic level, gets into trouble.

A final example of economic factors is that of privatization. In some countries, it may well happen that the role of government, beyond certain standards and system architecture issues, will be minimal. IVHS systems could be operated as profit-making entities like cellular telephone services. In other countries, government may play a larger role, underwriting the cost, at least at the supporting infrastructure level, of IVHS systems. It is evident that there will be a significant difference between the affordable levels of functionality between these two approaches.

Geographic Barriers and Facilitators

The geography of a country will influence the functionality of IVHS in a number of ways. The United States covers an area of more than 3.5 million square miles - more than three times that of Japan and Western Europe combined. It has 17 cities with a population between 500,000 and a million, and seven cities with a population of over one million people. Japan has nine cities with a population between 500,000 and one million and eleven cities with a population greater than a million, all in a land area of only about 146,000 square miles. The major countries of Western Europe cover an area of about 727,000 square miles and have large cities in the ranges stated above that number 22 and 12, respectively. The following Table summarizes other important geographical factors.

Table 4. Geographical Factors by Country

Country	Population	Pop. Density	% Urban *
United States	226.6	62.6	15
Japan	121.1	829.8	65
Germany	77.8	564.2	24
Italy	56.6	486.2	20
United Kingdom	55.8	591.8	12
France	54.3	258.7	14
Spain	37.7	193.7	16
Canada	26.2	6.8	45
Belgium	9.8	835.8	21

(* Estimated - residing in cities > 500,000)

Table 4 shows a wide variation (more than 13:1) in population density for these countries and about a 5:1 spread in the fraction of the population living in "large" cities. It is apparent that the functions needed by American and Western European drivers will differ from those needed in Japan. For example, IVHS functions for rural areas will be important for countries like the United States, the United Kingdom and France. Japan, on the other hand, may nearly ignore these functions in order to optimize their systems for hyper-congested urban environments.

Another geographical parameter of interest is the size of the highway infrastructure. The United States has more miles of highways than all of the other countries considered in this paper combined, but it also is far larger. Looking at the picture on a normalized basis for the United States, Japan and Germany, the picture is somewhat different, as is seen in Table 5.

**Table 5. Highway Area Density
(Miles of highway per square mile of area)**

United States	0.89
Germany	2.9
Japan	14.9

These figures reveal some major issues that will arise in IVHS system design and in the functionality provided. First, the United States will have to adopt an architecture that addresses the needs of a suburban and rural population (besides commuters in urban areas) over a much larger number of lane-miles of highway. This is true despite the recognized fact that the critical congestion problems that require the earliest attention involve commuters in urban environments. Further, those lane-miles are dispersed over much larger areas, dictating such factors as wide-area communications media, for example.

an, at the other extreme, has fewer total miles, but they are much more densely packed and a more localized communications medium may be feasible. In the extreme case, the vehicle densities in Japan may reach the point where local-area radio communications cannot handle the load, and all means such as infra-red beacons may be required.

inally, and perhaps of more significance than is currently apparent, the most obvious geographic difference between North America, Japan and Europe is the fact that the first two are (nearly) politically monolithic (Japan is an Island Arc; North America is composed of three very large-area countries), while "continental" Western Europe contains twelve countries in a relatively small area. There is a much larger incentive for Europe to adopt common functional requirements, because drivers routinely travel among several countries, even as commuters. [This same argument applies to IVHS systems in States within the United States].

These factors play a role in "internal-to-the-vehicle" subsystems like ATIS, because they effect data flows and the kind and quantity of data that the ATIS system has available to it. *Fundamentally, they will have a significant effect on the most basic issue in IVHS system architecture: the balance of intelligence between the highway infrastructure and the vehicles.*

Demographic Barriers and Facilitators

The demand for IVHS functionality in a country will be strongly influenced by the demographic factors that determine the number of people who drive cars and the attitudes of those people toward technology. Another factor that the author intuitively felt would be present is World War II, since it had a somewhat dramatic effect on the surviving population in the 18 to 30 year age range in some countries at a point in time between 45 and 55 years ago.

Somewhat surprisingly, the fraction of people of "driving age" in the United States, Japan and Germany shows very little variation (Table 6).

Table 6. Percent of Population by Age Group
(1986 data)

Country	1-19 yrs	20-64 yrs	Over 65 yrs
United States	29	59	12
Germany	29	60	10
Japan	24	62	14

Unexpectedly, the fraction of drivers that would be most likely to both want IVHS functions and be amenable to the technology is about the same for all three countries. What is

different, though, is the fact that a large fraction of the over-65 drivers in the United States are more likely to have driven a car most of their life than the corresponding group in the other two countries. They are thus more likely to drive later into their lives, and would be more likely users of IVHS functions (like ATIS) aimed at the needs of elderly drivers.

Examining birth rates for the United States, Germany and Japan, we find values of 11.2 for Japan, 12.9 for Germany and 15.9 for the United States. The first derivative of these rates is more illuminating. In the United States, the rate has remained about the same for seven years. The rates in Germany and Japan are both declining, to the extent that Germany's projected population by 2025 decreases about 6%. The net result of these data is that these countries will all have "aging populations" that are increasing during the period when IVHS is being implemented. It thus seems reasonable that some IVHS functions aimed at that group of drivers could be standardized internationally.

Cultural Barriers and Facilitators

As applied to IVHS, cultural factors can be divided into three groups: (1) acceptance of technology; (2) attitudes toward authority; and, (3) patience with delay.

Acceptance of technology is critical to the success of IVHS, but this factor is a two-way street. To be sure, the users have to have some level of technology acceptance, but more importantly, the system designers and implementers must make their products user-friendly. A related parameter is the rate of technology introduction. If one asked most drivers today if they would buy an end-state Advanced Vehicle Control System, they would respond negatively for a variety of reasons. But, if that technology is introduced incrementally over a period of several years, acceptance of the final "step" to full AVCS would probably meet little resistance.

Although trivial on the surface, the cultural desire for "gadgets" cannot be overlooked as a factor in IVHS acceptance in its early stages. As long as the human factors and real benefits are not ignored, cultural amplifiers of technology demand will drive functionality to some degree. An example of this phenomenon is the car radio. In the 1950s, the radios in high-end cars came equipped with station-scanning features. These radios were quite a bit more expensive in an absolute sense, but were in line with the cost of the cars in which they were installed. There was a benefit to the user, but the feature was more a "toy with a prestige factor". Today, nearly all car radios have station scanning, because the electronics to do it has become inexpensive, making the cost/benefit ratio favorable for the average buyer. But high-end gadget-lovers had to pave the way and pay for much of the early engineering.

Attitudes toward authority vary widely throughout the world. In the United States, drivers are adamant about personal freedoms, privacy and the like. These cultural biases will have to be addressed before functions like alternate routing, vehicle ID and AVCS are defined. In other societies that are more accustomed to a stronger government role in their lives, these factors are of little concern, especially if the national interest and personal benefits are high.

Patience with delay is a generic term for a broader cultural trait having to do with population density, zones of aggression and other factors. Within the scope of this paper, an example might be the best way to make the point. It has been reported that an IVHS experiment in Japan resulted in a reduction from 10 light-cycles to six in the time required for commuters to clear a specific intersection. Tolerance of such a delay on a regular basis by the average commuter in the United States is inconceivable. The functional requirements for IVHS will almost surely be different in different cultures to accommodate those attitudinal disparities.

Summary

The decision on the feasibility and/or desirability of international commonality for IVHS functional requirements is a multi-dimensional one. The factors involved are not technical, for the most part, and are thus not likely to be well understood or accommodated by engineers alone. The factors fundamentally represent a broadened definition of the term "Human Factors". Many of the concerns that drive a decision on internationalization of functional requirements for IVHS have their direct analog in decisions about national functional requirements standardization in the United States.

Acknowledgement

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IVHS-What is the Appropriate Level of Compatibility

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Introduction

This paper addresses the issues in defining a level of compatibility in Advanced Traveler Information Systems (ATIS) and, more globally, Intelligent Vehicle/Highway Systems (IVHS). This paper not only discusses the authors' recommendations on this compatibility, but also addresses the definition of the problem, the need for compatibility, the approach to the solution, and getting the process started. This compatibility is certainly a key to the success of implementing ATISs and IVHSs in the U.S. and worldwide.

The Problem

We face several problems in defining a level of compatibility for ATIS and IVHS. Some of the major roadblocks are as follows:

- Multiple IVHS subareas (ATIS, ATMS, CVO, etc.)
- Multiple, non-integrated initial trials and products
- Multiple communication options
- No explicit existing IVHS standards
- Many existing "general" standards (ANSI, CCITT, Bellcore, etc.)
- Many vendors with different focus (vehicle, communications, displays, etc.).

If left to develop on their own, the individual IVHS subareas will have little motivation to create compatible solutions. The wide variety of IVHS "customers", such as local, state, and federal DOTs, commercial fleet operators, and commuters, all have different needs as well as different economic motivators. Also, the technical requirements that result from those needs and "willingness to pay" can vary drastically.

Consistent with these different needs, many IVHS trials are taking place, and many more have been proposed. These non-integrated trials have utilized many different products and communication systems. Many vendors are working on second generation products that use proprietary communication protocols. The communication options available to ATIS and IVHS are numerous, from wireless technologies such as cellular, satellite, RDS, beacons, and private radio to emerging wireline options such as fiber and ISDN. Special characteristics and functions of each of these communication technologies will lead to installed systems with a variety of communication networks.

A key component to successful ATIS and IVHS implementations will be standards. Currently, no explicit IVHS standards exist, though many non-IVHS standards do exist. A wide variety of both wireless and wireline communication standards have been developed by national and international organizations. Several of these could be used for IVHS applications (ex. U.S. and GSM Digital Cellular), though the unique needs of IVHS will likely warrant IVHS-specific standardization.

Finally, there are many vendors in the IVHS arena with different areas of focus. Automobile manufacturers, communications vendors, display manufacturers, and computer suppliers, to name a few,

have valuable expertise and exciting technologies that can be applied to IVHS. Unfortunately, harnessing these assets in the pursuit of successful IVHSs will be difficult without adequate standardization.

The Need

The goal of those seeking success for IVHS should be a strong foundation of architecture and standards that will provide for the growth of all emerging IVHS systems. However, the creativity of the early entries into IVHS can not be stifled. Therefore we need to identify the key components of interoperability that will increase the value to the end customers. Truly seamless interoperability may be a noble goal, but the reality constraints are likely to lead to an initial set of core interoperability capabilities. Finally, the initial framework must be flexible enough to allow for the incorporation of changing customer needs and the expected advances in relevant technologies.

The Approach

The approach to defining an appropriate level of IVHS compatibility can be outlined as follows:

- Determine customer needs
- Specify required compatibility
- Develop architecture with OSI model base
- Identify service elements and protocol suites
- Identify options

The first critical job to be undertaken in defining an appropriate level of compatibility is to define customer needs. Unfortunately, the different IVHS subareas and even the needs within these subareas result in a long list of customer needs. We tend to think of the vehicle driver as the customer for IVHS. This thinking needs to be expanded to include at least the following additional customers: public safety personnel, highway maintenance personnel, government regulatory agencies, government planners, highway user groups (AAA, AARP, ...), toll authorities, vehicle manufacturers, trucking and transportation firms, and unions (Teamsters, ...). Any shortcut in accumulating and analyzing these needs will result in a rapidly antiquated architecture and interface design.

The needs of the above stated customers can be mapped to identified technical concepts (functions) to specify the most important functions for emphasis and compatibility. One approach that is a refinement of the basic input-process-output method is Quality Functional Deployment (QFD). QFD is being used by many major companies and has resulted in shorter concept to delivery time, fewer changes in later stages of deployment and increased customer acceptance.

Once the key, required interfaces have been identified, we can begin to develop an architecture by defining those interfaces as common, standard interfaces. The Open Systems Interconnect (OSI) Reference Model promulgated by the International Organization for Standardization and International Electrotechnical Committee (ISO/IEC) is the vehicle that can provide both the political and technical solution for our IVHS networking needs.

Using the determined knowledge of the needed network environment from our mapping of customer needs and technology options, we can now define service elements and protocol suite that will support the necessary quality of service, reliability, error rates, delay, etc.

Once the basic interface standards are agreed to, various vendors can determine the support for options within those standards. We would also expect IVHS extensions to be added to support message sets and classifications not currently identified in the specifications. In addition, vendors will likely add proprietary enhancements on top of the basic specs, much like the enhancements for vendor specific products that we see riding on top of Group 3 Fax.

The Model

IVHS adoption of the Open System Interconnection communications architecture will provide an environment that will support distributed processing in an open multivendor environment. Over 500 OSI standards exist or are in development in standards bodies such as ISO, CCITT and IEEE. This open standards process is vitally important in achieving the desired multivendor interoperability.

Figure 1 shows the overall architectural structure of the OSI model. This logical structure supports the communication needs of Application Processes through the partitioning of functions. The familiar seven layers are defined with each layer performing a particular set of communication functions and contributing to the overall functionality of an instance of communication. Each layer has associated layer services and protocols. The protocols are the rules of communication between systems, while the services model the interactions between the layers. The seven layer stack divides into two halves. The lower half (layers 1-4) deals with the transfer of information between end systems. The upper half (layers 5-7) deals with the semantics and syntax of the information being communicated and the structure of the dialogue to support communications between the end systems.

The applications are entities onto themselves that should be developed independent of the communications services and protocols. The availability and rapid deployment of applications will depend on our ability to define a common application programming interface for accessing the application layer services of Message Handling Services (MHS) for store and forward communications; File Transfer, Access and Management (FTAM) for file transfer; TP for transaction processing and Common Management Information Protocol (CMIP) for management. Further proliferation of applications will occur as IVHS object libraries are developed for programming interactions and code reuse.

The presentation of a common user interface to the end customer is perhaps the most important aspect of compatibility and the gaining of acceptance of IVHS systems. Ease of use will evolve as a very important ingredient to success. But designers always want to have the freedom to be creative and consistency in user interface is seen as a deterrent to creativity. The key will be realizing those interfaces that lead to ease of use. The automotive manufacturers already have one key example of the type of common interface that is being recommended. It's the PRNDL, park, reverse, neutral, drive and low. Designers can put the function on the column or on the console, they can display the operation with a pointer or with lamps; but the user perceived function and arrangement always remains intact. IVHS commands and operating procedures must be this

There are some functions whose control needs to span the seven layers, the application and the user interface. Important examples of such spanning functions are management, naming and addressing and security.

Implementation

It is our requirement that any given IVHS application must function over any given physical network. It is also required that different IVHS networks be able to interconnect and that an application function properly over any combination of physical networks.

As cited by Wall and Williams, three types of wireless vehicle-infrastructure information transfer will need to be supported for the currently known ATIS applications:

- Broadcast information
- Statistical up-link
- Individual communications.

Each of these types of information transfer have unique communication needs, and each has several alternatives for lower layer protocols.

Broadcast information, the simplest of the three types, is connectionless and requires a one-way infrastructure-to-vehicle data transfer. Several alternatives have been proposed by Wall, et. al. and others

for lower level communications (RDS-TMC, GSM Cellular, Paging, etc.). Any of these alternatives could probably satisfy the needs of simple broadcast data transfer, though one would need to be chosen for any given country or region.

The statistical up-link information transfer is likely connectionless and arguably less critical than either broadcast information or individual communications. Occasional transmission failures can be tolerated, though more complicated in-vehicle equipment is required than is necessary for broadcast data transfer. Again, several alternatives have been proposed (IR and RF beacons, digital cellular, private radio), and one solution needs to be selected for a given region. Perhaps with the one-way vehicle-to-infrastructure nature of this communication, more than one method could be tolerated, given existing infrastructures (i.e. cellular) and the relatively low number of infrastructure-based receivers.

Finally, individual point-to-point information transfer is connection-oriented and requires the most sophisticated data transfer of these items. The two-way link between the vehicle and infrastructure necessitates the use of mediums such as cellular, private radio, or possibly satellites. Dual-purpose in-vehicle units are not practical, therefore a given infrastructure would need to accommodate multiple types of in-vehicle equipment.

There are three key elements of the OSI model that address the capabilities of interoperation between alternative physical networks:

- the service provided to the transport layer by the network layer: this can be either Connection Oriented Network Service (CONS) or Connectionless Network Service (CLNS).
- the method for networking of networks: this can be either hop-by-hop concatenation or internetworking.
- the nature of the service provided by each individual network: this can be either connection oriented (e.g. an X.25 public data network) or connectionless (e.g. a LAN using logical link control 1).

The hop-by-hop concatenation method is used for networking of subnetworks in support of CONS. The internetworking protocol method is used for networking of subnetworks in support of CLNS. Figure 2 illustrates the protocol stacks to accomplish both of these methods. Internetworking between a CONS and a CLNS end system is very difficult and can be achieved only in very limited circumstances. Support for both CONS and CLNS may be necessary to avoid creating non-communicative islands.

An attractive approach to getting agreement on an IVHS OSI Architecture would be the adoption of the United States Government OSI Profile (GOSIP). GOSIP defines and describes a common set of data communication protocols which enables systems developed by different vendors to interoperate and enable the users different applications on these systems to exchange information. Shown in Figure 3 is Version 2 of GOSIP, approved in the Spring of 1991, which supports both connection and connectionless services. The U.S. government has not only embraced both the philosophy and protocols of OSI but it has already established a comprehensive conformance testing.

There is a need to define a standard within the application layer of the reference model that has particular capabilities for supporting IVHS communications and information exchange. Needed is an Intelligent Vehicle and Highway System Service Description and Protocol Specification. The authors recommend that the American National Standard Z39.50, Information Retrieval Service Definition and Protocol Specification for Library Applications be considered as the model for IVHS. Such an IVHS Service Definition would describe the activities between two IVHS end systems that the protocol must support; while the protocol specification would include the definition of the protocol control information, the rules for exchanging this information, and the conformance requirements to be met by implementations of this protocol. The first step is to define a robust set of basic IVHS service elements. Some potential candidates are: locate, movement, search, and account. Identifying a good set of basic service elements will be a critical and difficult activity. In addition to agreeing on the basic service elements, we need to agree on the protocol specification, usage and values for each service element.

Another standard's area where important work has been done that can be applied to IVHS is the Application Programming Interface work of X/Open and IEEE. X/Open has defined MHS, FTAM and TP APIs for Unix and a CMIP API is under development. Operating System independent APIs specifications are also being standardized through IEEE.

Conclusion

There are several key activities that need to be addressed in order to achieve the desired compatibility between IVHS systems.

- All user needs must be identified. Users might or might not know what they need. Determining the actual needs is a difficult and necessary task.
- Achieving network and application independence will require the adoption of a suite of IVHS standards. The current GOSIP specifications provide an attractive starting point. If agreement can be reached to begin with GOSIP and make modifications from that core decision, much time and frustration will be saved.
- Creation of an IVHS Service Definition and Protocol Specification is needed and Z39.50 for Library Applications may provide a beginning structure.
- The specification of a common application programming interface and the creation of an IVHS object library will speed the deployment of compatible applications.
- Consistent user interface elements will speed IVHS acceptance but will likely be difficult to achieve for several years.

These are all difficult tasks that will require demanding customers and motivated participants to achieve success.

Acknowledgements

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OSI OVERVIEW

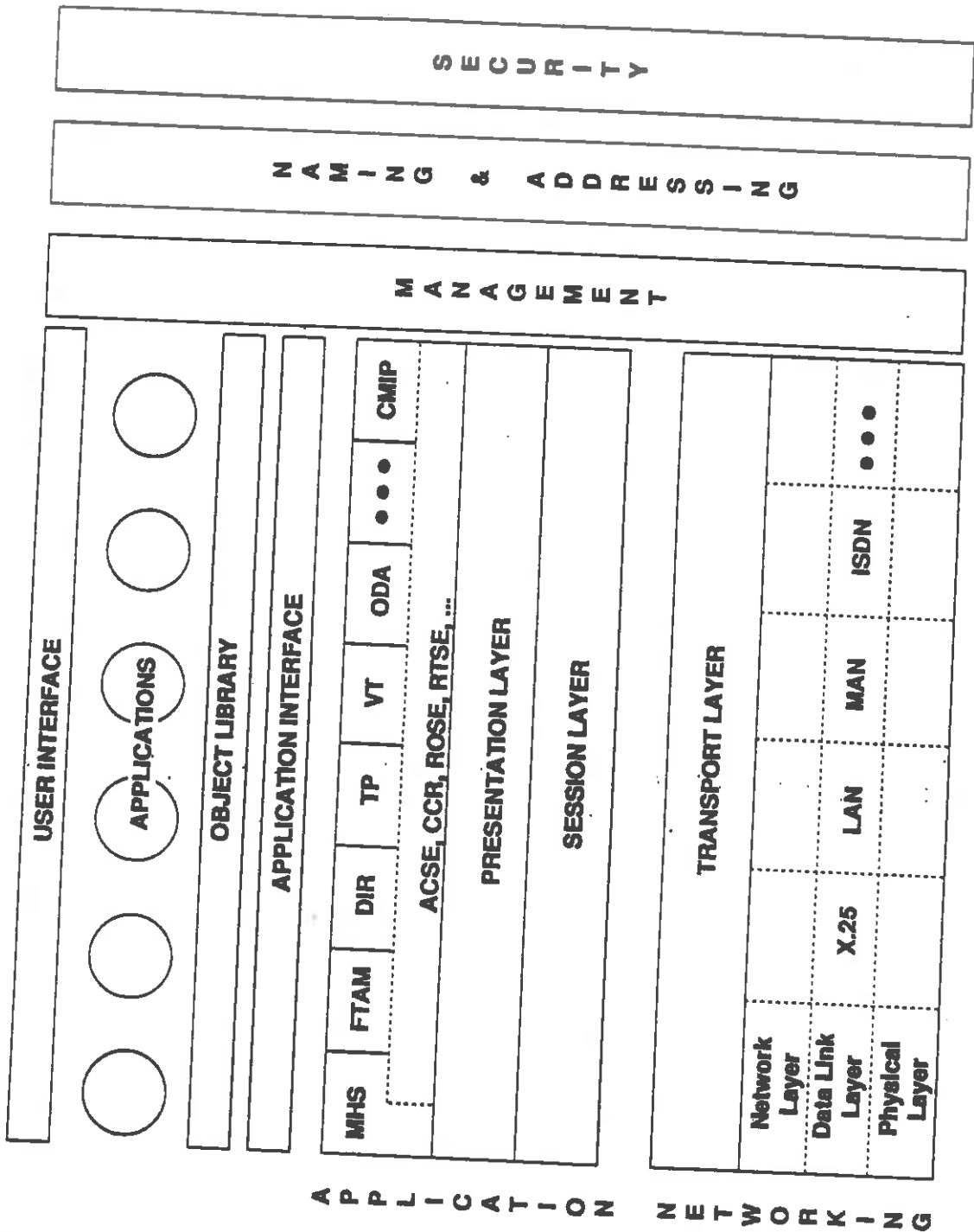
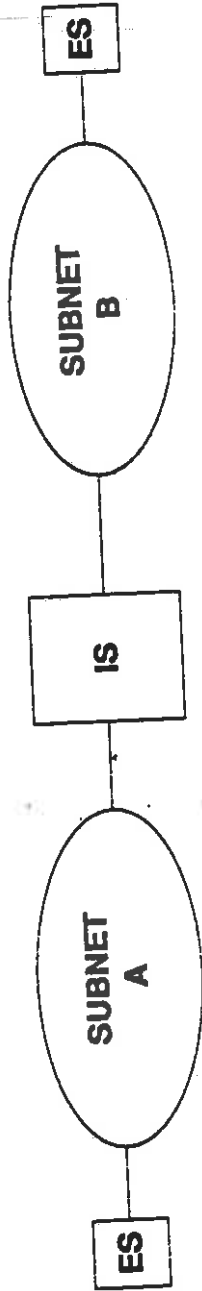


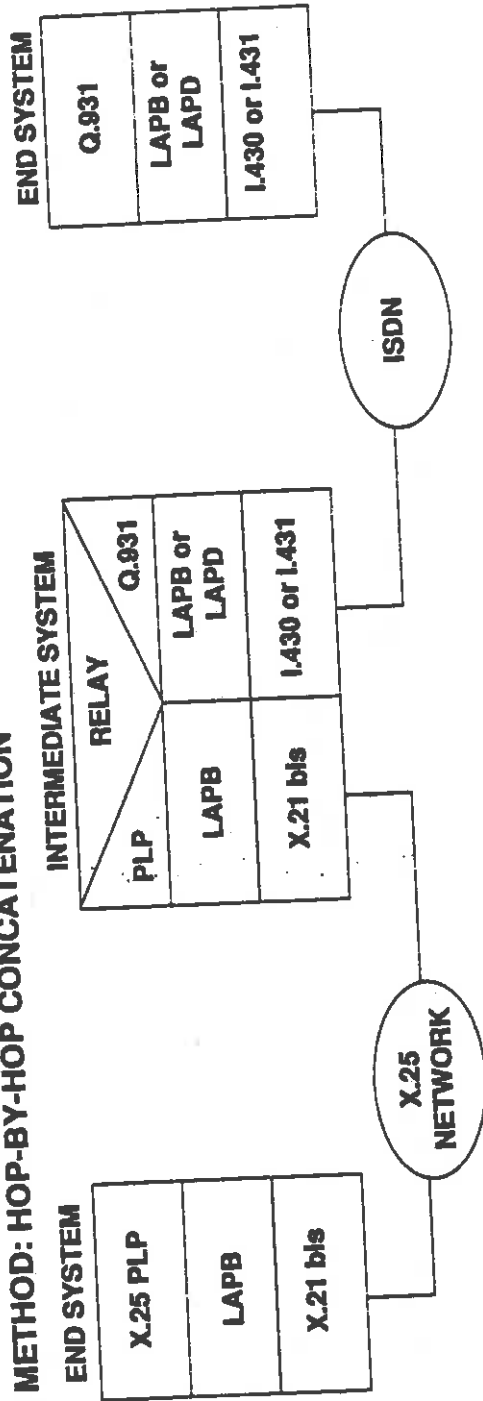
FIGURE 1

KMH0121

OSI NETWORKING OF NETWORKS



CO METHOD: HOP-BY-HOP CONCATENATION



CL METHOD: INTERWORKING PROTOCOL

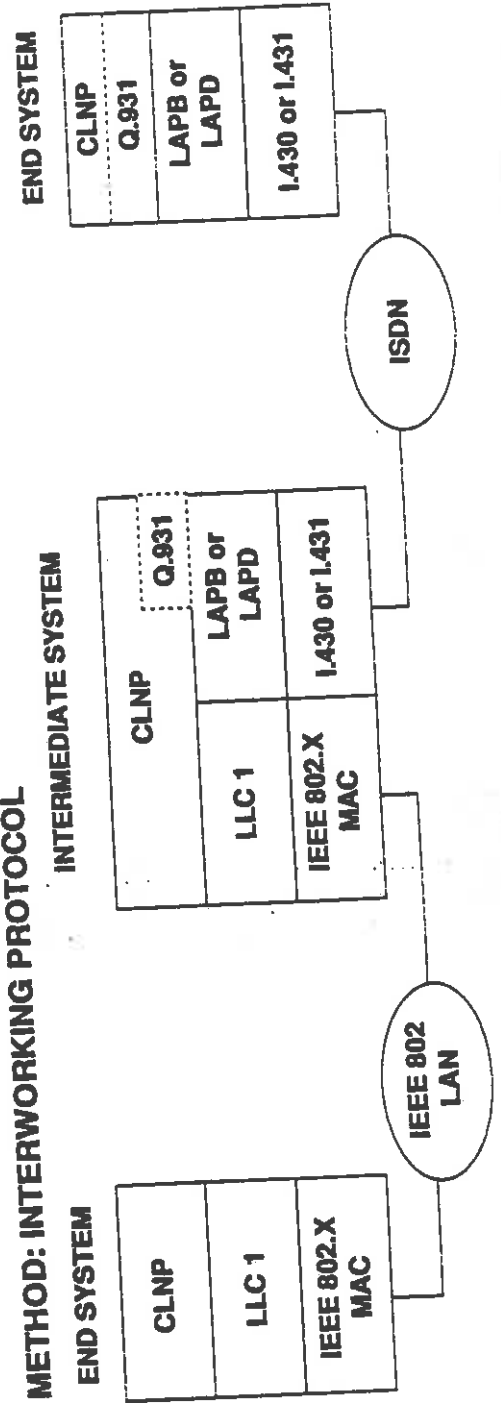


FIGURE 2

IVHS OSI ARCHITECTURE

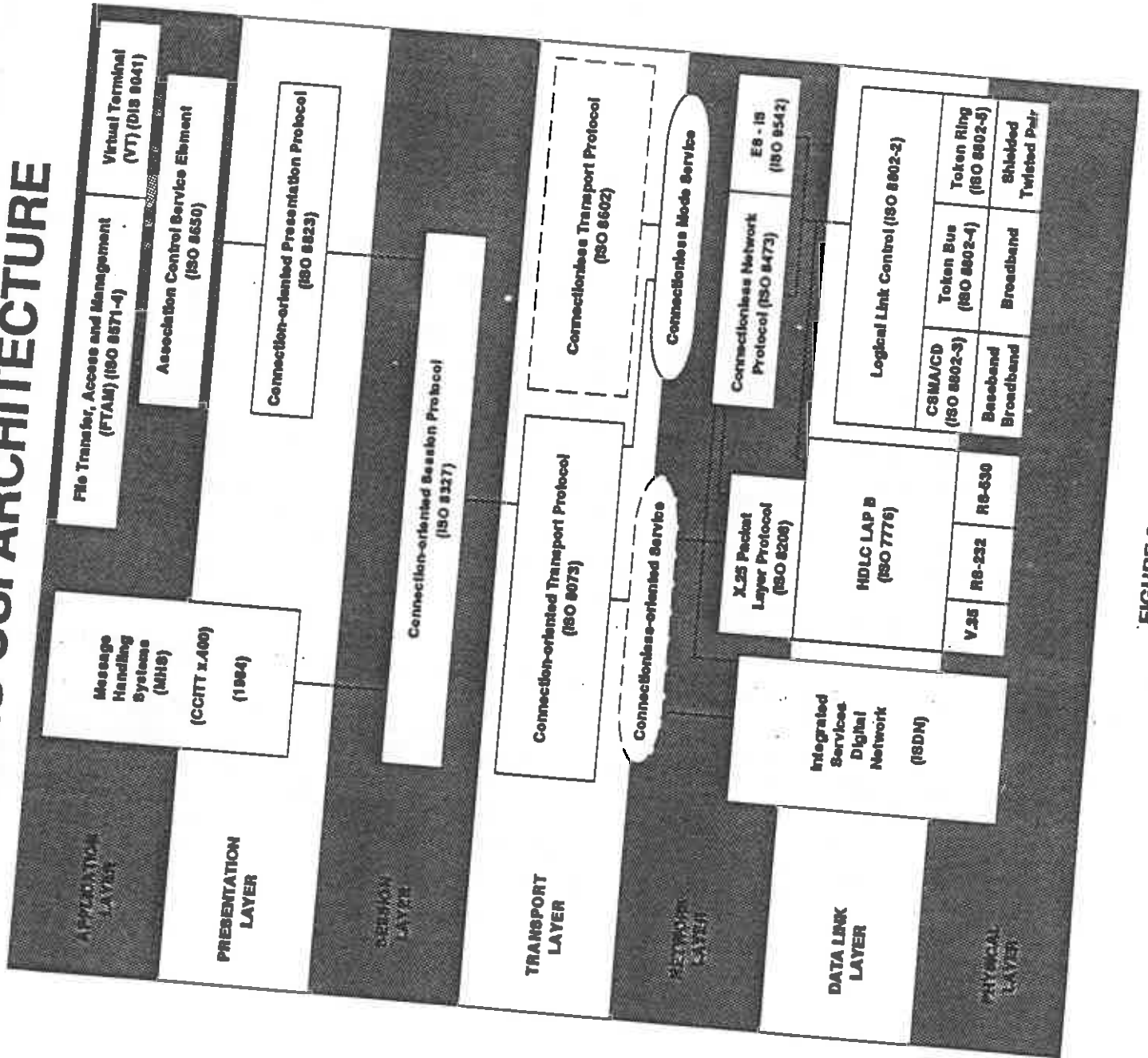


FIGURE 3

A Candidate IVHS Systems Architecture Process

by Nancy Rantowich
Hughes Aircraft Company

Purpose – The purpose of this architecture development process is to produce cost-effective, evolutionary IVHS architecture concepts that will continue to meet IVHS objectives as traffic conditions, technologies, solutions, and political and social environments progress and change over the next 20 years. Architecture development includes selecting IVHS content and functions (and showing its evolution over time), and delineating information needs, data flows, and interface specifications. Multiple architectures are developed, as appropriate, for differing geographical regions and settings.

Scope – The IVHS architectures include Advanced Driver/Traveler Information Systems, Advanced Vehicle Control Systems, Commercial Vehicle Operations, and Advanced Traffic Management Systems. The quantitative evaluation of operations, strategies, and technologies is part of the architecture selection process. Potential political and social changes, and their effects on the assessed value of the preferred operations, strategies and technologies, are also considered.

Methodology/Task Breakdown – The classical methodology for synthesizing architectures traditionally uses the four basic steps shown in Figure 1: (1) defining the goals, (2) assessing the largest problems in reaching those goals, (3) identifying and assessing the entire range of solutions, and (4) synthesizing/assessing/refining architectures encompassing these solutions. We apply these same steps in constructing IVHS architectures. When complete, the documentation of this methodology provides a quantitative substantiation that the chosen solutions are effective, more flexible and more cost-effective than competing solutions. It also indicates that they will well stand the test of time as traffic conditions, consumer preference patterns, vehicles, local solutions, and political and social environments continue to change.

This entire process can be repeated a number of times. Each pass is called a phase.

Phase I, representing the first pass through the process, is typically the most controversial. As such, it inevitably draws the most feedback and critical review. The second, third and fourth phases are generally performed at higher and higher levels of fidelity. Other phases that follow can usually be accomplished more quickly, and are essentially reviews of the earlier processes (and their assumptions), done in light of more recent social, political, legal and technological developments.

The four basic steps within any phase, when applied to IVHS architectures, can be expanded as follows:

- Define IVHS Goals
- Assess the Largest Problems in Reaching IVHS Goals
 - Define measures of merit (MOMs)
 - Build tools to assess architectures
 - Describe the current, projected, and potential conditions (including vehicles, local solutions, political and social environments, and consumer preference patterns)
 - Describe the known, probable and potential subsystems and subarchitectures with which IVHS must coordinate or interact
 - Identify and analyze the problems
- Identify and Assess the Entire Range of IVHS Solutions
 - Identify candidate solutions (strategies, technologies, operations, etc.)
 - Assess the cost-effectiveness and robustness of alternative solutions over the entire range of known, probable and potential conditions
- Synthesize/Assess/Refine the Architectures
 - Synthesize architectures
 - Compare cost-effectiveness and robustness over the range of known, probable and potential conditions
 - Refine architectures
 - Derive solutions.

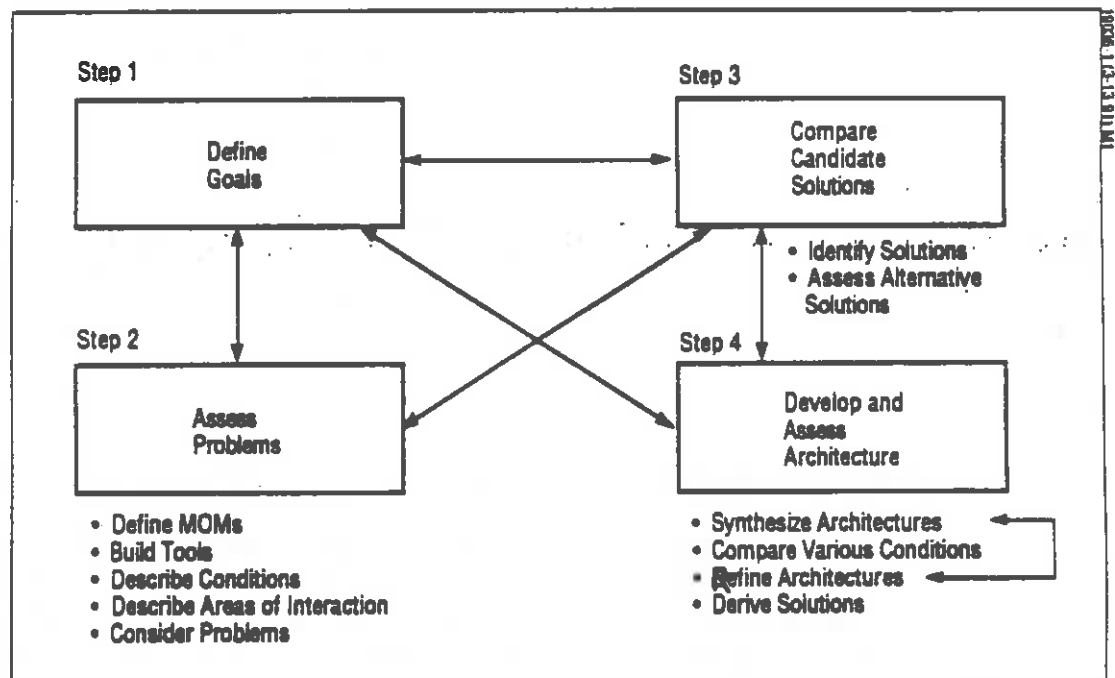


Figure 1. Classical Approach to Architecture Development. These four basic steps indicate the effectiveness of the chosen solutions. Each pass following this procedure is called a Phase.

These steps, shown in **Figure 1**, can proceed in parallel, and are highly recursive and interactive. The various steps must be frequently reviewed by multiple segments of the IVHS community to ensure that the assumptions, the spectrum of potential solutions being considered, the goals, and other factors reflect multiple and diverse concerns and experiences. These segments must include the FHWA, the various state and local departments of transportation, universities, commercial and individual road/vehicle drivers, industry, and those who maintain and operate the IVHS system. Each of the four steps in this process is discussed below:

Step 1. Define IVHS Goals and Objectives – Work on the first step has already started. The results of these preliminary efforts indicate that some of the goals (**Table 1**) are to reduce congestion, improve safety, reduce fuel consumption and improve air quality. As architects, we must make sure that the list of goals is complete, and, where possible, quantitative, such as "reducing incidents by 50% by the year 2000" or "increasing the vehicle flow by 25% by the year 1995." The baseline environment (e.g., vehicle density per km of road, generic city model for comparison, assumptions) must also be defined.

Examples of
TABLE 1. [^]IVHS GOALS AND OBJECTIVES

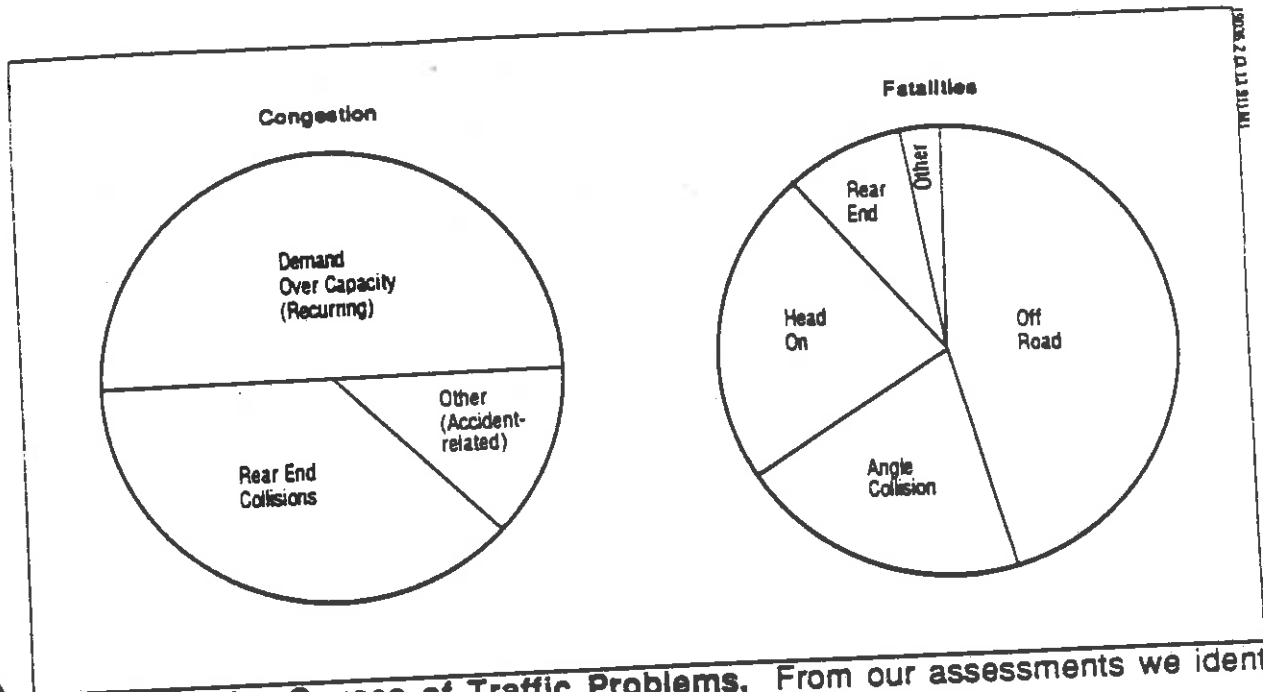
-
- Reduce Congestion
 - Improve average vehicle speed at peak hours
 - Reduce total trip time per vehicle
 - Increase road capacity
 - Improve Safety
 - Reduce number of fatalities
 - Reduce number of accidents
 - Reduce Fuel Consumption
 - Improve Air Quality
 - Reduce carbon monoxide production
 - Reduce nitrogen oxides
 - Reduce production of organic compounds
-

Step 2. Assess the Problems – This step includes the following tasks:

- **Define Measures of Merit (MOMs)** – Defining MOMs is important because they are used to quantitatively assess and compare the various solutions and architectures. Examples include "average number of incidents during rush hour during the work week," or "average number of vehicles passing point A per hour."

- **Build tools to assess IVHS Architectures** – We next need to build or modify tools to assess architectures – both current and hypothetical – in terms of selected MOMs. Many models already exist that assess the performance of subsystems, subarchitectures or entire architectures. Some of these will be applicable, while others will have to be developed. In some cases, field tests will be used to verify model predictions.
- **Describe the Current, Projected and Potential Conditions under which our IVHS Architectures will Operate** – Many levels of uncertainty are involved in this process. For instance, we do not know what future vehicles will look like, which items consumers will purchase, or which improvements will eventually succeed in the marketplace. Some items may become less expensive simply because they have "won" in the marketplace -- not necessarily because they are inherently better technologically. We can't be certain what future political and social environments will be, or what the price of fuel will be. We can't foresee what new technological developments will occur, or predict their impact on IVHS solutions. Because of these uncertainties, we must fully describe all conditions under which we might have to operate, and we must attach levels of uncertainty to them all. The architectures that we eventually choose (and there will be many of these architectures) must be capable of operating under all known and probable conditions. They should also be capable of operating under as many of the "possible" conditions as prudently possible. Choosing these "prudently possible" sets of conditions will involve considerable judgement, -- provided by IVHS America. Step 3, is crucial to determining the entire range of probable and possible conditions in which our architectures must be able to excel.
- **Describe the known, Probable and Potential subsystems and subarchitectures with which IVHS will have to coordinate or interact** – As with the IVHS external environment discussed above, components and subsystems of our future IVHS Architecture are also uncertain. Many candidate subsystems are being proposed, developed and tested today. Some will flourish. Others will fail. Many will change in nature. It is incumbent upon us to attempt to identify the full scope of these known, probable and potential subsystems and subarchitectures. This will give us the best possible basis for generating an architectural framework that can accommodate future developments.
- **Identify and Assess the Current and Projected problems:** The current and planned Traffic Management Architectures must next be assessed using a variety of empirical data, field tests, legal/political/social standards, analytical models and statistical data. From these assessments we can identify the largest deficiencies i.e., the problems that most seriously hamper our reaching our goals. An example of this process of "Deficiency Analysis" is shown in Figure 2. Many helpful statistics, such as the percentage of incidents now occurring as a result of spilled loads, or collisions, or weather, already exist. Others will have to be assessed empirically or by using our models that perturb various parameters, such as the number of vehicle lanes, number of incidents, number of vehicles on the road, time to clear up incidents, frequency of traffic-condition reports to drivers, etc. Some of the problems will be political or social. Others will be legal. Some of the causes will be amenable to solutions, and some may not. Some may be solved rather

readily, and in the near term. Others may have to wait for technology development or for some extended implementation period. As architects, we must address the largest problems first to ensure maximal marginal returns at each stage of our architectural evolution.



Examples of Figure 2 Major Causes of Traffic Problems. From our assessments we identify statistics that can prove helpful in our efforts.

Step 3. Identify Candidate Solutions (strategies, technologies, operations, etc.) – Through brainstorming and research, we identify the entire range of suggested solutions to our traffic problems. This activity should be as all-inclusive as possible, barring no idea as too far-fetched, until we have reasonably covered the spectrum of suggested. These candidate solutions (some of which are shown in Table 2) should include strategies, technologies, operations, networks, etc. Their descriptions should be sufficiently quantitative that the next step, the evaluation of their cost, feasibility, and value, can be undertaken.

- **Assess the cost effectiveness and robustness of alternative solutions over the entire range of known, probable and potential conditions** – We must now carefully assess each alternative for its potential feasibility, effectiveness, social/legal/political acceptability, maintainability, cost, and robustness to changes in traffic conditions of each solution (as quantitatively as possible). These assessments must be made over the entire range of known, probable and potential conditions. Since there are so many ideas, our first few passes can be quite coarse, (temporarily) rejecting some as not operationally feasible, not technologically mature enough in the time frame needed, not versatile enough to accommodate many of the probable or potential conditions, etc. We must record each rejected item and the reason for its rejection. All these

assessments should be subjected to the scrutiny of as many knowledgeable people as possible, exposing any flaws in assessment as early as possible.

Successive passes at the remaining "winners" should begin to include assessments of their cost, their effectiveness, and their robustness to changing traffic conditions. Eventually the list will be pared down to a core group of solutions, which we can now begin to group into logical combinations and run through our models for comparisons. All these evaluations should be carefully documented so that all members of the IVHS community can use this work. These groups of solutions, when they become large enough, can be classified as architectures.

Step 4. Synthesize/Assess/Refine Architectures of These IVHS Solutions and Derive Solutions – Each architecture can be assessed in terms of its cost, effectiveness, political/social and legal acceptability, and its ability to operate under the various known, probable and potential conditions along each MOM. **Figure 3** shows an example of such comparisons in which each architecture is represented as a dot indicating its cost and effectiveness. On the left for example, we can see that "Architecture A" has a rather high cost, yet a rather low effectiveness along MOM 1. Unless it has some redeeming features along other important MOMs, it would appear to be an architecture that is not as promising as the other architectures under

TABLE 2. EXAMPLES OF CANDIDATE SOLUTIONS

<ul style="list-style-type: none"> • Driver Information Systems <ul style="list-style-type: none"> - Computerized rationalization of direction signing - RDS through information broadcasting systems - Self-contained, on-board navigations systems - Electronic guidance systems - Automatic vehicle ID technology for automated toll collection • Surveillance Systems <ul style="list-style-type: none"> - Roadside radars - Loops in pavement - Roadside video cameras - Satellite-based system - Airborne electro-optical systems 	<ul style="list-style-type: none"> • Automatic Vehicle Control Systems <ul style="list-style-type: none"> - Antilock braking systems - Speed control systems - Variable speed control - Radar braking - Automatic headway control - Automatic steering control - Automatic highway system • Traffic Control Systems <ul style="list-style-type: none"> - Optimized Vehicle Actuation - Fixed time coordination - Partially adaptive coordination - Fully adaptive coordination (SCOOT) - Ramp control
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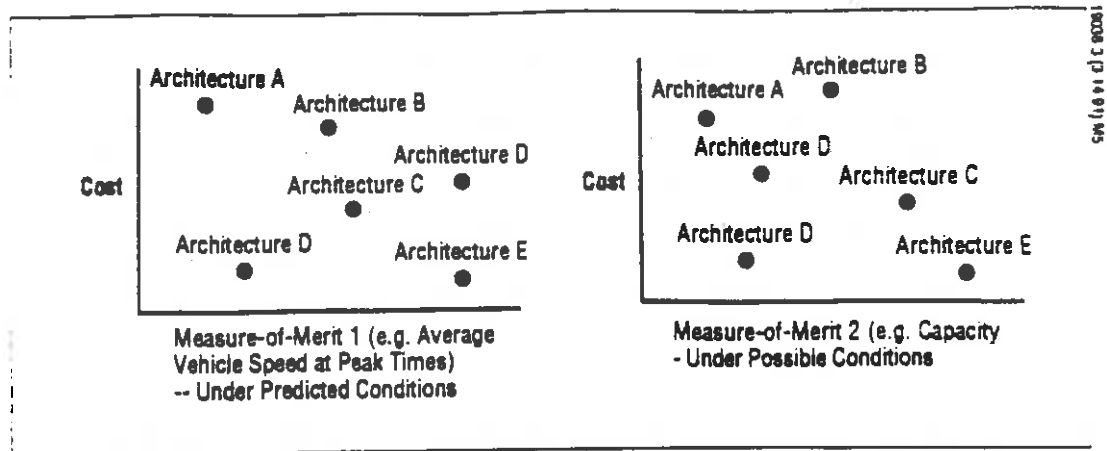


Figure 3. Examples of Architecture Assessments. The list of evaluated architectures should include: current architectures, currently-advocated architectures and any architectures that appear to be cost-effective robust solutions.

consideration. In contrast, "Architecture E" has a rather low cost and a very high effectiveness along MOM 1. Hence, unless it fails along other MOMs, it appears to be quite promising. The right graph in Figure 3 shows another set of comparisons along a different MOM, and under a differing set of conditions.

Naturally, all architectures must be examined along each of the MOMs and under many conditions. Some of the MOMs will be more important than others. Some will have thresholds of acceptability, and some will not. The assessments must consider these thresholds as well as MOM importances in determining which architectures to reject, which to keep, and which to modify. As we continue to assess these architectures, we will be able to determine that major and minor adjustments to them will make them less expensive, more effective, more politically and socially acceptable, and more robust. The fact that costs are a function of time and production quantity will be addressed, and life-cycle costs of both architectures and architecture constituents will be used. We continue to refine the "winning" architectures (i.e., those most cost-effective and robust) until we arrive at the best solutions over our broad range of conditions that our schedule for any given phase of this process will allow.

To construct these architectures, we must determine the architecture constituents, the information needs of each constituent, the data flows, and the interfaces required. Once we arrive at our final solutions, we can use this information to generate more formal and more detailed definitions of the information needs, data flows and interface specifications.

Other aspects of our effort include the following.

Reviews: The architecture team should submit periodic (perhaps monthly) reports of progress and plans to a diverse team of reviewers. These reviewers should include members of the public and private sector, academia. In addition, interactive technical reviews (briefings by the architecture team with interactive commenting, suggestions, and questions by the reviewing audiences) should be held regularly.

Deliverables: Outputs of this process should be both written and briefed. The written document should contain sufficient detail that reviewers and users can understand, validate and extend all quantitative assessments. This written document should include (but not be restricted to) all of the following:

- **Goals and Objectives of IVHS Architectures** (as quantified a description as possible)
- **Measures of Merit** (with a description of each measure's importance and any thresholds that exist)
- **Traffic Conditions** (current and projected. A quantified description, with all references documented)
- **Deficiency Analysis** (a quantified description of the magnitude of all deficiencies and problems, again with all references documented)
- **Candidate Solutions** (a qualitative description of each, and a quantitative assessment of each solution that was promising enough to continue through successively detailed levels of assessment)
- **Candidate Architectures** (a quantitative description of each assessed architecture, reasons for its rejection, if rejected. If not rejected, then its effectiveness along each assessed measure of merit, its feasibility, robustness to evolving conditions, maintainability, etc.)
- **Recommended Solutions and Architectures** (a clear description of the solutions and architectures recommended by the architecture team, and quantitative substantiation of these recommendations)
- **Models** (a description of all models used in the study)
- **Information Needs** (a description of the information needs of the recommended architectures)
- **Data Flows** (a description of the data flows for the recommended architectures)
- **Interface Specifications** (a description of the interface specifications of the recommended architectures).

Aspects of IVHS Architecture Design

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¹This paper is prepared for discussion at the IVHS System Architecture Workshop, University of Michigan, Ann Arbor, October 24-25, 1991. I am grateful to Steve Shladover, Tony Hitchcock, and other participants of the PATH seminar on AVCS for discussions; however, they do not necessarily endorse all the views expressed here.

Abstract

IVHS systems influence four kinds of decisions that drivers make during their trip. The corresponding tasks that IVHS systems carry out are route and flow control, congestion control, vehicle coordination, and spacing. A comparison of two scenarios shows how IVHS influence over vehicle behavior can range from minor (under a strategy limited to providing information and advice) to major (under full automation which preempts driver control). The four IVHS tasks have three differentiating features: time scale or the time available to carry out the task; spatial scope or the impact of executing the task on the traffic system; and information span or the extent of information needed to carry out the task.

An IVHS architecture organized in a hierarchy of four layers - network, link, coordination, and regulation - is proposed. This hierarchy resolves in a natural way the three differentiating features. The architecture can accommodate a wide range of automation strategies from the simplest, which limits itself to providing driver information, to the most complex, which achieves total control of the vehicle. The architecture permits the incorporation of new functional capabilities over time, and encourages a decentralized implementation of IVHS tasks.

An open architecture specification is urged as a means to promote rapid development of IVHS and to ensure the interworking of independent subsystem implementations. It is also suggested that IVHS standards should be specified in a formal-mathematical language to simplify later problems of design validation and conformance testing of products.

1 Introduction

Engineers face daunting challenges as they attempt to meet a growing demand for travel at a time when the traditional response of building more roads is less acceptable because it is too costly or too damaging to the environment.

There is a growing consensus that an appropriate combination of intelligent vehicles and intelligent highways may assist drivers in ways that lead to greater capacity and safety without building new roads. However, there is a wide diversity of opinion about the form of this 'intelligence'. This diversity has several dimensions including:

- Function – the range and extent of transportation and driving functions that should be automated;
- Architecture – the functional decomposition of IVHS systems, the assignment of tasks to various subsystems, the information flows between subsystems, and their interfaces;
- Design – the appropriate forms, including the division of intelligence between vehicle and highway, in which control, computing and communication technologies should be combined to realize this architecture;
- Evolution – the timing of system development, the extent to which earlier architectures should be capable of accommodating new functions;
- Evaluation – the effectiveness, costs and benefits of different IVHS proposals.

§2 presents a framework for describing IVHS functions, their relation to key decisions that drivers make, and the degree of influence that IVHS can have on those decisions. This framework provides a quick comparison of different IVHS proposals.

§3 proposes one IVHS architecture. The architecture arranges subsystems tasks in a hierarchy that corresponds to the functions introduced in §2. The architecture supports

- Uniformity – it accommodates a wide range of IVHS automation capabilities;
- Evolution – it permits the incorporation of new functions;
- Decentralization – it encourages an implementation in which the tasks are carried out in a decentralized manner; consequently most of the intelligence is in the vehicle.

§4 urges the specification of an open architecture, i.e. the formulation of standards in the form of reference models for each layer of the architecture hierarchy. It also urges the consideration of formal-mathematical methods for standards specification, design validation and conformance testing.

§5 argues that significant safety and capacity gains from IVHS will only be achieved by much larger degree of automatic vehicle control (AVC) than most proponents of IVHS are at present willing to contemplate. We recommend, therefore, that IVHS architectures be designed with the explicit requirement that they be able to accommodate AVC functions.

2 IVHS functions

Table 1 lists a sequence of six decisions made by an automobile driver in the course of a trip.¹ The decisions are divided into three phases - pre-trip, in-trip, and post-trip. IVHS systems seek to improve these decisions and IVHS subsystems must carry out corresponding tasks. Generally speaking, driver decisions may be influenced by four strategies of intervention - providing information, offering advice, taking direct control of the decision, and changing incentives by pricing, eg. tolls.

Phase	Driver decision	IVHS goal	IVHS task	Strategy
Pre-trip	Trip generation, modal choice, etc	More efficient resource utilization	Demand shift	I, P
In-trip	Route choice	Reduce travel time	Route guidance and flow control	I, A, C
	Path planning	Smooth traffic	Congestion control	I, A, C
	Maneuver	Increase safety, flow	Vehicle coordination	I, C
	Following	Increase safety, flow	Proper spacing	I, C
Post-trip	Parking, etc	Add value	Efficient use	I, P

A = Advice, C = Control, I = Information, P = Pricing

Table 1: Driver decisions and IVHS functions

Henceforth we restrict attention to the four in-trip decisions. Note that as the strategy adopted to influence driver decisions shifts from giving information to offering advice to exerting preemptive control, the decisions become more automatic and predictable, and the burden on system 'intelligence' increases.

A better appreciation of this shift of responsibility from the driver to the IVHS system is gained by comparing a scenario of a highly automated IVHS system with that of a system which eschews direct control.

A highly automated IVHS scenario

Vehicles enter and leave the automated network of interconnected highways at various gates and travel through the network under system control. Upon admission, the driver announces the vehicle's ultimate destination. (The system may delay admission for purposes of flow control.) The system responds to the driver's request by assigning a nominal route through the network. This is a sequence like

$$R = (H_1, s_1, f_1) \cdot (H_2, s_2, f_2) \dots$$

The interpretation is that the route is a sequence of segments. The first segment on highway H_1 starts at gate s_1 and ends at gate f_1 which connects to gate s_2 on highway H_2 and so on, as illustrated in Figure 1.

¹This applies to a typical commute trip. Somewhat different decisions may be involved in vacation trips, trips by drivers of commercial vehicles, etc.

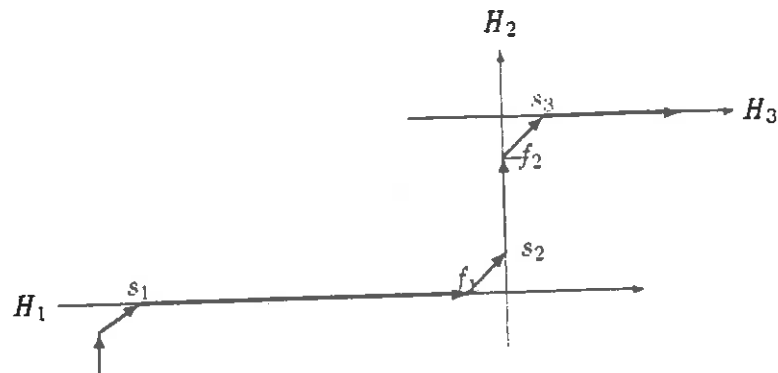


Figure 1: A route is a sequence of segments

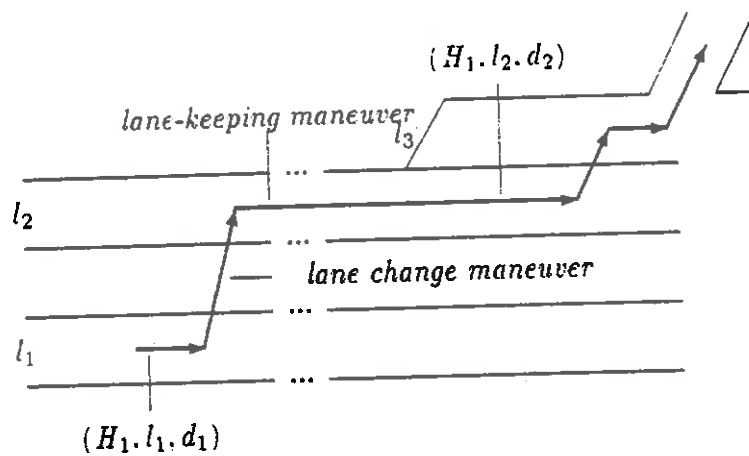


Figure 2: A path within a segment

We assume that the vehicle continuously senses the section of the highway on which it is traveling. A section is denoted by a triple (H, l, d) where H is the highway name, l is the lane number and d is the lane section number. A section is about 500 m long. It is used for congestion control as discussed below.

Suppose our vehicle enters H_1 through gate s_1 at section (H_1, l_1, d_1) and declares that it must exit at gate f_1 . The system assigns a path (l_2, d_2, l_3) . The interpretation is that the vehicle must change to lane l_2 , travel along it until section d_2 , and then change to lane l_3 from which it must exit at gate f_1 . See Figure 2. As the vehicle travels along this segment the system announces target speeds $v(H, l, d)$ for each section of this segment. The vehicle must execute an actual trajectory that conforms to the assigned path at the announced target speeds.

The vehicle's trajectory can be decomposed into a sequence of lane-change and lane-keeping maneuvers. Before it engages in a lane-change maneuver, the vehicle's control system exchanges messages with those of neighboring vehicles to ensure there is space in

the adjacent lane, that this space will be kept available until the lane-change maneuver is complete, or, if such space is not available, the neighboring vehicles will accelerate or decelerate to create such space. (The sequence of message exchanges is called a protocol.) Once agreement with its neighbors has been reached, the automatic vehicle control system (AVCS) executes the lane-change. In a lane-keeping maneuver, the AVCS system seeks to maintain the target speed $v(H, l, d)$ as it follows the vehicle in front of it at a safe distance.²

Comparison of partial and full automation

Table 2 compares the implementation strategies for the four tasks in the fully automated IVHS system with the strategies that might be adopted in a partially automated system. The fully automated system exercises a degree of control which effectively preempts driver actions, whereas the partially automated system seeks only to influence those actions by giving information and advice.

Task	Fully automated IVHS	Partial automated IVHS
Route guidance.	Assign route.	Provide travel time
Flow control	Admission control	information: ramp-metering
Congestion control	Assign path, section target speeds	Indicate incidents, advisory speeds
Vehicle coordination	Automated protocols	Legal rules and social protocols
Spacing control	Automatic vehicle control	Collision warning

Table 2: Implementation strategy in full vs partial automated systems

The fully automated system assigns the route that the vehicle must follow; the partially automated system predicts travel times which the driver may take into account in route selection. Both systems may control admission.

The fully automated system seeks to avoid the propagation of congestion by assigning the target speed in each section. The partially automated system attempts to achieve this effect by posting advisory speeds or information about incidents. In this case, both systems provide the same advice; the fully automated system guarantees that vehicles will conform to the advice, in the other system drivers may ignore this advice.³

The safe execution of a lane change maneuver requires the coordinated movement of neighboring vehicles. Partially automated IVHS may offer no assistance to drivers who must assume, as they do at present, that the neighboring drivers follow legal rules and social

²In [1], during a lane-keeping maneuver, the vehicle must also try to stay in a platoon. The platoon size is announced by the system. Simple models suggest that organizing traffic in platoons offers a large increase in capacity [2, 3, 4].

³The effectiveness of congestion control under full automation is discussed in [2], while [5] discusses the effectiveness under partial information. Using a simulation model of the Santa Monica (SMART) corridor in L.A. [6] concludes that savings "under recurring congestion conditions were found to be insignificant and in the order of 10 min for a 40 min trip under induced incident congestion."

conventions. Fully automated systems achieve guaranteed coordination through formal protocols.⁴

Finally, in a lane keeping maneuver, partial automation may improve safety by alerting the driver to the threat of a collision; fully automated systems minimize collisions by automatic reaction to information about the relative speed and distance between adjacent vehicles.⁵

It is important to note that the two scenarios compared above span a large range of alternative strategies. For instance, in addition to travel time information, the IVHS system may offer static or dynamic route guidance.⁶ Similarly, greater safety may be achieved by adding collision avoidance control which overrides driver actions under specified conditions.

Generally speaking in moving towards greater intelligence, one trades off increased complexity of the IVHS system for greater predictability and control of vehicle behavior which can be used to achieve increased safety and capacity.

3 IVHS architecture

In §2 we identified a set of four 'in-trip' decisions that drivers must carry out assisted by the IVHS system. In this section we examine the corresponding IVHS tasks in greater detail. Three features have a crucial impact on the design of IVHS subsystems which will implement those tasks. They are:

- Time scale - the time available to carry out the task;
- Spatial scope - the impact of executing the task on the traffic system;
- Information span - the extent of information needed to carry out the task.

Table 3 shows that the four tasks differ significantly in terms of these features.

⁴Such protocols have been designed and proved to be correct under specified conditions, see [7, 8]. For work based on 'artificial intelligence' see [9, 10, 11].

⁵Much research has been carried out on automatic longitudinal and lateral control [12, 13, 14, 15]. A representative Japanese work is [16]. European researchers use the term 'cooperative driving' for what we call 'vehicle coordination'. For examples of their work see [17, 18].

⁶There is a large body of work on this exemplified by [19, 20, 21].

Task	Time scale	Spatial scope	Information span
Route and flow control	Hour - under large shift in demand or highway conditions	Changes in routes and flows affect entire network	Systemwide data on demand, highway conditions, flows
Congestion control	Minute - target speeds updated after incidents and disturbances.	Changes in target speed affect traffic over few kms.	Data on incidents, disturbances over few kms.
Vehicle coordination	Minute - when vehicle does lane change	Affects neighboring vehicles	Predictions about neighboring vehicles, target section speeds
Spacing	Second - based on vehicle time constant	Direct effect limited to single vehicle	Data on neighboring vehicle speed, position

Table 3: Features differentiating four IVHS tasks

Observe that the tasks must be executed more rapidly, the spatial scope reduces, and the information span is more localized as we proceed from the first task to the fourth. This systematic variation in the features suggests a distribution of these tasks in the four layer hierarchy of Figure 3.

Starting at the top the layers are named: network, link, coordination, and regulation. Their functions correspond in order to the four tasks in Table 3, namely: route and flow control, congestion control, vehicle coordination, and spacing. The function of the physical layer is to provide relevant vehicle sensor data and to accept actuator (steering, throttle, braking) commands.

It seems natural, as the figure suggests, to distribute the tasks in each layer among several identical controllers. Then, there would be one controller per vehicle at layer 1 and 2, one controller per highway link (consisting of several km long section of highway) at layer 3, and one or a few controllers at the top layer 4.

If the tasks are distributed in this way the lines interconnecting the controllers in the figure represent communication links. Thus, the physical layer in a vehicle sends sensor data to its regulation layer and receives command signals from it. The regulation layer receives commands to execute lane change, maneuvers from its coordination layer. The latter exchanges messages (protocols) with its peer controllers and receives target speeds from the link layer, and so on.

*and lane
keeping*

The hierarchy provides a uniform treatment of automation strategies since it leaves open the extent to which the tasks are automated. For example, the commands received by the physical layer from its regulation layer may be automatic signals generated by the on-board vehicle control system or they may be generated by the driver. Similarly, the messages exchanged between adjacent (peer) coordination layers may be formal protocols or they may be informal messages that drivers exchange and interpret according to social convention.

The hierarchy can preserve an evolution of IVHS capabilities. That is, the extent to which each task is automated can vary over time depending on need and experience.

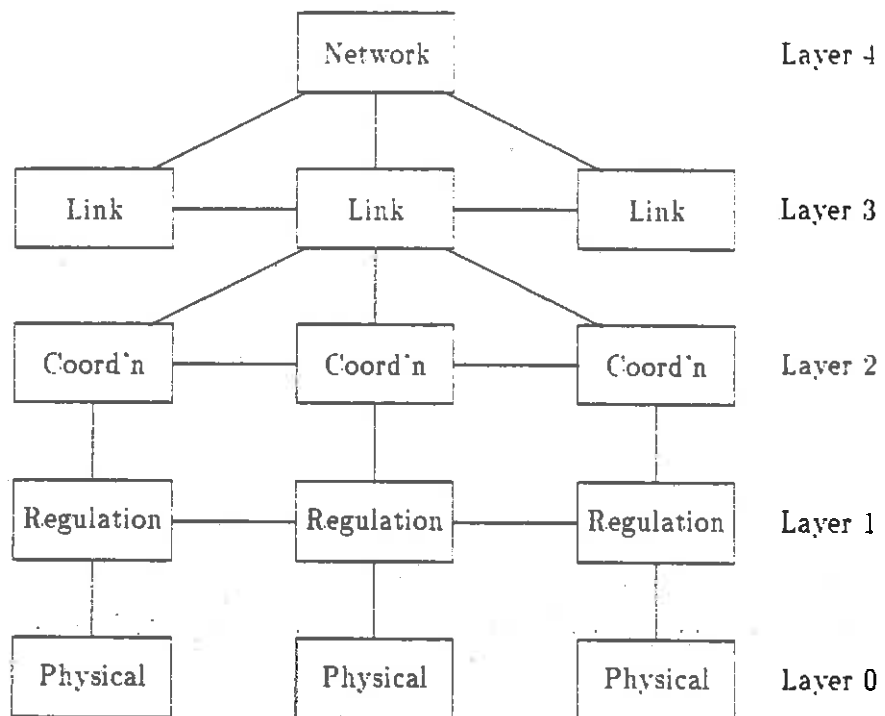


Figure 3: IVHS architecture

Finally, the proposed task distribution strongly encourages a decentralized implementation. For example, in principle, vehicle control signals may be generated in a centralized computer and communicated down through the hierarchy; but the more natural implementation is one where the control signal is generated by the regulation layer itself. A decentralized implementation would be more robust than a centralized one since the impact of failures would be spatially limited.

To achieve fully these advantages of uniformity, evolution, and decentralization it is necessary to go further and specify an open architecture.

4 Towards an open architecture

An IVHS architecture specifies

1. a functional decomposition of IVHS systems,
2. the assignment of tasks to various subsystems, and
3. the information flows between subsystems.

The architecture is *open* if it provides

- a reference model for the external behavior of each subsystem, and
- subsystem interfaces to which information exchanges must conform.

Reference models only specify the external behavior. This permits different implementations to conform to the same reference model. Ideally, the reference models and interfaces are unambiguously spelled out and contain enough detail so that subsystems implemented in conformity with them can interwork. Perhaps the most important advantage of an open architecture is that the design and implementation of each subsystem need only consider the external behavior of other subsystems as defined by the reference models and interfaces. Thus an open architecture permits independent and parallel subsystem design, which reduces development time.⁷ It also allows changes in one subsystem design to incorporate new technology without the need to change other subsystem designs.

Central to an IVHS open architecture specification, then, is the standardization of subsystem reference models and interfaces. Efforts to produce standards must steer between two conflicting requirements: sufficient and unambiguous detail must be given so that subsystems conforming to those standards can interwork smoothly, but the standards should not be so overspecified as to preclude conformance of innovative and more economical implementations.

⁷The importance of this cannot be overestimated. The open architecture standards adopted in the data communications and personal computer fields has spurred innovations enormously.

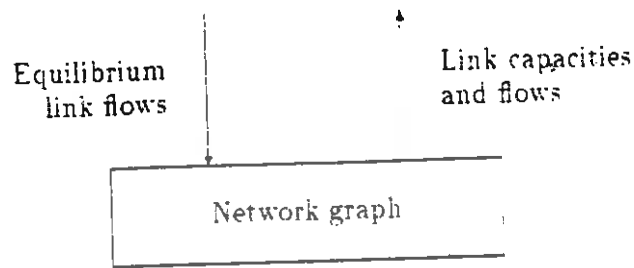


Figure 4: Link layer reference model

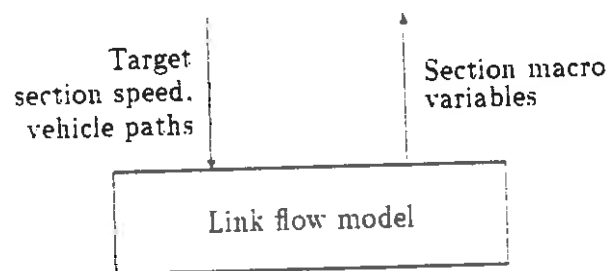


Figure 5: Coordination layer reference model

In the context of the architecture proposal summarized in Figure 3 there would be four layer reference models, one for each of layers 0, 1, 2 and 3, and three peer reference models at layers 1, 2 and 3. We briefly discuss each set of reference models.

The *link layer reference model* provides an aggregate description of the flows in each link. It indicates to the network layer any significant changes in link capacities and flows. Thus this reference model can be formulated as a graph each of whose links is characterized by the current capacity and flows. (Such a reference model suggests that layer 5's route and flow control task can be formulated as a mathematical programming problem of network flow optimization.) See Figure 4.

The *coordination layer reference model* is a dynamic model describing the behavior of vehicles on a link.⁸ The 'inputs' to the model are the section target speeds (set by the link layer); its 'outputs' are macroscopic variables of speed and density in different sections of the link. The congestion control policy of the link layer is based on this reference model. Examples of such models can be found in [2, 5]. See Figure 5.

⁸Recall that a link is several km long stretch of highway.

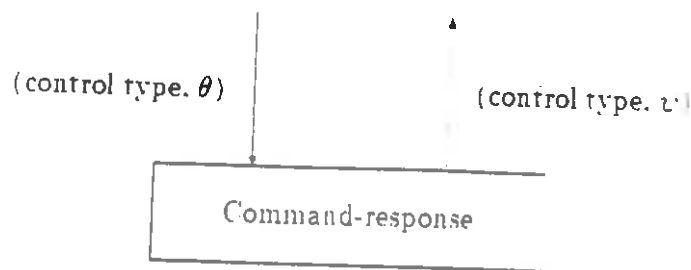


Figure 6: Regulation layer reference model

The *regulation layer reference model* is a 'command-response' model of the feedback controlled dynamics. The commands to execute various maneuvers are issued by the coordination layer. These commands can be encoded as parameters for each type of feedback control law. For example, there would be a command to change lane and a command to keep lane at a specified speed and headway. The parameterized response to each command would indicate how well the command was executed. Thus the regulation layer reference model takes the form:

$$(\text{control type. } \theta) - (\text{control type. } v)$$

where 'control type' is 'change lane' or 'keep lane', and θ is the associated parameter vector.⁹ See Figure 6.

Finally, the *physical layer reference model* is a model of the vehicle, actuator, and sensor dynamics. In the case of full automation this model might be given in terms of differential equations. In the case where the regulation layer task is implemented by a human driver, the model would be in terms that are intelligible and useful to the driver. See Figure 7.

These layer reference models define the relations between different layers in the hierarchy of Figure 3. In addition, that figure indicates interaction between peers at layers 1.2.3. Reference models for such peer interaction need to be specified. For example, the coordination layer peer reference model would specify how messages exchanged between neighboring vehicles should be interpreted in terms of their behavior. In [7], these models are in terms of state machines. In the case of partial automation, such models might specify the probable meaning of turn signals, brake lights, etc.

We end with several observations. A reference model for an architecture of the kind indicated by Figure 3 accommodates a variety of implementation strategies. That is its advantage. As details of implementation strategies get worked out, they will be reflected in standard reference models at different layers.¹⁰ Consequently, as implementation strategies

⁹In the example above, θ would encode the the 'specified speed and headway'.

¹⁰This is similar to the situation in communications networks. The famous seven-layer OSI reference model applies widely, but there are different standards for different protocols which conform to the seven

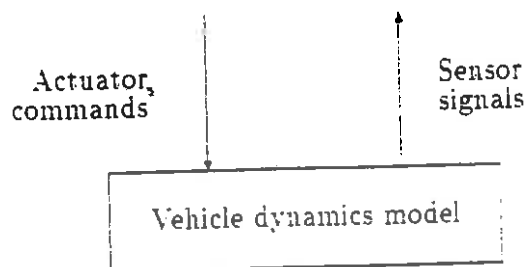


Figure 7: Physical layer reference model

evolve over time (presumably towards increased automation), the reference standards will change. One may insist that the new standards be 'backward' compatible. The reverse side of this coin is even more important in our view. Standards designed at an earlier point in time should be 'forward' compatible, that is, they should accommodate the incorporation of new functions. This will be best achieved if the setting of standards is done not with a myopic view of IVHS prospects, but with a vision that incorporates the tremendous advances in communication, control and computing technologies.

We offer one final remark about standards based on the lessons of the communication networks community. Standards are generally specified in a language that is a mixture of English (or some other natural language) and some formal language, (eg. state machines, pseudo-programming language). Built into such a semi-formal language is a wide latitude for interpretation. As a result, systems implemented by different organizations and conforming to the 'same' standard often are mutually incompatible. To minimize this incompatibility, the communication networks community is moving towards the adoption of formal languages in which standards should be formulated. The IVHS community can learn from this experience and strive towards the development of such formal languages at an early stage. This will serve three purposes: (1) it will impose a discipline on standards setting bodies to reduce ambiguities; (2) it will help those designing IVHS components and subsystems to check the validity of their designs; and (3) in the long run, it will help in the conformance testing of IVHS products.

5 Conclusions and recommendations

The predominant goals of IVHS are to influence drivers in ways that increases capacity and safety.¹¹ The strategy adopted to implement IVHS tasks can range from partial automation

layer model.

¹¹Other goals relating to the impact of IVHS systems are reducing pollution and fuel conservation, increasing GNP as a result of reduced travel time and safeguarding international competitiveness of U.S. industry.

(in which IVHS only provides information and advice) to full automation (in which most decisions are under computer control).

The evidence suggests that a 'partial automation' strategy will not materially affect the goals of increased capacity and safety. Under partial automation, capacity is increased because travel time is reduced since drivers have more accurate and timely information about traffic conditions and advice about the best routes. Simulation and analytical studies, and data from demonstration experiments suggest little or no improvement under recurrent congestion and some improvement under incident induced congestion.¹² One may with confidence suggest an upper bound of 15 % on the capacity increase from partial automation. The capacity 'bottleneck' in a partially automated system will continue to be, just as it is today, the driver response characteristic. By contrast, studies based on admittedly simple models suggest capacity gains by a factor of two to three under full automation.

There is little evidence about the gains in safety achieved by partial automation. The general wisdom is that up to 90 % of accidents today are caused by the driver's inattention, faulty anticipation, and slow reaction.¹³ These relate to tasks we have called 'vehicle coordination' and 'spacing'. Partial automation strategies may include 'collision warning and avoidance', and 'intelligent cruise control' but AVCS systems offer much more. They hold the promise of making vehicle movement much more predictable and regular, thereby reducing incidents and preventing accidents. Of course, the prospect of full automation raises many other concerns including system reliability, public acceptance, and legal liability.

In summary, then, while partial automation can more readily be implemented, and involves few surprises of technical or social nature, its impact will also be minimal, and it is unclear whether the cost/benefit tradeoffs are favorable. Full automation offers more promise ... and more uncertainties. The wisest course would seem to be one in which IVHS architecture standards, initially conceived for partial automation, be made to accommodate evolution to more complete automation. At the same time, a serious effort should be undertaken to reduce the technological and social uncertainties of full automation.

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¹²A simulation study based on the CACS project suggests that travel time in Tokyo could be reduced by 6 % [22]; U.K. researchers estimate an average benefit of 10 % from dynamic route guidance [23]; preliminary results from the Berlin route guidance experiment show no savings in average travel time under normal conditions [24]; simulations of the Santa Monica freeway (SMART) corridor suggest insignificant savings under recurrent congestion and savings on the order of 10 minutes for a 40 minute trip under incident induced conditions [25, 6]; a careful examination of data on driver response to advisory speeds posted by the Dutch Motorway Control and Signalling System showed no increase in capacity [26]; theoretical considerations also suggest little or no benefits from route guidance under recurrent congestion [27]; lastly, experiments using the CONTRAM simulation model show that single 'best route' guidance can even lead to *negative* benefits [28]. I am indebted to H. Al-Deek for many of these references.

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Advanced Transport Information Systems (ATIS):

**Should the early implementers design systems
with a future proof architecture?**

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**This paper is prepared as a discussion paper for the IVHS System Architecture
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**The paper will consider the broad issues and attempt to answer these questions, giving
detailed considerations on the communications aspects. The author will draw from his
background in the communications service industry and the European DRIVE
programme to illustrate the issues. The ideas presented are those of the author and are
not a policy statement by British Telecom nor the European DRIVE community.**

1 Introduction

It appears that there will be an initial rush by several potential ATIS service providers to implement service ahead of the field. Clearly the ATIS market will support a wide variety of services to drivers, passengers, vehicle owners and the road authorities. It is likely that these initial systems will be incompatible with each other and little consideration will be given to the future migration of the services implemented. Indeed, it will not be possible to foresee all the possible applications at the outset.

This discussion paper will consider the following key questions:

Is it technically possible for a single ATIS system implementation to support all the different services and applications that are likely to emerge?

Is it sensible (cost effective) to seek a single solution for the entire range of applications?

What are the advantages and disadvantages of defining a future proof architecture?

Are there partial solutions: key elements of the architecture that should be made future proof, whilst others are not ?

Are there efficient ways to build a future proof architecture with only a minimum overhead ?

2 Customer Requirements and Expectation

Customers will require low cost efficient ATIS systems. The early purchaser will be motivated by a need to find solutions to their particular well understood problems. However, perhaps the real growth will come from purchasers who see some initial advantage but buy the system because of its long term pay-back. They will want to perceive a migration route for their investment so that their investment is safe and can be updated incrementally to include new applications that become available, or to switch to a more efficient or economical communications system. It is not clear what premium customers might be prepared to pay for choosing a system with a future proof architecture: however, it is imperative that the cost of providing openness is kept to a minimum.

The user will want to be presented with a seamless service when crossing national or regional boundaries. The user does not want to know that the system is operated over a different company's communication system or from a different database; when borders are crossed. Similarly, if new services become available the user will want access to these with the minimum of formality, bureaucracy and expense.

3 Components of an "ATIS" system

It is first necessary to understand what is implied by the term "ATIS". Essentially this is a distributed information system with part of the process running within the vehicle and part on one or more host computers within the fixed infrastructure. The in-vehicle system gathers information from in-vehicle sensors, databases and user instructions. It uses this information, supplemented by information (usually time varying information) from remote databases to provide pertinent information to the driver (or passenger). Additionally, the in-vehicle system passes carefully selected information to databases within the infrastructure where necessary: for example, for monitoring traffic flows or tracking specific vehicles.

Systems such as cooperative driving, where the in-vehicle equipment takes over parts of the driver's role, are beyond the capability of ATIS systems. However, route guidance and automatic tolling may be included within ATIS (even though some proposals for tolling include a means to disable the vehicle when the driver's credit limit is exceeded.)

Clearly any systems that interact directly with the control of the vehicle's behaviour on the road must operate to exacting standards, and if there is to be vehicle-to-vehicle communications all must operate to exactly the same standard for all vehicles, to avoid any ambiguity. Progress on implementing these systems will only be possible when comprehensive technical standards have been agreed. Ad hoc solutions will not be allowed. However, it is the issues of legal responsibility that will delay (and ultimately may prevent) the implementation of commercially marketed cooperative driving systems. ATIS systems will have a much lower impact on safety (assuming that they do not cause distraction to the driver). Standardisation of ATIS systems is less urgent, being required primarily to allow interworking and to facilitate development of new services.

The ATIS system will probably consist of the following elements (fig 1):

- Man Machine Interface (MMI) - particularly for the driver
- in-vehicle applications
- in-vehicle processor and operating system
- in-vehicle databases
- in-vehicle sensors
- in-vehicle communications
- mobile communications link(s)
- host processors and operating systems
- host databases
- host applications
- fixed network links to other systems

To a great extent it is the openness of the interfaces between these elements that provides the flexibility of the system to accommodate new applications, new communication systems and new vehicles. [1]

4 Likely Early Service Scenarios

It is inevitable that non-standard systems will appear in the market place whilst work is progressing on defining common standards to be used within the ATIS industry. Initially there is likely to be a rapidly increasing range of ATIS systems emerge, with no thought to compatibility. Some of these systems will target unique, or at least, subtly different parts of the market and will not, at first, be direct competitors. However, many more implementations will address common customer requirements, again in quite different ways, and competition between incompatible systems will build up.

Ironically the most efficient solutions are likely to be those with applications and communications systems that are closely integrated. Clearly if one such implementation can become established to a much greater extent than its rivals, then it has the potential to become the de facto standard, at the expense of all other solutions. If that system could be developed quickly, then other manufacturers may back the de facto standard and remove effort from the development of the long term standard.

The consequence of such a process would be to limit the growth of new applications until the latent demand could motivate the development of a new system. Backward capacity would then be unlikely.

4.1 Possible Evolution of Automatic Tolling into an Isolated Application

All automatic road tolling systems have the same basic requirements: these are common throughout the world. Already there are several totally incompatible systems being trialled within the United States, Europe and Japan. Whilst each of these systems is being evaluated or introduced within limited geographical areas they may be regarded as independent systems. Each will aim to be optimised for high reliability at minimum cost. Customers will probably be satisfied with whichever system they have, until they drive to another area and discover that they must purchase a different automatic tolling system. Whereas the cost of a single system may be acceptable, the cost of buying several systems and the inconvenience of having to accommodate and manage several systems, each apparently performing the same function, would be quite unacceptable.

Ultimately the market must be resolved in to just one interface standard, albeit with many different manufacturers producing different variations. The overriding constraint is that any vehicle equipped with any automatic tolling system must be able to successfully complete a tolling transaction with any automatic toll booth

(plaza). It is interesting to speculate on the way in which the original market, with a wide range of systems will migrate into a unified implementation.

Perhaps the best solution is that each toll booth should be equipped with a full range of equipments, compatible with the whole range of in-vehicle systems. Users will then have a free choice and in due course will select the most successful system on cost and convenience and a single solution will emerge by "natural selection".

These systems will always be high volume low cost units. The idea of integrating their functionality with more powerful ATIS systems, such as route guidance, is elegant from an engineering view but it is not clear that there would be commercial gain in combining these systems. Consequently there is probably little need to consider a long term migration strategy for these systems.

5 Interfaces within an ATIS system to be Standardised

The following ATIS sub-systems must all be designed to allow interconnectability via defined interfaces if the objective of implementing future-proof open ATIS systems is to be realised.

5.1 MMI

This crucial interface has to work efficiently and unambiguously. Misinterpretation of information could cause an accident - with horrendous litigation problems to follow.

The first issue here is that vehicle manufacturers will want to offer their own versions of MMI, perhaps with special features to give their vehicles advantages over competitors' vehicles. However, there must be a certain minimum conformity such that the driver of one vehicle must not be confused by the different MMI when switching to an unfamiliar car.

The second issue is that there will be a wide range of applications which must be capable of being supported over a wide range of MMI systems and a clear set of capability and requirement definitions will be needed to ensure that the applications only require information to be presented that is within the capability of the MMI. Clearly MMI may be via spoken word (in different languages), by textual or diagrammatic display, head-up display or a mixture of all of these.

5.2 Interfaces to In-vehicle sensors

It is necessary that sub-systems within the vehicle should be able to communicate and this may be achieved by some form of "Vehicle Local Area Network". Furthermore, the response of sensors from different manufacturers will need to comply with

common interface standards, in order to avoid inaccurate data being derived. Proposals for vehicle buses appear to be well advanced. (fig 3)

5.3 In-vehicle applications

Applications are supported by a real-time operating system that runs on the in-vehicle computer. All in-vehicle computer operating systems will need to be compatible if applications are to be easily ported onto the range of in-vehicle ATIS platforms.

5.3 In-vehicle databases, physical storage medium and logical meaning.

The way that digital maps are stored is vital to the efficiency with which they can be used. Pictorial representations may not lend themselves to optimal route finding. Application friendly ways of storing the data are being developed [2],[3]. Clearly any static in-vehicle road system database must match the real-time database in the fixed infrastructure so that dynamic updates of road conditions may be correctly interpreted. When the structure of the database is defined it is necessary to decide on the extent of any additional data that will be supplied initially, and in the longer term. Once the database has been dimensioned it may be difficult to add additional information fields that the end user may wish to access. An open database standard could lead to new applications, allowing corporations to add information specific to their own company's business.

5.4 Vehicle to Infrastructure mobile data communications

Ideally applications should be designed independently of the exact nature of the underlying network, although all applications must be designed to take account of the limited capacity and/or real-time availability of mobile communications systems (fig 3). Communication systems can be classed as offering either continuous or discontinuous coverage, each has certain limitations as outlined below. In practice it may be desirable to optimise certain applications to be supported by one class or the other, as will be explored in section 5.4.3. Specific issues relating to creating open communications are discussed further in section 6.

5.4.1 Continuous coverage communication systems

In Europe, Mobile Data networks will give virtually continuous coverage, but initially will offer limited capacity. Paging systems and the FM radio "Radio Data Service" (RDS) will offer a low cost one-way, down-link only, service with national coverage potential. Current satellite systems offer lower capacity but with very large area (continental) coverage. Mobile data systems will, in general, be operated by a public service operator who will be responsible for the migration strategy of the communications system. Note that using a public system in this way

reduces the start up costs for the ATIS service whilst preserving options for later migration.

5.4.2 Discontinuous coverage communications systems

Short range communications based on Infra-Red, microwave, cordless telephone or radio LAN technology all offer a much greater instantaneous capacity than the continuous coverage systems. However, the communication with the roadside beacon is only possible for a small percentage of time which may lead to a much smaller net capacity. Thus applications such as emergency calls (when the vehicle is stationary) will not be possible, except when in range of the beacon. Effectively communication is achieved via a store and forward process which introduces the additional problem of delay before data transfer is possible.

5.4.3 Dynamic Route Guidance - optimised for one class of communications

There are essentially two ways to offer dynamic route guidance: using beacons to communicate with the vehicle (examples include LISB in Berlin, Germany) and, secondly using two way packet radio data (examples include SOCRATES in Europe and Advance in the USA).

Because of the extent of divergence of the two underlying communications technologies it is likely that applications will be developed to match one of these communications systems. Applications for beacon systems must be designed to operate without on-demand access to instantly available communications. Full decoupling of applications and networks may not be possible. However, it should still be possible for these two approaches to both utilise a common MMI and a common road network data base with common information such as current and predicted traffic congestion.

5.5 Infrastructure host databases

Clearly the databases used by the infrastructure based computers must match those used by the in-vehicle processor. Furthermore, there would be little sense in rival ATIS suppliers developing entirely incompatible road network databases for the same geographical area. The cost of building such a databases needs to be shared by the maximum number of users. It should still be possible for rival companies to bid for the task of preparing the database to the standard format. [3],[4]. Similarly, databases for neighbouring geographical areas must be compatible if a visiting vehicle is to be passed information that its in-vehicle computer can interpret.

5.6 host to host communications

The mobile communications link should be fully open, for the reasons already stated. However, there is no fundamental need to make any service provider's internal interfaces conform to any particular standard (fig 3). It is up to the service provider to design the system to give the best possible performance for the lowest price. The other interfaces that must be implemented openly are those which connect to other service providers, or sources of information, such as the Police, road authorities, motoring associations etc. Interworking between systems also requires that common data message formats are employed

6 Towards A Future-Proof Communications Architecture

The main objective in defining a "future proof" architecture is to define a standard which everyone is prepared to implement in the short term, but which has the necessary hooks to add greater functionality whilst maintaining backward compatibility. The major problems with this approach are that the standards committee can take a long time to agree a common standard. Consequently, there is a risk that a clear market leader, from the initial proprietary solutions, may emerge before the standard can be implemented.

A good example is the need for open standards for telecommunications. The International Standards Institute (ISO) and CCITT have been working on Open Systems Interconnection (OSI) and an enormous effort has been invested in the definition of such systems. OSI is intended to include a great deal of flexibility, to allow the user to establish whatever communications are needed, in a way that other systems will understand.

However, during this development period the Internet suite of protocols (including TCP/IP), originally developed for the US Department of Defence, has become widely adopted and is readily available at competitive prices. Whereas OSI conformant software currently has limited availability from a small number of suppliers and high costs. OSI is generally felt to be inefficient compared to the Internet suite (as a consequence of building in an enormous number of options to make the system future proof). Although governments and major companies round the world have stated their commitment to OSI the growth in the use of Internet protocols continues and, in selecting which architecture to use, one has to determine the point in time when OSI will become the de facto standard. OSI introduces a wide range of options and implementation flexibility - but is still not designed to offer all the services that now appear to be necessary. For example, the multicast or broadcast modes are not well defined. Neither is the implementation of an embedded store and forward capability (within the Transport layer) which would be advantageous when operating through areas of discontinuous coverage.

The message is simple: the probability of the chosen architecture being future proof depends on the speed of definition of the architecture, the rate acceptance and take-up and its capacity to accommodate the uncertainty that the future will hold.

6.1 Open Communications - the DRIVE Normalised Transmission (DNT) concept

The work of DRIVE project CIDER (Communications Infrastructure for Drive on European Roads) has focused on identifying a method to create a flexible interface between applications and communications systems to allow any ATIS application to operate over the most suitable of the communications networks available to that vehicle (fig 2). Part of the requirement is to decide on the most suitable network where there is a choice. This will be done by an enhanced communications management function.

At first inspection the obvious route is to base the implementation on OSI protocols. These are designed to facilitate interconnectability of communications systems. However, most OSI protocols create this flexibility by introducing a very significant overhead of parameters that must be passed between the communicating systems, in order to establish the exact nature of the information being passed. Whilst this overhead may be acceptable in the fixed network environment, it presents a major problem in the mobile communications environment where the communications capacity is limited either by spectrum availability for a mobile data solution (like Socrates & Advance) or limited contact time, in the case of beacon based systems. Consequently the search has been for a means to achieve an open interface between the network and the application associated protocols, such that adherence with the OSI seven layer model is maintained, together with compatibility with the existing OSI conformant protocols, but minimising the overhead introduced.

The DNT concept [4],[5] is based on creating an open interface at layers 4 and 3c in the OSI model. The underlying network provides the lower layers (1 and 2) and usually part of the Network layer (3) whilst the Transport layer (layer 4) provides a means to ensure that the underlying network provides an adequate quality of service as perceived by the higher layer. Fig 4 shows the OSI 7 layer model as a "wineglass": the broad top and bottom indicating many different applications each potentially connected to one of many different networks, via a common interface at layers 4 and 3c. The OSI conformant protocols are included in this diagram, these will be of use exceptionally where it is essential to access an application in the fixed infrastructure which is implemented using the OSI protocols. The user must accept the concomitant overhead. Such application protocols would normally prove unacceptable in the mobile environment because of the enormous protocol overhead.

The DNT also introduces a minimal protocol interface that, if included within all the initial implementations, will allow non-OSI protocols to run over the DNT. (Fig 4) also shows the area where future developments will be required to create more efficient protocols. This profile of new protocols has been tentatively called MOSI - "Mobile Open Systems Interface" (by the author!). The MOSI protocols would align with the OSI framework and would avoid ambiguity with the existing OSI protocols.

Efficient lower layers for mobile packet data protocols are already being considered by ETSI RES6 (Mobile Digital Trunked Radio System), GSM, FPLMTS, IS54 etc. Work is not so advanced on developing higher layer protocols, however, the DRIVE RDS Alert project has developed the Traffic Message Channel (TMC) protocols, initially to run on the FM broadcast's RDS service [6]. TMC includes a very efficient travel information coding scheme which could be mapped into a Presentation layer.

In order for the DNT to be accepted, the impact of the DNT on data comms overheads must be minimal. Fortunately the OSI Network layer header can be reduced to a single byte, if the end to end connection is over an isolated network: all the address information can be contained within the Data Link (layer 2) address fields, with full address translation at an application gateway at the "roadside node" (Fig 3). This single byte representation of the network protocol should prove adequate to maintain openness and acceptable to the short term implementers who wish to minimise any overheads.

Current ISO standards do not include a totally null Transport layer protocol. The minimum protocol overhead is that associated with the connectionless transport service, as defined in ISO 8602 (similar to UDP from the Internet suite). This protocol includes a simple frame check sequence (errored packets are discarded, no retransmission is requested). Errored data is simply lost. Secondly the Transport Protocol Data Unit (TPDU) includes the source and destination application addresses, known as TSAPs. This information is necessary where the host or in-vehicle processor is required to run more than one application, so that the correct application is used. The overhead from all this is 8 bytes, which implementers of early ATIS systems consider to be unreasonable. Where these early implementations will provide only a single application on each processor there may be no need for the TSAP information. However, it must be noted that elimination of the TSAP space in the protocol would mean that adding additional functionality would be difficult. Further savings of protocol overhead could be made by allowing the application to determine any errors and what to do about them.

The DRIVE CIDER project has concluded that a null Transport protocol should be defined. This will have no function except to allow more powerful Transport protocols to be used across that link at a later date, without the risk of ambiguity. This should require only a single byte of overhead data, which would also be taken to imply null transport and presentation layers, and a single application at each host machine. These ideas have been formulated following many meetings and preparation of discussion papers by interested members of the DRIVE community. These latest ideas have yet to be presented to the DRIVE Integrated Communication Architecture (DICA) forum, but are thought to offer the best possibility for convergence in the short term.

6.2 The Service Platform

For systems to be future proof it is necessary that the wide range of sub-systems are implemented in an open way. However, this will not be enough in itself. These services will need to be managed. Issues of authentication and access to applications are not covered by the standardisation process. Meeting the customer's requirements for a seamless service with simple migration to include new services will require someone to operate a service platform. It is apparent that this role aligns with the service management ambitions of several Telcos. fig 5. However, the management of ATIS services will require access to a very wide range of skills and is likely to require cooperation between key companies each bringing its own expertise.

7 Conclusions

Early implementations of ATIS systems are unlikely to have future proof architectures.

The second generation implementations will need to consider the wide range of interfaces that need to be made open, if they are not to be made obsolete at an early stage.

Future proof systems will be much more attractive to the customer than single application systems.

A new, minimal overhead, OSI Transport protocol is needed.

High efficiency OSI conformant upper layer protocols are needed.

Even if systems are built using entirely open interfaces (once these have been specified) it will be necessary to manage the interconnections and migration route so as to achieve the future proof objective of offering the end user a system that can migrate to meet the corporate or individual's needs without undue churn of equipment and software investment.

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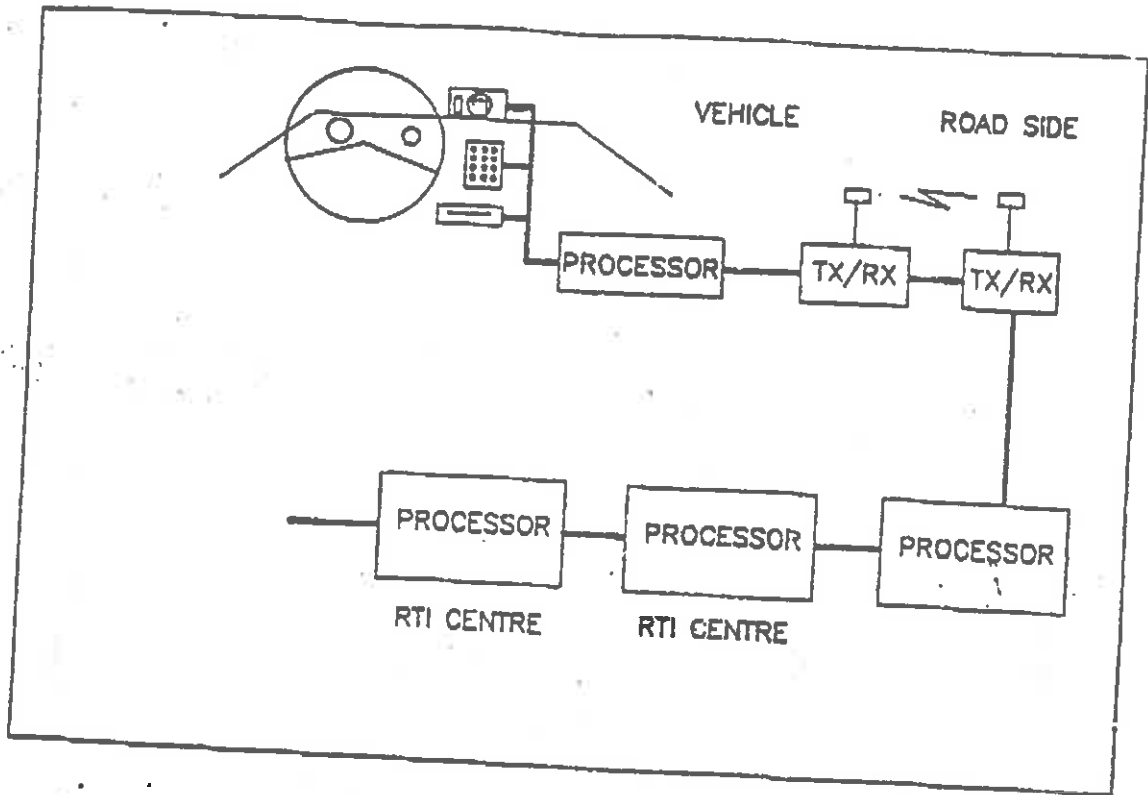
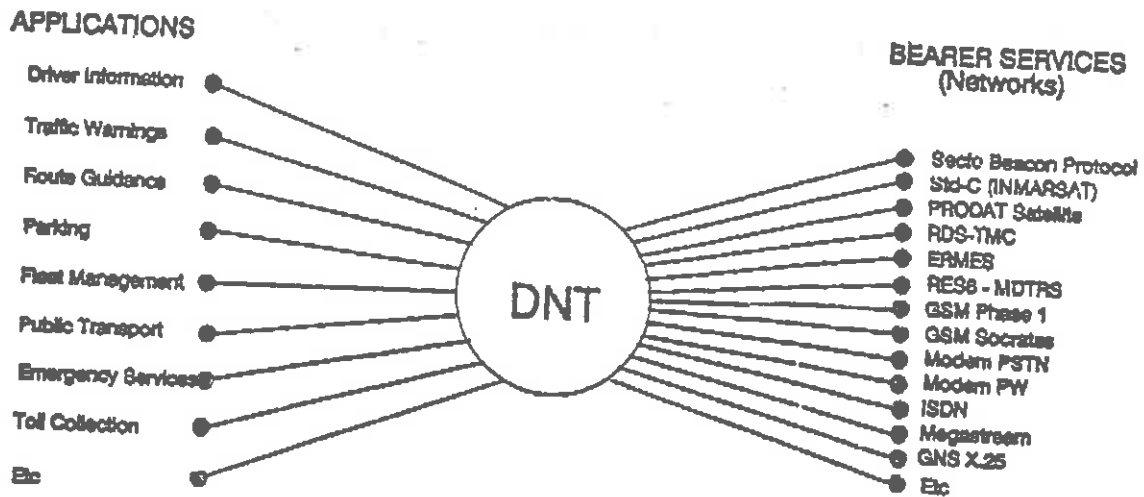


fig. 1

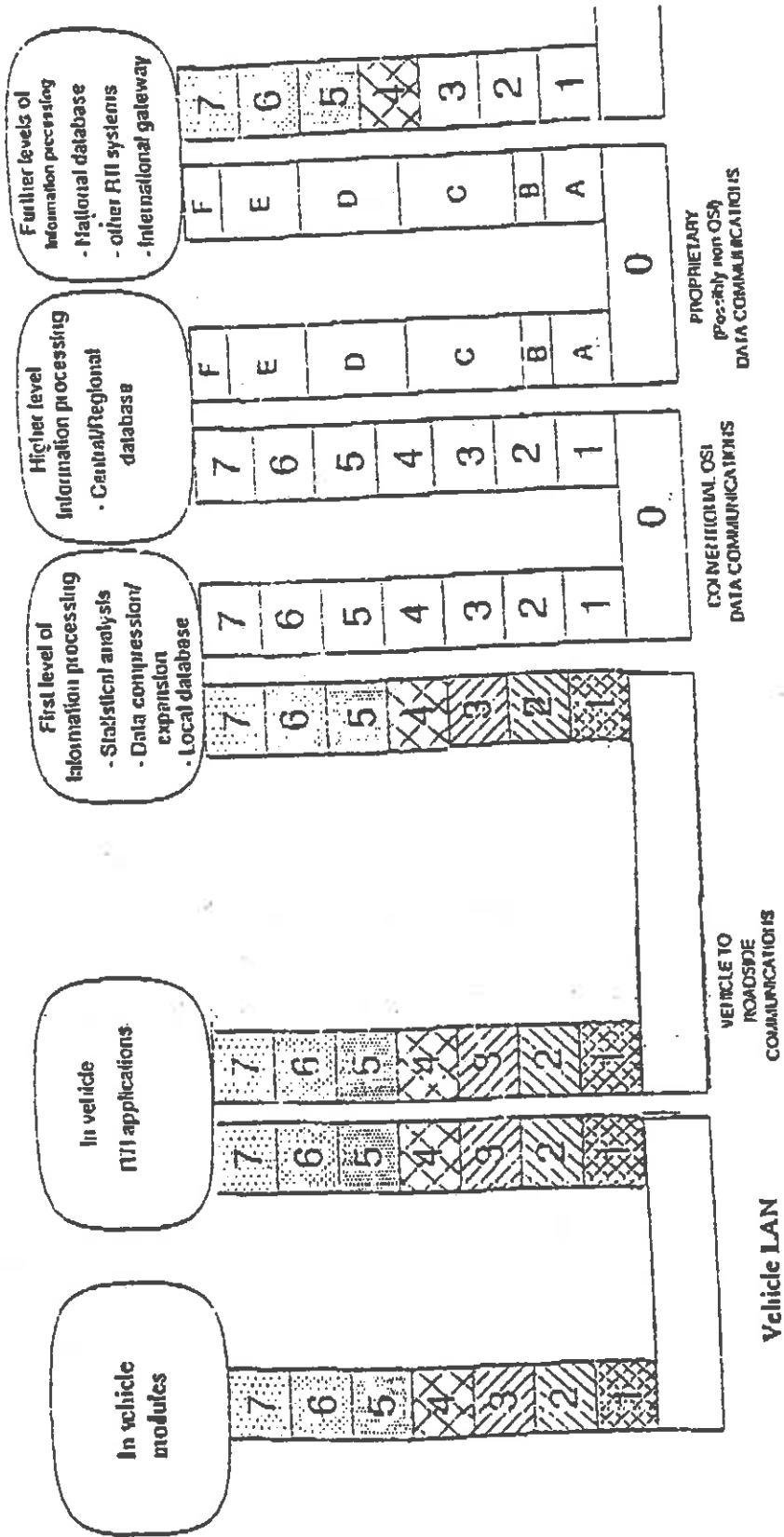
The Functional Architecture



DNT = DRIVE Normalised data Transmission

fig. 2

GENERIC COMMUNICATION PROTOCOL REFERENCE MODEL FOR DRIVE



Shaded OSI layers are DRIVE specific, the other communications stacks (unshaded) use conventional or proprietary protocols

fig. 3

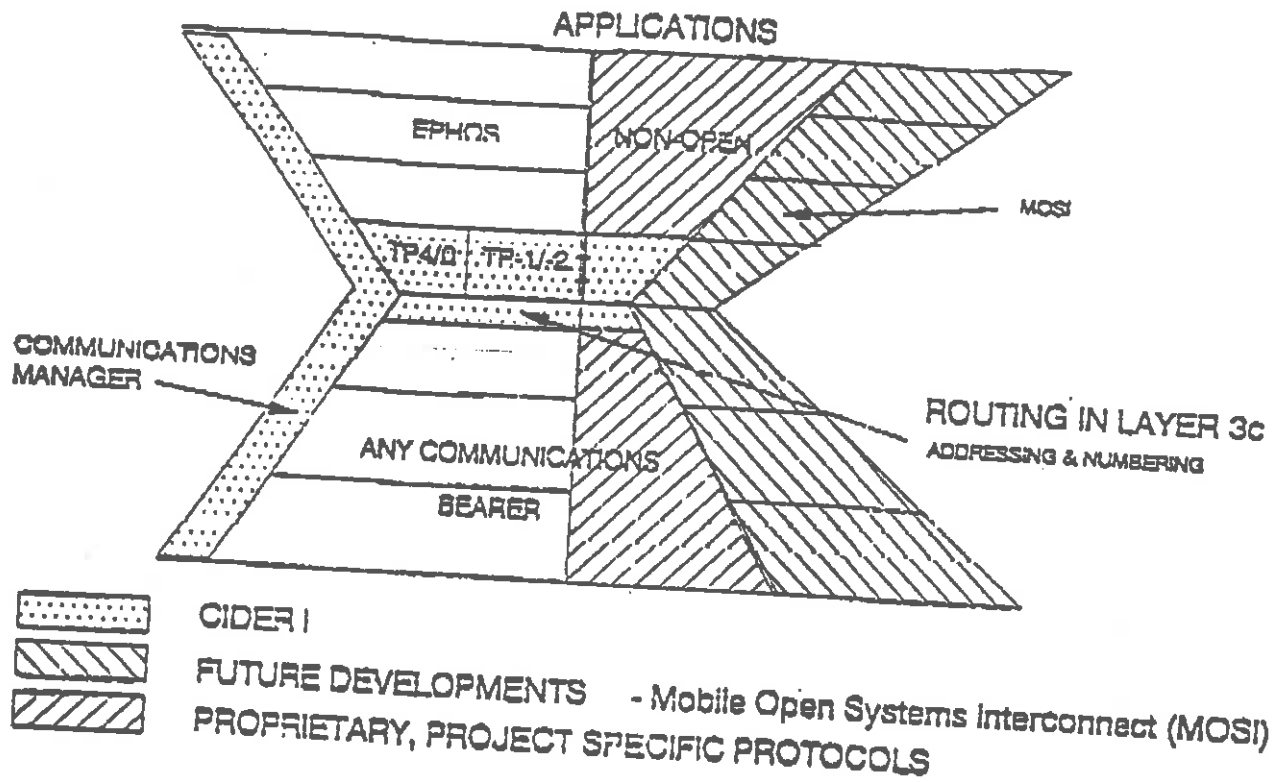


fig. 4

THE SERVICE PLATFORM

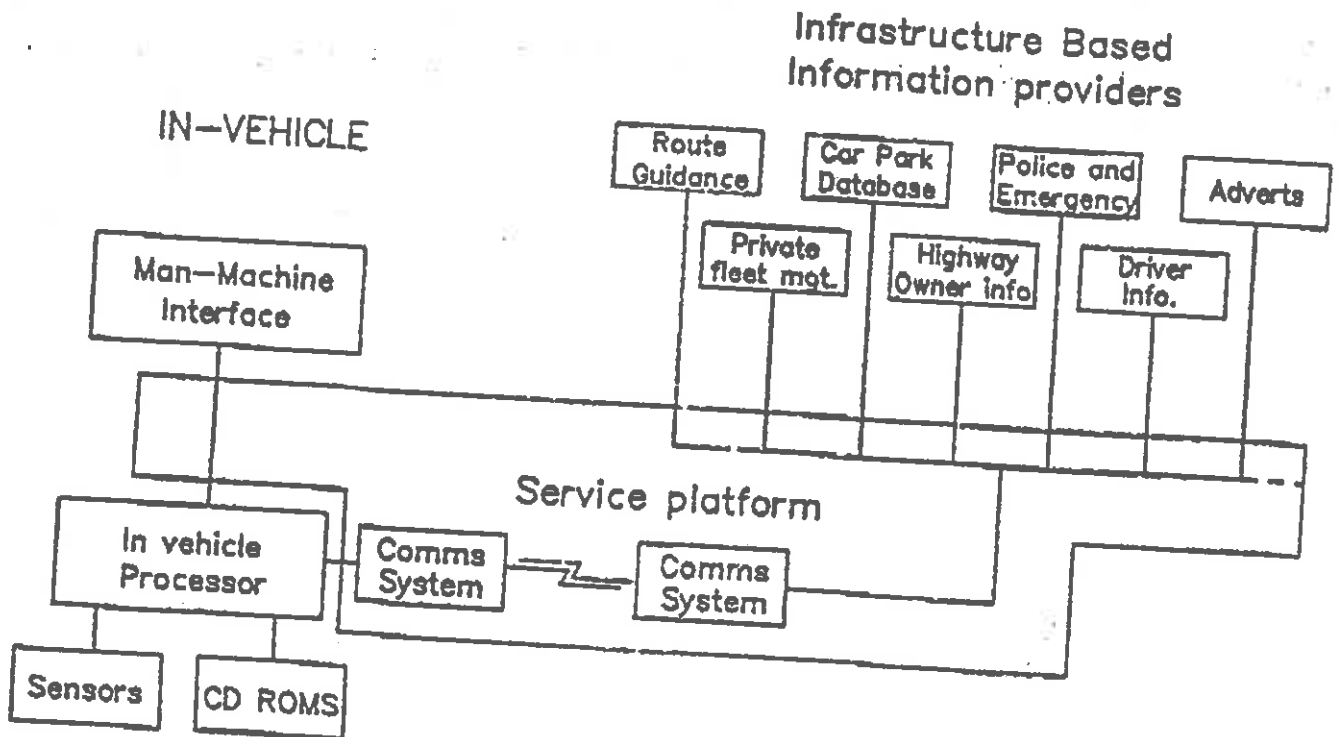


fig.5

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Rockwell
International

28 January 1992

Professor Kan Chen
Electrical Engineering and Computer Science
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Dear Professor Chen:

Globally numerous IVHS research type projects are being conducted around the world with different approaches to the method of measuring the achievements. This paper is suggesting that projects, which have a common global interest, be standardized for world wide data sharing.

Clearly Japan is leading the evaluation for on-board navigation and information systems. Europe is deeply involved with automotive safety while North America is searching for methods to double or triple highway capacity without additional expansion of existing highways. In all three cases industry, government and the universities have been working together to better understand the opportunities IVHS has to offer. Initially the unique needs of the continents will result in different IVHS emphases but with time and a growing global emphasis it is inevitable that the needs/markets will converge.

IVHS-America, as the first national organization open to the global community, has a responsibility to help in defining needed standards and organizing workshop meetings that benefit the world. Standards take time, and it may be best to allow the testing phase to be completed before involving world players. On the other hand, standardizing the IVHS projects evaluation procedure is a task that would be a great benefit to the global community. The help is needed now and the global community appears eager to work together. All parties would benefit through a greater consideration for the measurement procedure and the

added possibility of studying the effect that cultures, environment, government, etc., may have on the results. This is a task well suited for universities and private Centers of Excellence.

Each continent has been utilizing their universities' talents in helping to define the IVHS opportunities. Clearly, the IVHS industrialization is not an area where our schools can be involved but they can play a significant roll by helping to evaluate what has actually been accomplished and recommending changes. The Travtec project in Orlando, Florida is using two universities to evaluate the actual performance compared to project objectives. This is one real positive way to involve teaching facilities and educate the future generations needed to improve/maintain the evolving complex systems.

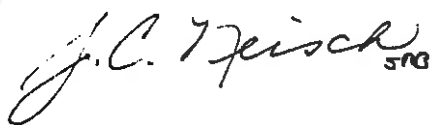
Each continent has been defining this task with Japan and Europe leading the way. This is a great opportunity to start working together since each participant will have studied the problem and is eager to make a contribution. Also with different levels of experience, the exchange of information is richer and far more beneficial to all involved.

The concept of standardizing test data was first publicly proposed in a meeting between the European project, Prometheus, by Mr. Glathe and representatives from Mobility 2000 meeting at the University of Michigan in October 1989. However, North American had no official organization such as IVHS-America to initiate the approach. The International Liaison Committee of IVHS-America is now formed and would seem to be the logical starting point for these discussions. Japan has delegated a similar group and Europe is planning to do the same. I personally have observed the Europeans eager to exchange ideas at technical workshop gatherings.

The universities are the ideal leaders for this task. They totally understand the technology involved. They have helped design the key agriculture in their respective countries and they are eager to play a benefiting roll. The universities could serve two vital rolls: first, the auditing function to assure the financial backers and the technical community on the actual results obtained vs the predicted results. This is a crucial task that needs objective evaluation if the global community is to make real progress. Secondly, the universities/industrial

research facilities are well suited to play the ambassador roll. Workshop meetings could be held internationally on a regular basis, meeting in alternate continents where IVHS activities could be reviewed. This concept of discussing and exchanging ideas using our universities on a global basis was first presented and well received at the 1991 ISATA Conference in Italy by the writer.

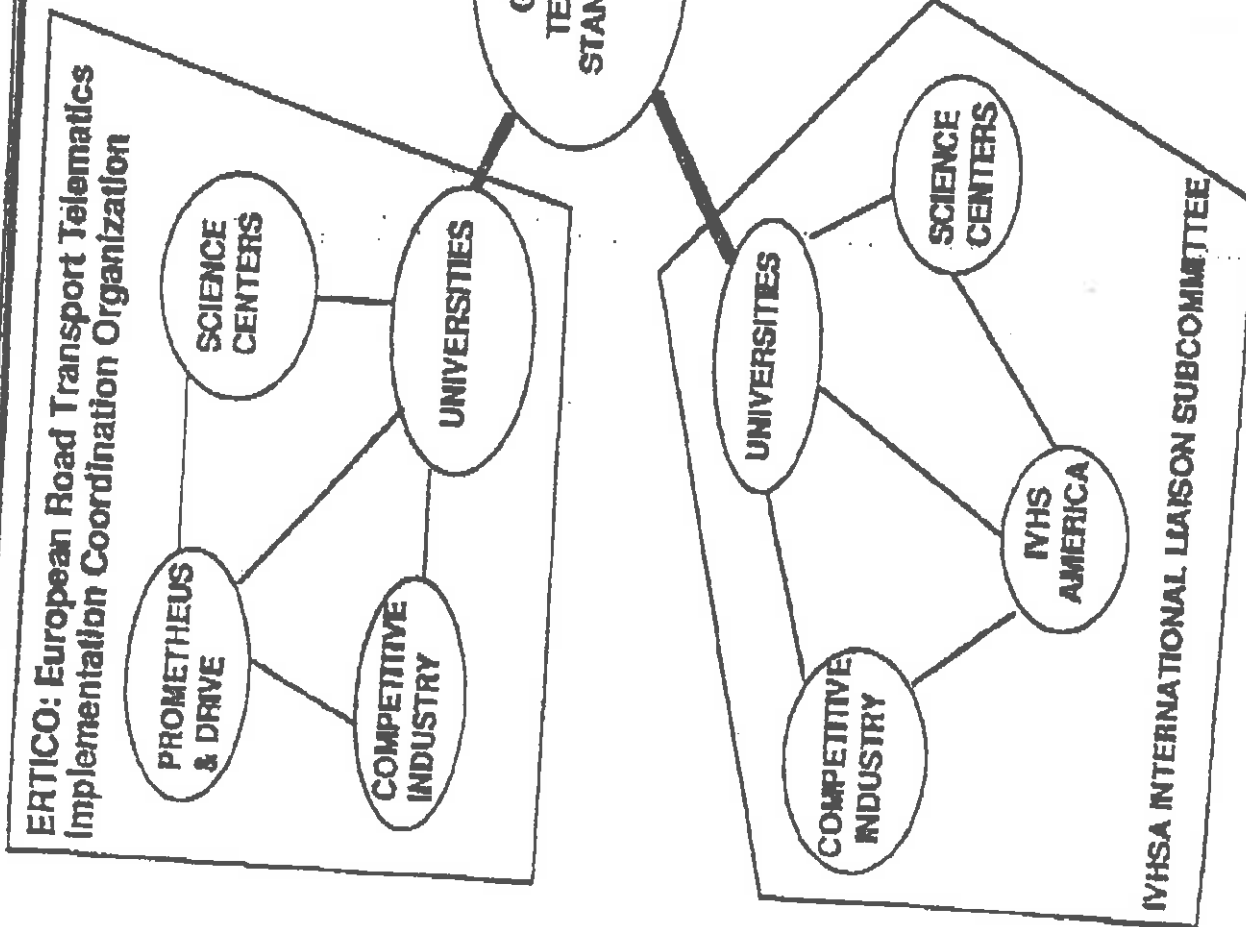
During the question and answer period that followed, the concern was for the financial support needed. Mr. Lamm, President of IVHS-America, was first to point out that for North America, IVHS-America could provide the funding. I am convinced that both Japan and Europe would do the same. Personally, I have had discussions with both AMTICS and RAC Japanese representatives, and the idea was well received. What is needed is for the universities to explore this idea further with delegations from all three continents meeting to plan the architecture of how they would function and be funded. I challenge Dr. Kan Chen and the University of Michigan to accept this task and begin the planning. IVHS is a long range program involving more than 30 years of research. We have a unique opportunity to work and grow together as a global team and, through the universities, the students can make it happen.

A handwritten signature in cursive script that reads "J.C. Neisch" with a small "570" written below the name.

James C. Neisch
Advanced Engineering Manager
Automotive Body Systems

APPENDIX D

A GLOBAL STRATEGY



BENEFITS:

1. Universities provide a free thinking, pre-competitive, neutral environment.
2. Global team effort.
3. Global communications and discussions

