Using Systems Engineering
To Develop TMDD Version 3.0

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Acknowledgements

• Siva Narla, ITE

• Robert G. Rausch, TransCore
Presentation Outline

- **Background**
- **Review of the Systems Engineering Process**
- **Development Approach**
- **Using the TMDD Standard**
Background

• **TMDD / MSETMCC**
  - Traffic Management Data Dictionary / Message Sets External Traffic Management Center Communications
  - Supports exchanging information between a traffic management center and other centers
    - Traffic Network
    - Events
    - Traffic Devices
  - Version 1 – 2000
  - Version 2.1- 2004
Background

• **Version 3.0**
  - Incorporate feedback received from deployments of the standard (CARS, TRANSCOM, TxDOT, FDOT)
  - Address additional areas of scope
  - Address issues unresolved from earlier versions of the standard.
  - Extend support for the Clarus initiative and the Archived Data User Service (ADUS) standards effort.
  - Effort started Fall 2006
Systems Engineering Process

- Regional Architecture(s)
- Feasibility Study / Concept Exploration
- Concept of Operations
- System Requirements
- High-Level Design
- Detailed Design
- Software / Hardware Development
- Implementation
- System Validation Plan
- System Verification Plan (System Acceptance)
- Subsystem Verification Plan (Subsystem Acceptance)
- Unit / Device Test Plan
- Unit / Device Testing
- System Validation & Deployment
- Subsystem Verification
- Operations and Maintenance
- System Verification Plan
- Changes and Upgrades
- Retirement/Replacement
- Document/Approval

Integration and Recomposition
Systems Engineering Process

- **Using the SEP to develop the standard**
  - Makes the selection of interfaces easier and traceable to user needs
  - Simplifies setting up a requirements-based verification and validation program.
Systems Engineering Process

• **Systems Engineering Management Plan**
  • Is a top-level plan to manage the SE effort
  • Defines how the engineering effort will be organized, structured and conducted to provide a product that fulfills customer requirements
  • Configuration Management Plan – Change process
  • Verification and Validation Plan – Verify requirements and validate the concept of operations
  • Risk Management Plan – Identify, track and resolve risk.
Development Approach

• **Concept of Operations**
  - Define the user needs to be addressed by the standard
  - User workshop for all stakeholders – September 2006
  - 123 user needs identified

2.3.3 Need to Provide Information on Organizations, Centers, and Contacts

To support the exchange of other types of data it is important to share information about the organization, centers and contacts that are connected. Additionally, this information can be used to help operations personnel contact the other centers with which they do not often coordinate. Also, the contact information for each center is important as a prerequisite for shared control.

*Centers need to exchange organization, center and contact information. This includes:*

- Organization name and identification;
- Center site-level information; and
- Contact personnel who contribute to or use C2C data.
Development Approach

• **Requirements**
  - Identify the interface requirements to satisfy the user needs
  - Face-to-face Meeting – July 2007
  - 1,124 requirements identified

<table>
<thead>
<tr>
<th>3.3.5.2.1.5.1</th>
<th>Required Node Inventory Information Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>The node inventory information sent from an owner center to an external center shall include:</td>
<td></td>
</tr>
<tr>
<td>a. Unique identifier of the owner organization;</td>
<td></td>
</tr>
<tr>
<td>b. Unique identifier of the roadway network;</td>
<td></td>
</tr>
<tr>
<td>c. Unique identifier of each node; and</td>
<td></td>
</tr>
<tr>
<td>d. Geographic location of each node (longitude and latitude).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.3.5.2.1.5.2</th>
<th>Optional Node Inventory Information Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>The following are optional requirements that an owner center may include in the node inventory information sent to an external center.</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.1</td>
<td>Node Name</td>
</tr>
<tr>
<td>The owner center shall provide the name of the node as assigned by the owner organization as part of the node inventory information for each node.</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.2</td>
<td>Node Description</td>
</tr>
<tr>
<td>The owner center shall provide a textual description of the node as part of the node inventory information for each node.</td>
<td></td>
</tr>
</tbody>
</table>
Development Approach

- **User Need – Requirements Traceability**
  - Used Rational RequisitePro, to maintain traceability between user needs and requirements
  - Needs to Requirements Traceability Matrix documents the traceability.
## Development Approach

<table>
<thead>
<tr>
<th>UN ID</th>
<th>User Need</th>
<th>UN Selected</th>
<th>Requirement ID</th>
<th>Requirement</th>
<th>Project Requirement</th>
<th>Other Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.2.1.1</td>
<td>Contents of Device Information Request</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.1</td>
<td>Required Device Information Request Content</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.2.1</td>
<td>Username of the Requesting Operator</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Need to Share CCTV Device Inventory</td>
<td>Y/N</td>
<td>3.3.6.1.1.2.2</td>
<td>Password of the Requesting Operator</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.2.3</td>
<td>Owner Organization</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.2.4</td>
<td>External Center Organization</td>
<td>O</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.3</td>
<td>Content of Device Information Request Filter</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.3.1</td>
<td>Device Identifier Filter</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.3.3</td>
<td>Roadway Network Identifier Filter</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.3.4</td>
<td>Link Identifier Filter</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.3.5</td>
<td>Route Designator Filter</td>
<td>O</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.1.3.6</td>
<td>Linear Reference Filter</td>
<td>O</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1</td>
<td>Contents of the Device Inventory Header</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1.1</td>
<td>Required Device Inventory Content</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1.2.1</td>
<td>Device Description</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1.2.2</td>
<td>Device Control Type</td>
<td>O</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1.2.3</td>
<td>Controller Description</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1.2.4</td>
<td>Uniform Resource Locator (URL)</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y/N</td>
<td>3.3.6.1.2.1.2.5</td>
<td>Roadway Network Identifier</td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>
Development Approach

• **Design**
  - Identifies the design to fulfill interface requirements
  - Face-to-face meeting (Initial design) - July 2007
  - Completed design via series of focus teleconferences and webconferences

  • Consists of data elements, data frames, messages, and dialogs
    - 207 data elements, 187 data frames, 85 messages, 124 dialogs

  • Intended to be protocol-independent
    - Data elements – ISO 14817 standard
    - Data frames / messages – ASN.1 and XML formats
Development Approach

3.2.10.6 HARStatusMsg

3.2.10.6.1 DEFINITION

The information content describing an owner center’s highway advisory status for a given set of devices.

3.2.10.6.2 ASN.1 REPRESENTATION

```plaintext
hARStatusMsg ::= { 
  DESCRIPTIVE-NAME "hARStatusMsg:message" 
  ASN-NAME "hARStatusMsg" 
  ASN-OBJECT-IDENTIFIER { tmddMessages 49 } 
  DEFINITION "The information content describing an owner center's highway advisory status for a given set of devices." 
  DESCRIPTIVE-NAME-CONTEXT { "Manage Traffic" } 
  ARCHITECTURE-REFERENCE { 
    "traffic information coordination" 
  } 
  ARCHITECTURE-NAME { "U.S. National ITS Architecture" } 
  ARCHITECTURE-VERSION { "<.6" } 
  DATA-CONCEPT-TYPE message 
  STANDARD "TMDD" 
  META-DATA-SOURCE direct 
  PRIORITY "routine" 
  FREQUENCY-OR-MESSAGE-MODE "on demand" 
  REFERENCED-DATA-FRAMES { 
    { tmddDataFrames 122 } 
  } 
  DATA-TYPE "

  HARStatusMsg ::= SEQUENCE {SIZE(1..10240)} OF HARStatus

  "
```
Development Approach

3.3.8.17 EventHeadline

3.3.8.17.1 DEFINITION
The information content describing an event, including a list of phrases and identification of the key phrase.

3.3.8.17.2 ASN.1 REPRESENTATION

```
eventHeadline ITS-DATA-FRAME ::= {
  DESCRIPTIVE-NAME "EventHeadline:frame"
  ASN-NAME "EventHeadline"
  ASN-OBJECT-IDENTIFIER { tmdDataFrames 82 }
  DEFINITION "The information content describing an event, including a list of phrases and identification of the key phrase."
  DESCRIPTIVE-NAME-CONTEXT {"Manage Traffic"}
  DATA-CONCEPT-TYPE data-frame
  STANDARD "TMD"
  REFERENCED-DATA-FRAMES {
    tmdDataFrames 94
  }
  REFERENCED-DATA-ELEMENTS {
    tmdDataElements 85
  }
  DATA-TYPE = EventHeadline ::= SEQUENCE {
    headline EventType,
    headline-element Event-headline-element OPTIONAL,
    ...
  };
}
```

3.3.8.17.3 XML REPRESENTATION

```
<xs:complexType name="EventHeadline">
  <xs:sequence>
    <xs:element name="headline" type="EventType"/>
    <xs:element name="headline-element" type="Event-headline-element" minOccurs="0"/>
    <xs:any namespace="##other" processContents="lax" minOccurs="0"/>
  </xs:sequence>
</xs:complexType>
```
Development Approach

3.4.12.10 Intersection-timing-duration

3.4.12.10.1 DEFINITION
The measure of time in seconds that a signal indication is on.

3.4.12.10.2 ASN.1 REPRESENTATION

```
intersection-timing-duration ITS-DATA-ELEMENT ::= {
  DESCRIPTIVE-NAME "IntersectionSignal.Intersection-timing-duration:qty"
  ASN-NAME "Intersection-timing-duration"
  ASN-OBJECT-IDENTIFIER { tmddDataElements 137 }
  DEFINITION "The measure of time in seconds that a signal indication is on."
  DESCRIPTIVE-NAME-CONTEXT {"Manage Traffic"}
  DATA-CONCEPT-TYPE data-element
  STANDARD "TMDD"
  DATA-TYPE "Intersection-timing-duration ::= INTEGER (0..360)"
  "
  FORMAT "ASN.1 encoding"
  UNIT-OF-MEASURE "tenths of a second"
  VALID-VALUE-RULE "see the ASN.1 DATA-TYPE"
}
```

3.4.12.10.3 XML REPRESENTATION

```
<xs:simpleType name="Intersection-timing-duration">
  <xs:restriction base="xs:unsignedInt">
    <xs:minInclusive value="0"/>
    <xs:maxInclusive value="360"/>
  </xs:restriction>
</xs:simpleType>
```
Requirements Traceability Matrix

• **Requirements – Design Traceability**
  • Identifies the design (dialog, message, data frames, data elements) to fulfill the interface requirements
  • Key part of the validation activity
  • Completes the traceability documentation
## Requirements Traceability Matrix

<table>
<thead>
<tr>
<th>Requirement ID</th>
<th>Requirement Title</th>
<th>Dialog</th>
<th>Data Concept Name</th>
<th>DC Type</th>
<th>Standards Clause</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3.5.2.1.4</td>
<td>Contents of the Node Inventory Request</td>
<td>trafficNetworkInformationRequestMsg</td>
<td>message</td>
<td>3.2.19.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5</td>
<td>Contents of the Node Inventory Information</td>
<td>nodeInventoryMsg</td>
<td>message</td>
<td>3.2.14.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.5</td>
<td>Contents of the Node Inventory Information</td>
<td>NodeInventory</td>
<td>data-frame</td>
<td>3.3.16.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.1</td>
<td>Required Node Inventory Information Content</td>
<td>NodeInventoryList</td>
<td>data-frame</td>
<td>3.3.16.2</td>
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</tr>
<tr>
<td>3.3.5.2.1.5.1</td>
<td>Required Node Inventory Information Content</td>
<td>OrganizationInformation</td>
<td>data-frame</td>
<td>3.3.17.3</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.1</td>
<td>Required Node Inventory Information Content</td>
<td>Transportation-network-identifier</td>
<td>data-frame</td>
<td>3.4.20.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.1</td>
<td>Required Node Inventory Information Content</td>
<td>Irmx:GeoLocation</td>
<td>data-frame</td>
<td>LRMS:5.14</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.1</td>
<td>Node Name</td>
<td>Transportation-network-name</td>
<td>data-element</td>
<td>3.4.21.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.2</td>
<td>Node Description</td>
<td>Transportation-network-name</td>
<td>data-element</td>
<td>3.4.21.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.3</td>
<td>Roadway Network Name</td>
<td>Transportation-network-name</td>
<td>data-element</td>
<td>3.4.21.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.4</td>
<td>Route Designator</td>
<td>Link-route-designator</td>
<td>data-element</td>
<td>3.4.14.29</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.5</td>
<td>Linear Reference</td>
<td>Link-location-linear-reference</td>
<td>data-element</td>
<td>3.4.14.15</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.6</td>
<td>Node Direction</td>
<td>Link-direction</td>
<td>data-element</td>
<td>3.4.14.9</td>
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</tr>
<tr>
<td>3.3.5.2.1.5.2.7</td>
<td>Node Type</td>
<td>Node-type</td>
<td>data-element</td>
<td>3.4.15.3</td>
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</tr>
<tr>
<td>3.3.5.2.1.5.2.8</td>
<td>Number of Links</td>
<td>Node-links-number</td>
<td>data-element</td>
<td>3.4.15.1</td>
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</tr>
<tr>
<td>3.3.5.2.1.5.2.9</td>
<td>Owner Organization</td>
<td>OrganizationInformation</td>
<td>data-frame</td>
<td>3.3.17.3</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.1.5.2.10</td>
<td>Inventory Date and Time Change Information</td>
<td>DateTimeZone</td>
<td>data-frame</td>
<td>3.3.10.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.2.1</td>
<td>Send Node Status Information Upon Request</td>
<td>dINodeStatusRequest</td>
<td>dialog</td>
<td>3.1.14.3</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.2.2</td>
<td>Publish Node Status Information</td>
<td>dINodeStatusUpdate</td>
<td>dialog</td>
<td>3.1.14.4</td>
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<td>3.3.5.2.2.3</td>
<td>Subscribe to Node Status Information</td>
<td>dITrafficNetworkInformationSubscription</td>
<td>dialog</td>
<td>3.1.19.1</td>
<td></td>
</tr>
<tr>
<td>3.3.5.2.2.4</td>
<td>Contents of the Node Status Request</td>
<td>trafficNetworkInformationRequestMsg</td>
<td>message</td>
<td>3.2.19.1</td>
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</tr>
<tr>
<td>3.3.5.2.2.5</td>
<td>Contents of the Node Status Information</td>
<td>nodeStatusMsg</td>
<td>message</td>
<td>3.2.14.2</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

• **Process**
  - Can be applied to define, build, and test any project specific communications specification
  - Structured the standard in a format that is easy for agencies and implementers to deploy because the focus is now user-centric.
  - Traceability, from user needs, to requirements, and to the systems interface specification, is maintained and documented.
Conclusion

• http://www.ite.org/standards/tmdd

THANK YOU

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