Deploying ITS Map Database Interoperability Standards

A two-day workshop

sponsored by

Caltrans — California Department of Transportation
NCGIA — National Center for Geographic Information and Analysis
ORNL — Oak Ridge National Laboratory

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Introduction

Intelligent Transportation Systems (ITS) are being proposed for managing and alleviating congestion on the transportation network. The technical and administrative issues surrounding the deployment of such systems are numerous, and considerable federal and state resources are being directed to research on ITS technologies. Selected ITS applications are currently being tested and implemented by the private and public sectors. This is resulting in the proliferation of public domain and commercial databases used for ITS and advanced transportation applications. Hence, one of the obstacles to a fully functioning nationwide network of intelligent transportation systems is the compatibility and interoperability of regional and federal map databases used to support ITS implementations at various jurisdictional levels.

The NCGIA in combination with the California Department of Transportation (Caltrans) and the Oak Ridge National Laboratory (ORNL) convened a workshop on December 3 and 4 to address issues associate with the interoperability of ITS map databases. The purpose and format of the workshop was determined by the Steering Committee composed of Michael Goodchild, Director of the NCGIA, Richard Church, Professor of Geography at University of California, Santa Barbara, Ramez Gerges from the Caltrans Testbed Center for Interoperability, Cecil Goodwin of Viggen Corporation, and Stephen Gordon from ORNL. The focus of the workshop was the potential for ORNL's Location Reference Message Specification (LRMS) and ITS Datum to serve as national standards to enable interoperability between ITS databases. In particular the workshop was structured to address questions about implementing these specifications in regional ITS databases. These specifications attempt to standardize the methods of communicating location references between databases (LRMS) and the way of registering databases to precise monument locations respectively (ITS Datum). The most current versions of these specifications are included in the appendices (Appendices A and B respectively) of this report.

A hypothetical situation in which the specifications would be necessary was outlined by Cecil Goodwin during the workshop. A driver has just crossed the state line into California. She has an in-vehicle navigation system made by a commercial vendor using their proprietary database. She now begins receiving message about traffic conditions from a traffic management center (TMQ in California, but the TMC is using its own database to locate events or traffic conditions. How will it be possible for the system in the driver's car to understand the messages from the TMC and properly locate the conditions being transmitted to her on its own database?

This report is a summary of the discussion and conclusions of the workshop. It includes the preliminary materials for the workshop as well as materials distributed during the workshop. The report proceeds as follows. It begins with a statement of the objectives of the workshop. It continues with a brief description of the format of and participation in the workshop. It then contains a summary of the substance of the workshop (i.e., a description of the presentations and discussion).

Workshop Structure

This section describes the objectives and agenda of the workshop. The objectives were defined by the steering committee in the form of a set of questions to be addressed by the workshop participants. In addition, participants were requested to provide input in the form of brief issue statements to refine the objectives and agenda of the workshop. The workshop attempted first to establish a common foundation of knowledge among the participants through a series of presentations about the LRMS and ITS Datum and issues related to map database standards and then to obtain answers, or at least refinements, to the questions that were posed as the workshop objectives.

Workshop Objectives

The steering committee wanted feedback on the potential obstacles to implementing ORNL's LRMS and ITS Datum in databases that are regional in scope. It was important to have input from the various organizations, public and private, that would be using or developing such databases. Participants were invited from the transportation agencies on the federal and state level, major map database vendors, and universities. The list of participants is included as Appendix C.

Each participant received a list of questions that reflected the information desired by the steering committee. The questions were the following:

1. How can the Location Reference Message Specification (LRMS) and ITS Datum being developed by ORNL be implemented at a regional level?
2. What are institutional issues for LRMS and ITS Datum implementation?
3. What technical and economic issues do vendors foresee in LRMS and ITS Datum implementation?
4. How does the Geographic Data Format (GD,F) standard mesh with the California Navigation Reference Database?
5. What are the requirements for lanes in ITS databases and data transfer standards?
6. What are the requirements for objects in ITS databases and data transfer standards?
7. What other standards are needed for ITS?
8. Who are the partners, and what are their roles and mechanisms for making conforming databases?
9. What are the prospects for success?

These questions cannot be answered in a one-day discussion, so the goal of posing these questions was to identify issues or more specific questions that must be answered to address them.

Workshop Format

The workshop took place in the Santa Barabara Radisson Hotel on Tuesday, December 3 and Wednesday, December 4. The first day of the workshop consisted of presentations by the steering committee and researchers doing work related to map database standards. The second day involved breakout discussions in the morning and reports from the breakouts in the afternoon. Appendix D contains the agenda of the workshop. The breakout discussions attempted to formulate responses to selected questions from the list shown above. The rest of this report will follow the structure of the workshop in describing the crux of the presentations and breakout discussions.

Presentations

Ramez Gerges - Caltrans, Testbed Center for Interoperability (TCF1)

Mr. Gerges began the workshop by establishing the administrative and technological context for the workshop. He described the technical infrastructure that has been established by Caltrans as well as the work by Caltrans on issues of interoperability and ITS. He also gave a good picture of the standards environment within which Caltrans must perform their ITS and interoperability work. The transparencies from Mr. Gerges's presentation are included in Appendix E. The following describes the major points of his presentation.

This talk gave an overview of ITS deployment in California focussing on interoperability and reuse of data and applications. The Testbed Center For Interoperability (TCFl) performs a variety of tasks:

- isolate applied technology
- address technology transfer
- demonstrate interoperability
- test deployment and dependency of selected standards
  - 45 standards were identified earlier this year
  - 25 were messaging standards
  - none address how to deploy distributed systems

Michael Goodchild - Director, NCGIA

Dr. Goodchild presented issues in data modeling that may constrain interoperability between map databases. Transparencies from his presentation are included in Appendix F.

A map database is an index that allows us to switch between coordinates and street addresses or monuments. For it to be navigable, it must have connectivity information. This puts us in the realm of GIS because of its traditional focus on handling location attributes and relationships between object. However it is still a messy problem because streets are complex objects.

There are several options in modeling streets. First is the data model. Data models represent different worldviews (e.g., streets, centerlines, etc.). For example, there is the question of where to start and stop streets. This raises the issue of representing intersections and whether to use a planar data model. The second option is whether and how to represent lanes.

The problem of interoperability is one of shared meaning. Shared semantics are necessary for interoperability. The best example of shared meaning is coordinates. The meaning of coordinates are shared effectively. Other examples include datums, projections and accepted standards.

However, it is important to recognize intrinsic accuracy limitations based on our limited knowledge of the figure of the Earth. We can locate a point only to within 10 meters of its absolute location on the Earth. Relative location is more accurate, but one must ask the question relative to what. We must standardize the reference points used for measuring relative locations. A good example of such points is the national geodetic network of monuments. This network should be densified for local ITS database use though.

In conclusion, the prospect for standardizing coordinates is promising, but the potential for standardizing street names and monument names is much more limited.

Cecil Goodwin - Viggen Corporation

Mr. Goodwin gave a presentation on the LRMS and ITS Datum. Mr. Goodwin's transparencies are included in Appendix G.

Location Reference Messaging Specification (LRMS)

Location is always with reference to something, and there are many location referencing methods (e.g., point/link id, coordinates, grids, linear referencing (complex and simple systems), cross streets, addresses). Most of the activity worldwide is geodetic (coordinate systems only) because of the long history and easy of interoperability with coordinate systems in map databases and the use of GPS to attain coordinate values. Location referencing must support ITS communication and data sharing. ORNL/FHWA LRS have recommended that there be standard message specifications and a common spatial reference datum to support multiple referencing methods.

LRMS is a flexible framework for accommodating different location referencing methods. It is a component of a larger system. Because transportation entails movement and therefore communication, LRMS is aimed at dynamic interoperability problems more than at static problems. It must fit within a context of many other proposed standards that are needed to convey application understanding, semantic understanding, and syntactical understanding. The OSI model is useful to place the LRMS within this context. The application level must be related to the message set level.

An example of a design decision that takes this into account is whether route objects should be included in the LRMS. Routing is a function that is on top of the LRMS and an application that can use the LRMS. Schema information should not be put in the LRMS because it would never be completed. LRMS cannot satisfy every user or every process.

LRMS is actually composed of several profiles. The LRMS message structure contains the following:

- a start code to identify the kind of message or profile
- a series of attributes associated with the kind of message
- one of several profiles including profiles for:
  - point/link ID
  - geographic coordinate
  - grid linear referencing

ITS Datum

The ITS Datum is a set of nodes and links in a standard non-planar network at a coarse scale for the entire nation for referencing purposes. It has been viewed as a product rather than a standard. It has two components: the ITS node set and the ITS geodetic datum. More information is available on the World Wide Web at http:H128.169.84.18/spatial/. This is a new web site that integrates Arc/Info and a web browser. It is an experimental site that can be used to test coordinates on the datum. The ITS geodetic datum is the WGS-84 datum which includes elevation and horizontal measurements. The ITS datum node set places nodes on key transportation intersections. Each node has a unique ID, and its latitude, longitude and elevation are recorded. The Datum also records for each node the ID's of connected nodes to which navigation may occur, the earth distance to the connected nodes, and street names of the links to the nodes. The density of the nodes varies based on the geography (i.e., population density) of the area. For example, the New York City area has ab 55,CO6'no-4s, and the Santa Barbara area has two. The ITS **Datum** has three purposes:

- provide commonly known ground control points for important highways,
- provide registration points for "rubber sheeting" datasets from many sources, and
- provide local reference points for LRMS referencing between "compliant" datasets.

The primary objective of the ITS Datum is to provide anchor points for matching different cartographic databases. This may be called the push-pin approach.

ORNL is avoiding intrusion into the private sector's responsibilities and products. However, to use and be compliant with the ITS Datum, dataset providers should agree to:
- possess the ITS Datum and LRMS,
- locate datum nodes within their own datasets, and
- understand references made in terms of the ITS Datum using LRMS formats.

The question of who will certify compliance with the ITS Datum is still unresolved. It is possible that the Society of Automotive Engineers (SAE) will be the appropriate institution. They are developing a testing institute to test the validity of accuracy claims by vendors for the road databases ("truth in labeling"). The ITS Datum is not responsible for the quality of the data that is being transferred, and it will not define message sets or transactions that may use the LRMS, but there will be assistance for users regarding their own applications There are several improvements to the ITS Datum that are possible. They include improvements to the accuracy of the Datum measurements as well as to the model of intersections and linear referencing methods. The accuracy improvements include enhancing the coordinate accuracy for the Datum nodes and measuring ground distances accurately. In terms of the intersection model and linear referencing, possible representations would be an intersection object model and local offsets from Datum nodes. These improvements raise several issues of local data collection procedures, accuracy of datum points for transportation applications, and the cost of data collection.

It is important to be clear about what the ITS Datum is not. The ITS Datum does not provide a national-level dataset to support linear referencing directly. The hardware (sensor) does not exist for **the individual vehicle yet, and the** technology of vehicle odometers and their associated errors would demand a very dense node network. Urban areas are particularly sensitive to these errors.

There are several new possibilities for positioning technology. They include:

- active beacons,
- passive markers/labels on infrastructure, and
- AVSS technology synergism’s.

John Nystuen and Rajendra Aggarwala -- Univeristy of Michigan

Drs. Nystuen and Aggarwala presented the results from their research on comparing the accuracy of different road databases. Their goal was to develop method for evaluating the accuracy of databases. This method could be applied to a third party to a vendor's database. Their transparencies are included as Appendix H.

There are several aspects to evaluating database accuracy, and the requirements for each of them are application dependent. The components of accuracy include: lineage, spatial, attributes, completeness, logical consistency, semantics, and temporal issues. All of these components must be tested, but this poses a problem because they are interconnected. This research attempted to assess one aspect of accuracy (i.e., positional and topological accuracy) without referring to another (e.g., road names).

One objective of the research was to identify difficulties that may be encountered in establishing a program of certifying a map as meeting a claimed level of accuracy. One possible approach for this is field testing vendor products. Another is matching a test map against a reference map or photograph with higher accuracy. Both of these approaches raise sampling issues. However, the interest of this research was in trying to develop automatic procedures of certifying a database with minimal field testing and minimal manual intervention.

The basic approach of this research was to conflate maps together and compare them in various ways. The databases were based on the same datum, so that different coordinate systems did not pose a problem. The two databases used were a prototype ETAK database and photogrammetric base map at a larger map scale. Both maps covered the Ann Arbor, MI area. The watercourses and administrative boundaries were removed from the databases before they were compared. Each database was tiled, and then street networks within selected tiles were compared. The comparison was based on an overlay of the tiles from the two databases.

The goal was to identify positional errors and errors of omission and commission. This was done by buffering around the arcs and nodes in one database and recording the number and kind of violations of a certain buffer size. Violations refer to buffers in the first database that do not overlay any nodes or arcs in the other database or nodes or arcs in the second database that do not fall within a buffer of the first. The distances between nodes and arcs and errors for each tile were then summarized. It was found that topological errors are difficult to identify and match between databases. However, the technique used in this research was helpful in identifying representational or definitional differences, for example boulevards represented as one line or two. The results of the comparison are shown in the table in Appendix H.

The research concluded that developing a low cost quality means of automatically checking map accuracy is very challenging. Some operator intervention will almost always be necessary. It also suggested certain observations and areas for future work. Among them are:

- Topological consistencies should be addressed in the future.
- Government databases may require specification of representations at different scales, but private sector developers would just as soon avoid such standards.
- Attempts to standardize representation have not succeeded because they limit innovations too severely, so perhaps guidelines are better than standards, where vendors can specify whether the deviate from the guidelines.
- How is it possible to differentiate temporal errors and errors of commission and omission
- A spatial sampling scheme for point and line and route samples **will probably helpful.**

Alan Vonderohe -- University of Wisconsin

Dr. Vonderohe presented his research on linking different linear reference systems in such a way that we could constrain the error involved in the reference systems or the resulting linkage. His transparencies are included in Appendix 1. He posed several questions to begin his discussion:

- Can we make statements about the accuracy of reference systems?
- Can we make statements about the linkages between reference systems?
- Is there a way to design these linkages such that we can make quality statements about the accuracy of the reference systems?
- Can geodetic methods be applied to linear methods?

There are many different representations and referencing methods used for transportation data. They include: business data, linear referencing methods, network representation methods, datums, and geographic representation. Each referencing system has a specific way of referencing data. For example, we can use anchor points (associated with the datum) versus links and nodes. The anchor points may be based on WGS84, NAD83, PLSS, or NAVD88. They may have variable spatial dimensions (i.e., 3D, 2D, I D). The objects necessary to model them would include: 3D Cartesian axes, an ellipsoid, a geoid, etc., and they would require reference objects such as GPS satellites and horizontal control stations. This research looked at existing reference systems to determine if it feasible to enforce accuracy in different systems while transforming the coordinates of one to another and if some of the methods in geodetic reference systems can be used in linear reference systems.

Within each referencing system we can make certain transformations; in each system a coordinate offset is measurable. Each system also has certain constraints, composed of closed shapes (e.g. a rectangle). For example, we can take four points, and **in error free conditions, the** sum of **the differences** of locations will be zero around these loops. That is:

Ax = 0,
Ay = 0, or
Az = 0 (if the system is in three dimensions).

In linear referencing systems a loop entails moving to a point along a line and returning to the origin point. It is not a rectangle.

It is then possible to calculate the magnitude of error propogated through a series of calculations. The error in a measurement is based on a linear combination of component measurements (parameters), and the error in the components is based on the variance in measurements. Variances relate to the uncertainty of point locations. Relative uncertainty describes the uncertainty of the distance between points. It is possible to calculate measurement error for linear events as well as points. Linear reference error is additive. Often the final measurement is known, but the problem is figuring out the error in the component measurements.

Calculating the uncertainty of distances that are derived requires us to know errors associated with location measurements and the correlation structure of those measurements. Redundancy is also required to determine error of locations. Therefore, a linear system must be overdetermined. This will provide standard deviations of the parameter values, and a variance-covariance matrix. Using the covariance matrix, and given an event, we determine the distance to that event, and the associated uncertainty. See Appendix I for the mathematical formulation of the error calculations.

There are several levels (orders) of system design:

- Zero Order Design - datum fixation. This is not important to the linear problem but ensures that the covariance matrix is computable. In linear systems direct measurements are used.
- First Order Design - system configuration.
- Second Order Design - measurement technology and procedures. This relates to which measurements are taken where? In this stage we must introduce sufficient redundancy to reduce uncertainty to an acceptable level.
- Third Order Design - adding new components. That is, how do we link reference systems?

The design problem in linear referencing is to take a look at the user's requirement for accuracy and specify the maximum value allowed in the covariance matrix and then 'back out' the requirements regarding the uncertainties of the reference points to figure out the best, most reasonable measurements. An example application of the error determination techniques to first order design showed that the reference data set should be 2 to 3 times as accurate as the acceptable final error. An interesting conclusion of this research is that it argues mathematically for fewer reference points.

Afternoon Panel - Speakers: Bruce Spear, Bureau of Transportation Statistics, US Department of Transportation; Ken Dueker, Portland State University. Moderator. Richard Church, NCGIA.

The purpose of the afternoon panel was to refocus the group onto the specific objectives of the workshop as expressed by the list of questions distributed to the attendees before the workshop. It consisted of two speakers, Dr. Ken Dueker and Dr. Bruce Spear, and was moderated by Dr. Richard Church. The speakers gave brief presentations that related the morning presentations to the objectives. Dr. Dueker began the panel session with a discussion about linear data models and a comparison of different work on ITS databases.

Ken Dueker - Portland State University

This presentation approached the problem of ITS database interoperability from a state and local perspective. What do we mean by data-sharing and interoperability? The focus of this brief talk was on data-sharing for map database updating. The maintenance issue is going to drive this. There are two points about the work by Butler and Dueker are relevant to this discussion.

First, Oak Ridge has focused on the data transfer rather than content. However, we are continuing to suffer with an integrated linear data model. This is the link-based legacy data model where there is a one-to-one correspondence between attributes, cartography, and the link. This overlooks basic questions of what is the basic underlying network and how we aggregate it; how do we get the most detailed network alleys, driveways, transit lines; how do we separate attributes, cartography, and links? It is important to recognize that the needs of network models differ for different applications. We can build a network for garbage truck routing or one for transit routing, or emergency dispatch vehicle navigation. Of course, vendors don't want to have to conflate networks from different sources, but we need a non-link-based approach.

Second, how does the Butler-Dueker work compare with the rest of the work that is being done? Different efforts are using different terms and focusing on different elements. The purpose of the Butler-Dueker paper was a data model / enterprise model. Oak Ridge is focusing on ITS datum network, is it link based? The NCGIA is working on a lane-based, non-planar model closely related to our named roads. The detailed comparison is shown in table among the copies of Dr. Dueker's transparencies in Appendix J.

One last question is can we avoid the conflation problem all together? This talk deliberately avoided bringing things to a close, and introduced more issues to the table.

Bruce Spear - Bureau of Transportation Statistics

Dr. Spear also discussed the definition of interoperability as well as how ITS databases fit into a general context of transportation databases.

Interoperability often has different meanings to different people. The definition of interoperability underlying this discussion is related to get everything working together in real time. However, an important question posed to this workshop that is, "How do we introduce a set of anchor points so that database vendors can interoperate?" This seems to be dealing with a transfer of static databases and transfers between them.

Another interesting part of this workshop is the ITS community. There are a lot of state DoT's and regional transportation management agencies who may be paying lip service to ITS, but they are really interested in facilities management, pavement, etc. Navigable databases are further down the road. Those agencies are the folks who will be maintaining this data, and so they should be involved these discussions. The Navtech's and ETAKs of the world are just as dependent on the state DoT's as the ITS community.

Who are the multiple stakeholders who will be involved? It's difficult to talk about just an ITS database. If we want to talk about these databases, then we need to design something that everyone can use. Whatever is developed, should be useable by a broader community that deals with transportation data.

There was a workshop in Seattle recently of non-transportation people who wanted to build a prototype database. After considerable discussion, they decided that a road segment goes from decision point to decision point. One thing interesting thing that came out of this is the notion of a named right of way. This makes it possible to transfer data between databases. Dueker's notion of separation of cartography, attributes, and topology is probably the right way to go.

It's going to be quite difficult to design a database or data model without having a clear application in mind. This is very difficult. We have been pursuing a database definition without a sound understanding of the application needs.

Richard Church - University of California, Santa Barbara

Dr. Church posed two questions to the panelists. First, various vendors have navigable databases in the field. We don't know what's under the hood. How successful are they in receiving information that is broadcasted?

Second, if we really want to focus on interoperability, what are the standards by which we say "how good is this approach." Current approaches exist, so how do we evaluate them? Should we be focused on the data definition, or should we focus on communication.

Response by Dr. Dueker - These questions focus on part of the interoperability problem. During an incident, it would work if we all had the same link id's. We don't all have the same link-id's.

Response by Dr. Spear - It all comes back to what is a road? What do I broadcast to a database? There are a lot of people building map databases who don't know the implications of what that map database might be used for. It comes back to data modeling.

Open Comments

The following segment summarizes the discussion that occurred after the panelists' presentations. This discussion was unstructured. It included questions for the panel and general comments from the other participants. Therefore it is presented as a list of salient points:

- The link-id problem is an indexing problem. Roads have always been problematic in this regard. Conventional indexing schemes don't work too well. Sometimes the user has an address, or a street name, etc. The more people who get involved in this problem, the more complex this problem becomes.

- Usually, state DOT's just work in a vacuum, and everything is fine. However, with other parties getting involved, the notion of interoperability becomes more critical.

- For now, ITS can do whatever they want. Just have a database czar say, "This is how we will do it." But down the road, two cities that have gone different directions must try to figure out how to cooperate.

- A data model is not created in a vacuum. In papers describing data modeling efforts, there was not a lot of business discussion or application discussion. What is it that we are trying to do?

- The purpose of this workshop is to avoid these top level discussions and focus on a microperspective. The LRMS is driven by a need to transfer information to existing vendors. While, it may be bottom up, people are considering the top down approach as well. The desired conclusions of this workshop are whether LRMS is going to be too restricting or not restricting enough. For example, are there problems implementing your data model that will influence the LRMS? Is a particular database going to force the LRMS to do something that we haven't considered?

- There is no perfect georeferencing systems. There are always problems. To reduce ambiguity, we need to use multiple methods of referencing things.

- We have been talking a lot about vehicles with GPS, and they are like big digitizers driving down the road.

- Transportation planners have been working with topological networks since the sixties. It is only a coincidence that it is related to cartographic representations.

- From a contraire approach, this discussion has been talking about how many angels can dance on the head of a pin because all existing models of roads are bad. We need to understand where these models break down based on their assumptions.

Wednesday 12/4 -- Morning Plenary

Moderator. Cecil Goodwin., Viggen Corporation This discussion provided specific instructions to the breakout sessions. It included some elaboration on the issues critical to regional implementation of ITS database standards. It began with a scenario posed by Dr. Goodwin. Such a scenario was a useful device for focusing the breakout groups on specific objectives and questions to be addressed. This was followed by a discussion in which the workshop participants clarified various issues that the scenario raised and refined the objectives of the breakout sessions. This section summarizes the scenario presented and the ensuing discussion.

The scenario was the following: assume there is a car coming into California with an invehicle navigation system provided by Navtech. We wish to broadcast information to that system regarding traffic conditions, etc. There's a map matching problem when the local database of Santa Barbara has to be used to transfer information to the Navtech database. This is the map interoperability problem. What is necessary from a local perspective to support this? What does a locality need to do?

The vehicle comes into the area, it is on an ITS datam link - 1101. The database in the vehicle is ITS Datum and LRMS compliant. In other words, the vehicle database has the ITS datum nodes and links resident in it. The in-vehicle system "knows" where the vehicle it is on its own database, but it can't guarantee that it knows where it is on another database. The national ITS database has only two nodes for Santa Barbara. However, the Santa Barbara database will have a much denser set of nodes. If the TMC is using a pure linear referencing system, then the shapes of the links are not important for matching the two databases. There may be a problem with passing tokenized information. The transmission of traffic or incident data to vehicles will always be bandwidth constrained environment.

Assume the TMC is using an ESRI map, one car is using a Navtech database and another is using an ETAK map. Each map may match an incident to a given link, different id's in each database, but they should represent the same point on the same link in real space. The way that Navtech would exist in a car would be as a CD ROM. It would probably use one CD. Currently Navtech has two densities: one national and one local city. A given driver would have one CD in their car (e.g., a detailed map of California and the major highways leading out of California).

Breakout Sessions

There were two breakout groups. Each group concentrated on either institutional or technical issues related to LRMS and ITS Datum implementation. The workshop participants selected which group in which they participated. The groups were directed to address relevant questions from the agenda (brochure). That is, some questions were technical in nature, and some were institutional in nature, and some could be both. It was not possible to answer the questions in a brief half-day discussion so the objective of the breakout sessions was to specify the issues involved in answering them. This could take the form of posing more specific questions to pursue. The division of the questions was as follows (the numbers correspond to their order in the initial sequence of questions):

Technical Questions:

1. How can the Location Reference Message Specification (LRMS) and ITS Datum being developed by ORNL be implemented at a regional level?

3. What technical and economic issues do vendors foresee in LRMS and ITS Datum implementation?

4. How does the Geographic Data Format (GDF) standard mesh with the California Navigation Reference Database?

5. What are the requirements for lanes in ITS databases and data transfer standards?

6. What are the requirements for objects in ITS databases and data transfer standards?

9. What are the prospects for success?

Institutional Questions:

1. How can the Location Reference Message Specification (LRMS) and ITS Datum being developed by ORNL be implemented at a regional level?

2. What are institutional issues for LRMS and ITS Datum implementation?

3. What technical and economic issues do vendors foresee in LRMS and ITS Datum implementation?

4. How does the Geographic Data Fon-nat (GDF) standard mesh with the California Navigation Reference Database?

7. What other standards are needed for ITS?

8. Who are the partners, and what are their roles and mechanisms for making conforming databases?

9. What are the prospects for success?

In addition, both groups were instructed to answers a tenth question: What does it mean to validate a standard?

After the groups considered their questions separately, they reconvened as the larger meeting to report on the results of their deliberations. The following description gives a brief summary of the discussions about each question in the breakout groups and the conclusions that were reported to the complete meeting when it reconvened. It is not possible to report on the entirety of the details of the conversations in the breakout sessions, so the topics that were discussed are only summarized. The results reported to the larger meeting are listed after the discussion summary as bulleted conclusions from the discussions.

Technical Group

1. How can the Location Reference Message Specification (LRMS) and ITS Datum being developed by ORNL be implemented at a regional level?

The group began addressing this question by asking the question, "What data requirements do we have?" It proceeded with a lengthy discussion of accuracy requirements for the ITS Datum. This raised questions about the accuracy requirements for different applications of the Datum, including but not limited to ITS applications, the necessary density of Datum nodes, appropriate locations for Datum nodes, and a procedure for including locally determined nodes in the national Datum. There was agreement that two levels of accuracy may be required, one for national ITS applications and one for local transportation databases. However, the federal government, at least in the context of the ITS Datum, will not be able to provide the accuracy and node density required for the local level applications. The FHWA is only interested in about 10% of the roads in the US. However, these roads support a significant majority of the total vehicle miles traveled. The Datum will also not provide any information between the nodes. Thus there may be a cascading densification from national to local levels of accuracy.

Questions/conclusions reported the meeting:

- What are the accuracy requirements for ITS applications?
- What are the accuracy requirements for local transportation applications?
- Who builds and maintains the ITS Datum hierarchy?

- What are appropriate node placements rules?
- Define a national level specification for ITS Datum node accuracy and node density.

3. What technical and economic issues do vendors foresee in LRMS and ITS Datum implementation?

The discussion on technical and economic issues reached early consensus that the primary issue is one of funding. The group also discussed some technical issues regarding LRMS and ITS Datum requirements such as the need for path lengths between nodes in the Datum or truth-in-labeling requirements for databases that claim to be in compliance with the Datum.

Questions/conclusions reported the meeting:

- Who builds the Datum and who funds it?
- How many bytes are necessary for streets names in the LRMS cross-streets profile?
- Are link lengths necessary in the Datum?

4. How does the Geographic Data Format (GDF) standard mesh with the California Navigation Reference Database?

The response to this question began by agreeing that neither GDF nor the California Navigation Reference Database actually exist yet. It then considered the use of GDF as a data model as well as a data transfer format. In this regard, GDF seems to offer an adequate data model although not an adequate physical format for storing data. Questions/conclusions reported to the meeting:

- GDF is adequate as a transfer format.
- It is possible to extract from GDF features, attributes and relationships.

5. What are the requirements for lanes in ITS databases and data transfer standards?

There was some slight disagreement about the usefulness of lanes in ITS databases. Some participants thought that they were not important for navigation applications while others thought that lane information would be necessary for lane diversion information and giving navigation directions to drivers. Questions/conclusions reported to the meeting:

- The general consensus was that there are some requirements for lanes in ITS databases.
- The requirements for lanes will impact vehicle database suppliers.
- How can the requirements be met?
- Can lanes be captured and understood with current implementations?
- Who will pay for the information, and how long will it take?

6. What are the requirements for objects in ITS databases and data transfer standards?

This raised issues of not only the benefit of object modeling but also of current efforts to design specifications for interoperability, such as CORBA and Open GIS. Questions/conclusions reported to the meeting:

- What is an "object"?
- Does Caltrans need them?
- CORBA a good and timely direction to go.
- This does not impact database vendors.

9. What are the prospects for success?

There full agreement that the prospects of success are good, as long as there is adequate funding.

10. What does it mean to validate a standard?

This question introduces issues of how to find out whether a standard is viable and useable. Several alternatives were offered including the possibility of borrowing concepts from computational complexity as well as simply trying to break it the standard. Questions/conclusions reported to the meeting:

- What needs to be tested?
- What testing programs are needed to validate ITS spatial data standards?
- How can it be done and who will pay for it?

Institutional Group

1. How can the Location Reference Message Specification (LRMS) and ITS Datum being developed by ORNL be implemented at a regional level?

Similar to the technical group, this group began with the question, "What are the problems?" Thus the response to this question overlapped with and is reported in the response to the second question.

2. What are institutional issues for LRMS and ITS Datum implementation?

The discussion touched on topics related to compliance with the ITS Datum and registering several different databases to each other or to the Datum. In addition, some consideration of sufficient accuracy arose as well as the position of the ITS Datum relative to existing geodetic frameworks.

Questions/conclusions reported to the meeting:

- Some regional, city and county government entities have advanced GISs. Is it cost effective to use their datums?
- The ITS Datum is not new. It exists within a national hierarchy of geodetic control.

3. What technical and economic issues do vendors foresee in LRMS and ITS Datum implementation?

Again the issue of accuracy was considered to have a significant effect on the cost of establishing the Datum. There may be the possibility of a company needing centimeter accuracy, but for most implementations, 2 - 3 meter accuracy will probably be acceptable. The cost for each node still varies widely. Locating and monumenting a datum node to an accuracy level of 7 meters costs between $ 100 and $1000 per node. The question of who will be responsible for funding the Datum is still unresolved. In addition, there was some question about the rationale for identifying 50,000 points in the Datum and whether the density of Datum points should be based on the population of an area or some other characteristic.

Questions/conclusions reported to the meeting:

The following points have implications on the cost of establishing the Datum:

- cost of datum points
- number of datum points
- density of datum points (should it be proportional to population)

4. How does the Geographic Data Format (GDF) standard mesh with the California Navigation Reference Database?

The discussion related to this question began to focus on the issues of standards. There are communication standards and messaging standards, but is there a need for a content standard? There are semantic aspects of implementing GDF (international aspects). In other words, there is not international agreement of what is meant by a road and other transportation objects. Should the meaning of a road be standardized. This raises the question of GDF as a content standard versus a transfer standard. It is important that the standard be constraint free. However, the appropriate standard may not exist until it is clear what is necessary within the system. The standard must work between proprietary clients and won't exist until relationships are explicit.

Questions/conclusions reported to the meeting:

- There is a need for transfer mechanism between proprietary environments.
- It is not clear that transfer standards will be able to do this ideally in the near-term.
- The value of a transfer standard depends on the number on vendors and the number of pairwise translations needed.

7. What other standards are needed for ITS?

This response began by considering standards in general. For example, what should standards be based on? There was some discussion of whether standards expedite progress or whether they simply assist what is being done currently. There was some feeling that standards are necessarily constraining because they are manifestations of past methods. Therefore, by definition they constrain potential change. If standardization removes ambiguity, are their alternatives to standardization that can remove ambiguity? It may be possible, and necessary given redundancy across jurisdictions to standardize locations, addresses and ids. In addition, a standard interface between systems allowing vendors' equipment to communicate would promote growth and improvement.

Questions/conclusions reported to the meeting:

> The group could not identify necessary additional standards, but moving to standardized names and naming conventions would further ITS.

8. Who are the partners, and what are their roles and mechanisms for making conforming databases?

The logical partners are those parties with a common interest in transportation systems including municipal administration entities such as emergency services, police, etc. The biggest problem may be getting local entities to buy into the general effort of developing an ITS database or complying with ITS database standards. There are few incentives for local government agencies to do this. Their current databases are fully functional for their needs. The exception is emergency service providers where ITS database may contribute to saving lives. State DoVs, parcel delivery services, real estate interests and retailers may also contribute. One problem is that set of possible partners is context specific.

Questions/conclusions reported to the meeting:

- There is no incentive for local, regional, or state agencies to implement ITS compliant databases.
- The exceptions are 1) emergency response providers and 2) impacted state, regional, and local DoUs.

9. What are the prospects for success?

There was agreement in this group that prospects for success were good as long as funding is available

10. What does it mean to validate a standard?

Evaluation may include whether the standard is used, whether it works, how easily it works and whether it increases required bandwith.

Questions/conclusions reported to the meeting-:

Who will validate standards? This requires field-testing and pilot testing by all stakeholders in the project.