

Location Referencing Message Specification

Foreword—This SAE Information Report describes a suite of alternative location referencing interface profiles for use in Intelligent Transportation Systems. Location referencing profiles enable the location of an event or thing to be communicated from one component of an ITS system to another component in an unambiguous and mutually understandable way. The profiles, when incorporated into relevant standards, will provide common language for the expression of location between the different components of an integrated transportation system, based on what is appropriate for its computer systems, digital map data sets, communications media, and users. The profiles specified here recommend standard meanings (semantics) for the content of location reference messages, and standard, public domain formats (syntax) for the presentation of location references to application software.

This document is based on the Location Reference Message Specification (LRMS) Revision B (MDI), dated May 22, 1997, with additional inputs received from both private sector and public sector parties. The LRMS was developed by Viggen Corporation, on contract to the US Oak Ridge National Laboratory (ORNL) for a project sponsored by the U.S. Federal Highway Administration (FHWA). This document also incorporates recent unpublished input from U.S. public sector agencies. The LRMS profiles included in this report are in varying states of development and will continue to evolve as ITS user requirements and results of computer and field tests become available. Extreme care will be taken in the evolution of the LRMS profiles to ensure that future profiles will maintain backward compatibility with those systems which are based on the Revision B LRMS and this document.

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- 1. Scope**—The LRMS is intended to provide a practical approach to standardization for location referencing within a mixed data set environment, i.e., where more than one kind of spatial data set exists, and where spatial references between these data sets must be made. Although some ITS applications in local areas may be satisfied by having one common data set—for which location references may be implemented in any number of ways—many ITS applications will have broad interoperability requirements within the nation or a region. For example, a vehicle driven from California to Florida in the U.S. should be able to receive and understand spatial references for traffic information or routing instructions throughout the trip. Similarly, information sent from a vehicle to a central site should be understood in any city regardless of the kinds of data sets in use, whether they are public or private, or how locations are referenced internally to particular data sets.

The LRMS can be applied to ITS systems involving mobile vehicles on roads, rails, and waterways. It can also be applied to location references to and from central sites to non-mobile sites such as kiosks, other central sites, or pedestrians. The broadest scope of the LRMS is therefore intermodal spatial data set interoperability at the national level and across all of ITS. Given the great variety of ITS systems, it is expected that individual LRMS profiles will generate location referencing standards for subsets of ITS applications, such as ISP→Vehicle→ISP, or center→center.

2. References

- 2.1 Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J2369—Standards for ATIS Message Sets Delivered Over High Speed FM Subcarriers

2.1.2 NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY (NIST) DOCUMENT—Available from NIST, FIPS PUB 173, U.S. Government Printing Office, National Technical Information Service U.S Department of Commerce, Springfield, VA 22161.

FIPS PUB 173—Spatial Data Transfer Standard (SDTS), 1992

- 2.2 Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO) PUBLICATIONS—Available from AASHTO, Suite 225, 444 North Capital Street, NW, Washington, DC 20001.

GIS-T '95—Reinterpreting the Location Referencing Problem: A Protocol Approach—Proceedings, Geographic Information Systems for Transportation Symposium (GIS-T)—Reno, NV, April 3–5, 1995, Goodwin, C., Gordon, S., and Siegel, D.

GIS-T '92—Dynamic Segmentation Revisited: A Milepoint Linear Data Model, Proceedings, Geographic Information Systems for Transportation Symposium (GIS-T)—Portland, OR, March 1992, Dueker, K.

and Vrana, R.

- 2.2.2 FEDERAL HIGHWAY ADMINISTRATION DOCUMENTS—Available from U.S. DOT, FHWA, Office of Safety and Traffic Operations, ITS Research Division, HSR 10, 6300 Georgetown Pike, McLean, VA 22101.

Task A: Spatial Data Interoperability Protocol for ITS Project—Location Reference Protocol Requirements, December 29, 1995, Goodwin, C., Siegel, D., Gordon, S.

Task B: Spatial Data Interoperability Protocol for ITS Project—Location Reference Message Protocol Preliminary Specification, February 29, 1996, Goodwin, C., Siegel, D., and Gordon, S.

Task B: Spatial Data Interoperability Protocol for ITS Project—Location Reference Message Specification: Final Design, June 28, 1996, Goodwin, C., Siegel, D., and Gordon, S.

Task B: Spatial Data Interoperability Protocol for ITS Project—Location Reference Message Specification: Revision A, September 18, 1996, Goodwin, C., Siegel, D., and Gordon, S.

Task B: Spatial Data Interoperability Protocol for ITS Project—Location Reference Message Specification: Revision B (MDI), May 22, 1997, Goodwin, C., Siegel, D., and Gordon, S.

Task C: Spatial Data Interoperability Protocol for ITS Project—The ITS Datum Preliminary Data Structure and Content, February 25, 1996, Siegel, C., Goodwin, C., and Gordon, S.

Task C: Spatial Data Interoperability Protocol for ITS Project—ITS Data Final Design Report, June 28, 1996, Siegel, D., Goodwin, C., and Gordon, S.

Task A3: Nationwide Map Database and Location Referencing System Project—Functional Requirements for National Map Databases for ITS, December 31, 1994, Goodwin, C., Xiong, D., and Gordon, S.

Task B3: Nationwide Map Database and Location Referencing System Project—Technical Requirements for National Map Databases for ITS, July 31, 1995, Goodwin, C., Gordon, S.

Task F1: Nationwide Map Database and Location Referencing System Project—Recommendation for Location Referencing for ITS, December 31, 1994, Goodwin, C., Gordon, S., and Xiong, D.

- 2.2.3 INTELLIGENT TRANSPORTATION SOCIETY (ITS) OF AMERICAN DOCUMENTS—Available from ITS America, 400 Virginia Avenue, SW, Suite 800, Washington, DC 20024-2730.

Standard Location (SLR) System: Road Name ID Scheme—Proceedings of the ITS America Annual Meeting, 1994, Ramakrishnan, R., Collier, C., Behr, D.

U.S. National Architecture Program Documents on World-Wide Web—<http://www.itsa.org/archdocs/national.html>

- 2.2.4 MINNESOTA DEPARTMENT OF TRANSPORTATION DOCUMENT—Available from Minnesota Department of Transportation, Transportation Data Section, Ford Building, 117 University Avenue, St. Paul, MN 55155.

Mn/DOT GIS Statewide Base Map—Report of the GIS Base Map Task Force to the Minnesota Department of Transportation Council for Geographic Information, January 1993.

- 2.2.5 NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM (NCHRP) DOCUMENT—Available from Transportation Research Board/NCHRP, 2101 Constitution Avenue, NW, Washington, DC 20418.

Project 20-27(2)—Report on the Results of a Workshop on a Generic Data Model for Linear Referencing Systems (second draft), 1995—Development of System and Application Architectures for Geographic Information Systems in Transportation

- 2.2.6 OAK RIDGE NATIONAL LABORATORY DOCUMENTS—Available from Oak Ridge National Laboratory, Center for Transportation Analysis, Oak Ridge, TN 37831.

- 2.2.7 TRANSPORTATION RESEARCH BOARD PUBLICATION—Available from Transportation Research Board, 2101 Constitution Avenue, NW, Washington DC 20418.

Transportation Research Circular 412—Primer on Intelligent Vehicle Highway Systems, 1993, Shuman, V.

- 2.2.8 UNITED STATES GEOLOGICAL SURVEY PUBLICATION—Available from US Geological Survey, U.S. Government Printing Office, Washington, DC 20402.

U.S. Geological Survey Circular 1048—An Enhanced Digital Line Graph Design, 1989.

- 2.2.9 UNITED STATES POSTAL SERVICE—Available from USPS, Customer Support Center, Memphis, TN 38188-0001.

United States Postal Service, Postal Addressing Standards, Publication 28, August 1995

- 2.2.10 VIGGEN CORPORATION DOCUMENTS—Available from Viggen Corporation, InterOp Division, 105 David lane, Knoxville, TN 37922-3204.

E1 Report—Location Referencing Systems: Analysis of Current Methods Applied to IVHS User Services (Draft), November, 1993

FHWA Location Referencing System for ITS User Services White Paper—An Alternative Approach: Coordinate Snapping, November, 1994

FHWA Location Referencing System for ITS User Services White Paper—Street Naming Conventions, November, 1994

ITS Location Referencing System: Dynamic Assignment of Network Attributes Specification—Draft, Version C, October, 1994

FHWA Location Referencing System for ITS User Services White Paper—An Alternative Approach: Cross-Streets, November, 1994

Linear Referencing Using DANA: Resolution of Control, November, 1994

3. Definitions

- 3.1 **Altitude**—Elevation above or below a reference datum, as defined in FIPSPUB 70-1; the z-value in a spatial address.

- 3.2 **Advanced Traveler Information Systems (ATIS)**—The acquisition, analysis, communication, presentation, and use of information to assist the transport traveler through single or linked, multiple nodes. Sources of information include value-added service providers and traffic management centers. ATIS communication technologies can include the following:

- a. FM subcarrier
- b. Television broadcast
- c. Digital cellular
- d. Dedicated short-range communications (DSRC)
- e. Beacon unit-to-unit transfer

- 3.3 **Advanced Transportation Management Systems (ATMS)**—An array of institutional, human, hardware, and software components designed to optimize traffic flow on roadways, including managing signals and lanes, ramp metering, and road pricing.

- 3.4 **Attribute**—A defined characteristic of an entity type. (NIST, 1992) Within a digital map database, attribute values of the digital object representation of an entity are typically alpha-numeric data within well-defined ranges.

- 3.5 **Base Map**—A map portraying background reference information onto which other information is placed. Base maps usually show the location and extent of natural Earth surface features and fixed position man-made objects. (Krzanowski et al, 1993)

- 3.6 Beacon**—A roadside device for transmitting information to nearby passing vehicles. Beacons are typically electromagnetic devices, operating in near infra-red, radio, or microwave frequencies.
- 3.7 Cell**—An element of a space that has been subdivided into regular tiles by tessellation. (Krzanowski et al, 1993)
- 3.8 Chain**—An ordered sequence of connected lines.
- 3.9 Computer-Aided Design (CAD)**—A combination of hardware and software used to assist people in the design of structures, devices, and plans, e.g., road networks.
- 3.10 (Ground) Control**—A system of points with established horizontal and vertical positions that are used as fixed references in positioning and relating map features. (NIST, 1992)
- 3.11 Coordinates**—Pairs of numbers expressing horizontal distances along orthogonal axes; alternatively, triplets of numbers measuring horizontal and vertical distances. (NIST, 1992)
- 3.12 Datum**—A set of parameters and control points used to accurately define the three-dimensional shape of the Earth (e.g., as an ellipsoid). The corresponding datum is the basis for a planar coordinate system. (MnDOT 1993)
- 3.13 Dedicated Short-Range Communications (DSRC)**—General category of devices and methods of transferring information from roadside to vehicle and vice-versa.
- 3.14 Digital Map Database**—A structured set of digital and alpha-numeric data that portray geographic locations and relationships of spatial features. Typically, such structures represent, but are not limited to the digital form of hard copy maps. For example, CAD drawings may be imported into a GIS and considered a form of digital base map.
- 3.15 Geodetic Datum**—A mathematical model of the Earth's shape. (Krzanowski et al, 1993) A geometric set of five quantities which serves as a locational reference or base for other quantities. The five quantities are the latitude and longitude of an initial point, the azimuth of a line from this point and two constants necessary to define the terrestrial spheroid. (MnDOT 1993)
- 3.16 Geographic Information System (GIS)**—A computer software system for the collection, integration, management, analysis, and display of geographic data with which spatial information may be captured, stored, analyzed, displayed, and retrieved. (Krzanowski et al, 1993)
- 3.17 Geoid**—An equi-gravitational potential surface around the Earth such that each point on the surface is normal to the direction of gravity; coincides with mean sea level of the oceans. (Krzanowski et al, 1993)
- 3.18 Grid**—A set of grid cells forming a regular, or nearly regular, tessellation of a surface. The tessellation is regular if formed by repeating the pattern of a regular polygon, such as a square, equilateral triangle, or regular hexagon. The tessellation is nearly regular if formed by repeating the pattern of an "almost" regular polygon such as a rectangle, non-square parallelogram, or non-equilateral triangle.
- 3.19 Grid Coordinates**—Two distances which fix the position of a point on a grid. The perpendicular distance to the point from the y-axis is called the x coordinate while the perpendicular distance to the point from the x-axis is called the y coordinate. (MnDOT 1993a)
- 3.20 Information Service Provider (ISP)**—In the context of the LRMS, a public or private entity which may be responsible for gathering, fusing, analyzing, and/or reporting transportation related information to users, including vehicles and non-mobile users.

- 3.21 Junction**—A collection of more than one node that represents a logical feature, such as a complex intersection. (Shuman, 1993)
- 3.22 Legacy Databases**—Databases that exist in an organization that must be maintained and used for some period of time regardless of new technology changes.
- 3.23 Linear Referencing**—Process of identifying location(s) on a transportation network or specific link in a network by specifying a start position, direction, and distance along a particular route. (NCHRP, 1993)
- 3.24 Link**—A topological connection between two nodes. A link may contain additional intermediate coordinates (shape points) to better represent the shape of curved features. (Shuman, 1993) A link may be directed by ordering its nodes.
- 3.25 Link Identifiers (or Link-ID)**—An identifier assigned to a link. Link-IDs may be arbitrary, or may be assigned by convention to assure that multiple occurrences of the same ID will not occur within one network or within the universe of similar networks or databases.
- 3.26 Location Referencing System**—System of determining the position of an entity relative to other entities or to some external frame of reference.
- 3.27 Matching (or Address Location)**—Translating a user-oriented place specification (e.g., house number, intersection, vanity address, named place) to a specific object (node or link) in a database. (Shuman, 1993)
- 3.28 Milepost**—A reference point along the linear objects of a road network used in a linear referencing scheme. Mileposts may or may not be at one-mile intervals.
- 3.29 Model Deployment Initiative**—One of the joint public-private programs to implement and test integrated ITS systems and infrastructure in the US.
- 3.30 NAD (North American Datum)**—The official reference ellipsoid used for the primary geodetic network in North America.
- 3.31 NAD27 (North American Datum 1927)**—Geodetic datum defined by the geographic position of triangulation station Meades Ranch and the azimuth from that station to station Waldo on the Clarke spheroid of 1866. (MnDOT 1993)
- 3.32 NAD83 (North American Datum 1983)**—Geodetic datum defining an Earth-fitting ellipsoid and for relating existing coordinate systems to the Earth's center of mass. It is based on both satellite and terrestrial data used in developing the Geodetic Reference System of 1980 and later the World Geodetic System of 1984 (WGS-84). This improved Earth-centered model slightly changes the latitude and longitude of almost every point in North America with respect to the earlier NAD27 datum. (MnDOT 1993)
- 3.33 National Transportation Data Set**—Any present or future public domain data set containing street information for the nation. Examples of present data sets are the National Highway Planning Network (NHPN) and TIGER.
- 3.34 Node (0-Cell)**—A topologically significant point, such as a simple intersection of roadways or other linear features, or an endpoint of such a feature. (Shuman, 1993) Alternate: A zero-dimensional object that is a topological junction of two or more links or chains, or an end point of a link or chain. (NIST, 1992)
- 3.35 Node Offset Method**—A class of referencing methods that use linear offsets from known locations.

- 3.36 Point-of-Interest (POI)**—A geographic location, representing a service or landmark of interest to a traveler. these may be used as origins, destinations, or way points. These are typically provided with descriptive information and references to links and/or nodes on the transportation network.
- 3.37 Proprietary Data Node**—A node in a Proprietary Data Set.
- 3.38 Proprietary Data Set**—Any present or future proprietary data set containing street information. A proprietary data set may be national or local in coverage.
- 3.39 Reference Ellipsoid**—The mathematical model of the Earth used in geodetic computations. (Krzanowski et al, 1993)
- 3.40 Regional/Local Data Set**—Any present or future public domain data set containing street information for a region or urban area.
- 3.41 Shape Point**—Intermediate coordinates within a link added to better represent the shape of curved features. (Shuman, 1993)
- 3.42 Spatial Data Transfer Standard (SDTS)**—A national spatial data transfer standard recently approved by the National Institute of Standards and Technology as Federal Information Processing Standard (FIPS) 172. SDTS provides specifications for organizing and structuring transfer of digital spatial data, defining spatial feature and attributes, and encoding data transfer between dissimilar computer systems. (NCHRP, 1993)
- NOTE—An SDTS profile is a clearly defined and limited subset of the SDTS, designed for use with a specific type of data.
- 3.43 State Plane Coordinate System**—Rectangular coordinate systems used by particular states, typically for production of state transportation maps and resource management.
- 3.44 Tessellation**—Division of space into regular or irregular polygons (2-D) or polyhedra (3-D). (Krzanowski et al, 1993)
- 3.45 Topology**—The logical relationships among map features in a digital base map. It can be used to characterize spatial relationships such as connectivity and adjacency.
- 3.46 Transactional Updates**—Updates to a database on an as-needed, rather than regularly scheduled, basis.
- 3.47 Universal Transverse Mercator**—A rectangular coordinate system for world use between 84 degrees North latitude and 80 degrees South latitude. The UTM system uses linear measurements with reference to zones and zone central meridians. Measurements are in terms of meters. (NIST, 1992)
- 3.48 World Geodetic System of 1984 (WGS-84)**—An earth-centered model based on satellite and terrestrial data that was modified slightly in 1996 (EGM-96). WGS-84 EGM-96 is used to derive latitude-longitude coordinates.

4. Requirements of LRMS Profiles

4.1 Scope Requirements

- 4.1.1 The LRMS should support the needs of all ITS communities-of-interest to communicate the spatial locations of events and objects of interest.
- 4.1.2 The LRMS should support the communication of location references by many location referencing methods). The LRMS should support legacy databases to the extent possible.

- 4.1.3 The LRMS should be capable of being implemented on a variety of computer hardware and software platforms, from any vendor. It should impose no unique requirements on computer environments that could only be satisfied by any particular hardware or software vendor.
- 4.1.4 The LRMS should not be restricted by design to operation in any one country or to the databases of any one country, but should be capable of supporting ITS products in international markets.
- 4.1.5 The LRMS specification should be written in a way that does not impose special labor or expertise requirements on ITS users. Specifically, LRMS syntax should not be written using an abstract specification language whose use would imply special staffing or expertise requirements for ITS users.

NOTE—ASN.1 is currently being received favorably by the ITS standards community.

4.2 Functional Requirements

- 4.2.1 The LRMS should support inter-operation of ITS applications within integrated local, regional, or national ITS systems.
- 4.2.2 The LRMS should support inter-operation in a mixed hardware/software environment, that is, where hardware or software items from different vendors and sources reside on either side of a communications link.
- 4.2.3 The LRMS should support inter-operation in a mixed database environment, that is, where spatial databases from different vendors and sources reside on either side of a communications link.
- 4.2.4 The LRMS should be suitable for computer processing, without human intervention.
- 4.2.5 The LRMS should not impose restrictions on computer software implementation languages.
- 4.2.6 The LRMS should preserve nibble and byte boundary alignment within its record and field structures in order to accommodate software environments for which this is an advantage.
- 4.2.7 The LRMS should be an open, public domain protocol.
- 4.2.8 The LRMS should be based on commonly available data types and location referencing methods.
- 4.2.9 The LRMS should impose minimal additional data gathering activity on the part of users and applications.
- 4.2.10 The LRMS should not require extensive conversion of formats by applications, but should support provision of locational data according to the requirements of an application and its available databases.
- 4.2.11 The LRMS should be flexible in design to support expansion to new communities-of-interest.
- 4.2.12 The LRMS should be implementable in stages for a region, without imposing additional requirements on transportation infrastructure.

4.3 Quality Requirements

- 4.3.1 Location references conveyed by the LRMS should be unambiguous to the extent technically and practically feasible, with the specification designed for ambiguity resolution.
- 4.3.2 The LRMS should not introduce spatial geometry or other errors in spatial locations conveyed due to any property of itself, beyond errors inherent in the locational data to be communicated.

4.4 Performance Requirements

- 4.4.1 Location reference messages within the LRMS should be small enough to be embedded within other ITS messages.
- 4.4.2 The LRMS should not impose performance limitations on communications channels due to its design.
- 4.4.3 The LRMS should not require extensive algorithmic processing or table look-ups on data sender or receiver, to the extent that application performance would be significantly degraded.

5. LRMS Profiles

5.1 Introduction—Seven LRMS profiles are described in this document. Each profile contains one or more individual format records. Bit numbering for the format records begins with 0 in all cases; one byte of data therefore contains bits numbered from 0 to 7.

5.2 The Geometry Profile (Start Code = 0001)—This profile contains referencing formats for locations based on spatial primitives. The two simplest primitives are points and links. A single point, for example denoting a Point-of-Interest (POI) such as a bus stop or roadside facility, can be referenced by a unique identifier (ID). Similarly, link identifiers (link IDs) can reference links between nodes. Nodes may or may not correspond to real world intersections. For example, a logical link can be defined between two points defined as offsets from intersections or from other points. The real world network may be represented with the data set by a planar graph, or by a non-planar graph containing links that cross without intersection nodes. Shape points are typically inserted between intersection nodes to represent road geometry between intersections. Chains of links are also represented. A third spatial primitive, area, is represented in the Geometry Profile by ID, by polygons composed of 3 or more points, and by radii from points. The Geometry Profile is detailed in Table 1.

TABLE 1—GEOMETRY PROFILE FORMAT

Bit	Content	Values/Range
0–3	Start Code	0001
4–7	Record Type	0000 = Node 0001 = Point with Offset 0010 = Link 0011 = Link with Offsets 0100 = Chain 0101 = Chain with Offset 0110 = Transition 0111 = Transition with Offset 1000 = Area 1001 = Polygon 1010 = Node Attribute 1011–1111 = Expansion
Case Type = Node (5 byte record)		
8–39	Node ID	1–4 294 967 296
Case Type = Point with Offset (10 byte record)		
8–39	Start Node ID	1–4 294 967 296
40–63	Chain ID	1–16 777 215
64–79	Offset	0–65 535 m
Case Type = Link (9 byte record)		
8–39	Start Node ID	1–4 294 967 296
40–71	End Node ID	1–4 294 967 296
Case Type = Link with Offsets (14 byte record)		
8–39	Start Node ID	1–4 294 967 296
40–71	End Node ID	1–4 294 967 296

TABLE 1—GEOMETRY PROFILE FORMAT

Bit	Content	Values/Range
72–87	Offset1 (from Start Node)	0–65 535 m
88	Side (optional)	Binary 0 = right-hand; 1 = left-hand
89–93	Pad	
94	Offset/Radius Flag	0 = linear offset; 1 = radius
95–111	Offset2/Radius	0–65 535 m
Case Type = Chain (16 byte record)		
8–31	Chain ID	1–16 777 215
32–63	Start Node ID	1–4 294 967 296
64–95	End Node ID	1–4 294 967 296
96–111	Start Sequence Number	0–65 535
112–127	End Sequence Number	0–65 535
Case Type = Chain with offsets (18 byte record)		
8–31	Chain ID	1–16 777 215
32–63	Start Node ID	1–4 294 967 296
64–95	End Node ID	1–4 294 967 296
96–111	Offset	0–65 535 m
112–127	Start Sequence Number	0–65 535
128–143	End Sequence Number	0–65 535
Case Type = Transition (4 byte record)		
8–15	Transition ID	1–512
16–31	Pad	
Case Type = Transition with Offset (6 byte record)		
8–27	Transition ID	1–1 048 575
28–31	Pad	
32–47	Offset	0–65 535 m
Case Type = Area (4 byte record)		
8–27	Area ID	1–1 048 575
28–31	Pad	
Case Type = Polygon (2 → variable byte record)		
8–15	Poly Point Count	0–255 points
	Poly Point Count * 64 bits *	
	(Point Longitude	± 180 000 000 microdegrees
	Point Latitude)	± 90 000 000 microdegrees
Case Type = Node Attribute (22 → variable byte record)		
8–39	Node ID	1–4 294 967 296
40–63	Chain ID	1–16 777 215
64–79	Sequence Number	0–65 535
80–82	Horizontal Datum	000 = WGS–84; 001 = WGS–84+EGM–96 010 = NAD83; 011 = NAD27; 100–111 = Other
83–85	Vertical Datum	000 = WGS–84; 001 = NAVD–88 010 = Vertical level Code; 011–111 = Other
86–87	Origin Node Order	00 = National Transportation Dataset node 01 = Regional/Local node 10 = Unused 11 = Proprietary node
88–119	Node Longitude	± 180 000 000 microdegrees
120–151	Node Latitude	± 90 000 000 microdegrees
152–167	Node Altitude	–8191 to +57 344 decimeters
168–171	Pad	

TABLE 1—GEOMETRY PROFILE FORMAT

Bit	Content	Values/Range
172–174	Node Valence	Integer Number of street names at node (0–7)
175	Street Name/Index Flag	0 = use Street Name; 1 = use Street Index
Repeat 0–7 (Node Valence Times)		
8 bits	Street Name/Index Byte Count	Integer number of bytes of Name data or Street Index (0–255)
8 bits * byte count or	Street Name	(Street Name/Index Byte Count ASCII characters of name
8 bits * byte count	Street Index	(Street Name/Index Byte Count) Integer

5.2.1 LINK IDs—A link identifier (link ID) is usually a numeric identifier assigned to each link in the network. Two modes of reference for Link IDs are:

- a. Unique Link ID—The link has one identifier, which may be unique, or non-unique within a hierarchical numbering scheme, or derived from some measure of location, such as coordinates.
- b. Node ID Pair—The link is identified by two identifiers, those of the link start node and end node. Identifiers may be unique, or non-unique within a hierarchical numbering scheme, or derived from some measure of location.

5.2.2 CHAIN ID/NODE ID PAIR—In addition to giving records for points and links, this profile provides for referencing of chains (sequences of links) by chain ID or by node ID pair. An offset is provided in the latter case. A chain with offset record could be used to specify an incident site, for example, and the extent of incident impact over multiple nodes and links along a network. Similarly, areas of impact extent can be specified by Area ID within the Area record, by polygons in the Polygon record, and by radii from points within the Link by Offsets record. Finally, a Transition ID can be used to reference all of the legal intra-modal turns at an intra-modal node.

NOTE—Nodes are not assumed to be National Transportation Dataset nodes, nor intersections. If they are intersections, multiple street names may be associated with the node in the Node Attribute record, which is provided for local downloads of node sets into vehicles or other sites.

5.2.3 GEOMETRY FORMAT RECORDS—Eleven different records are identified for the Geometry Profile, which are:

- a. Node
- b. Point with Offset
- c. Link
- d. Link with Offsets
- e. Chain
- f. Chain with Offsets
- g. Transition
- h. Transition with Offset
- i. Area
- j. Polygon
- k. Node Attribute

5.2.3.1 *Node*—This record passes the location of a node identified by an Node ID.

5.2.3.2 *Point with Offset*—This record passes the location of a point. The point is specified by a Node ID, Chain ID, and the Offset from the Node ID along the given Chain ID. A chain specified by Chain ID contains directionality for Offset.

5.2.3.3 *Link*—This record passes a link identified by start and end node IDs. Directionality is implicit for flow, but

would be passed as an attribute in an overlying message set for other purposes.

- 5.2.3.4 *Link with Offsets*—This record has additional fields specifying offset (as-driven) distance(s) from the start node. In this way, a single point or linear segment lying on a link can be referenced. The record also contains an indicator for the side of the street or road on which the point or linear segment resides; side is right-hand or left-hand with respect to directionality from start node to end-node.
- 5.2.3.5 *Chain*—This record specifies a sequence of links (a chain) by integer chain ID. The Link record can be used to pass a chain by start and end node ID.
- 5.2.3.6 *Chain with Offset*—This record specifies a chain by integer chain ID and also a point such as a transit stop or ramp meter by means of an offset along the chain. The Link-with-offsets record can be used to pass a chain with offset by start and end node ID.
- 5.2.3.7 *Transition*—This record references the “turn table” which specifies the legal intra-modal turns between chains of the same mode.
- 5.2.3.8 *Transition with Offset*—This record specifies a transition with an offset.
- 5.2.3.9 *Area*—This record provides for referencing of areas, for example of hazardous wind conditions or of extent of the impact of a lane closure, by area ID.
- 5.2.3.10 *Polygon*—This record passes a series of points comprising a polygon. Points may be either closed (first point = last point), or open (first point is not duplicated). Points are denoted by longitude and latitude pairs.
- 5.2.3.11 *Node Attribute*—This record passes the latitude, longitude, and altitude above the reference geoid surface of a node, and information about a street or road on which the node is located. This record allows parts of any local point dataset to be downloaded to a vehicle or roadside device within the context of a higher-level message protocol. For example, it provides a standard format for the downloading of POI locations.

NOTE—For consistency with USGS SDTS terminology, as defined in FIPS PUB 173, altitude is used in place of the more common term, elevation.

- 5.3 **The Geographic Coordinate Profile (Start Code = 0010)**—This profile contains record formats for the geographic coordinates of latitude, longitude, and altitude, expressed with reference to a specified geodetic datum. Format records are also provided for latitude, longitude, and altitude offsets from defined local reference nodes, regional, or proprietary nodes. Geographic Coordinate formats are provided for both points and links. The Geographic Coordinate Profile is detailed in Table 2.

NOTE—The term Altitude is used for elevation with respect to a vertical datum in conformance with SDTS terminology, ref. NIST, 1992.