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# Dynamically Generating Conformance Tests for Messaging Systems

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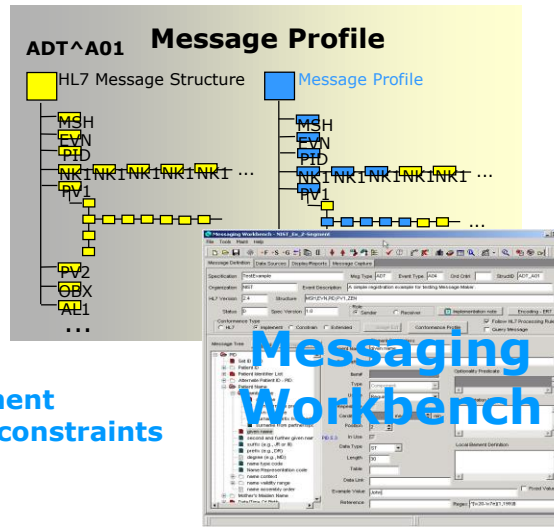
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<http://www.nist.gov/messagemaker>

# HL7 and Conformance: The Big Picture



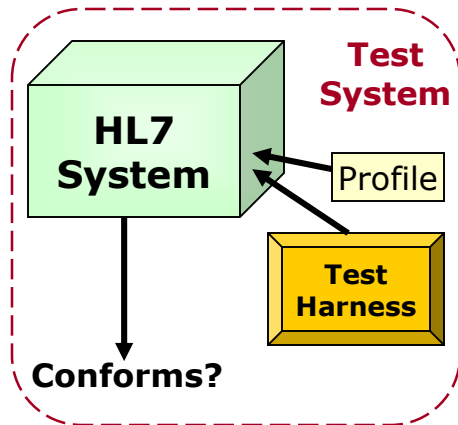
- ✓ Universal design
- ✓ Riddled with optionality
- ✓ Implementation chaos
- ✓ Interoperability difficult



- ✓ Tools to build profiles
- ✓ e.g., MWB (VA)
- ✓ XML representation

```
<?xml version="1.0"?>
<HL7v2xConformanceProfile H
<MetaData Name="CALINX" Or
<Encodings>
<Encoding>ER7</Encoding>
</Encodings>
<DynamicDef AccAck="NE" Ap
<HL7MsgType="ADT"
EventType="A01
<MetaData Name="CALINX" >
<Segment Name="MSH" LongN
<Field Name="Field Separator" Us
</Field>
<Field Name="Encoding Characters"
<Reference>2.16.9.2</Reference
</Field>
<Field Name="Sending Application"
```

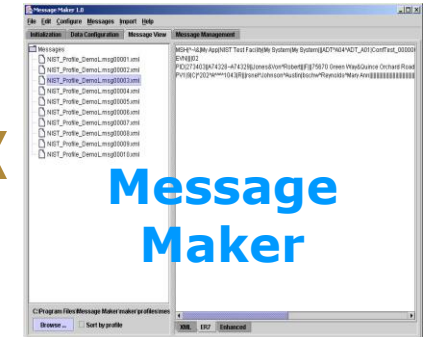
- ✓ Need for test messages



- ✓ Conformance testing needed
- ✓ Improves reliability and interoperability
- ✓ Testing Framework

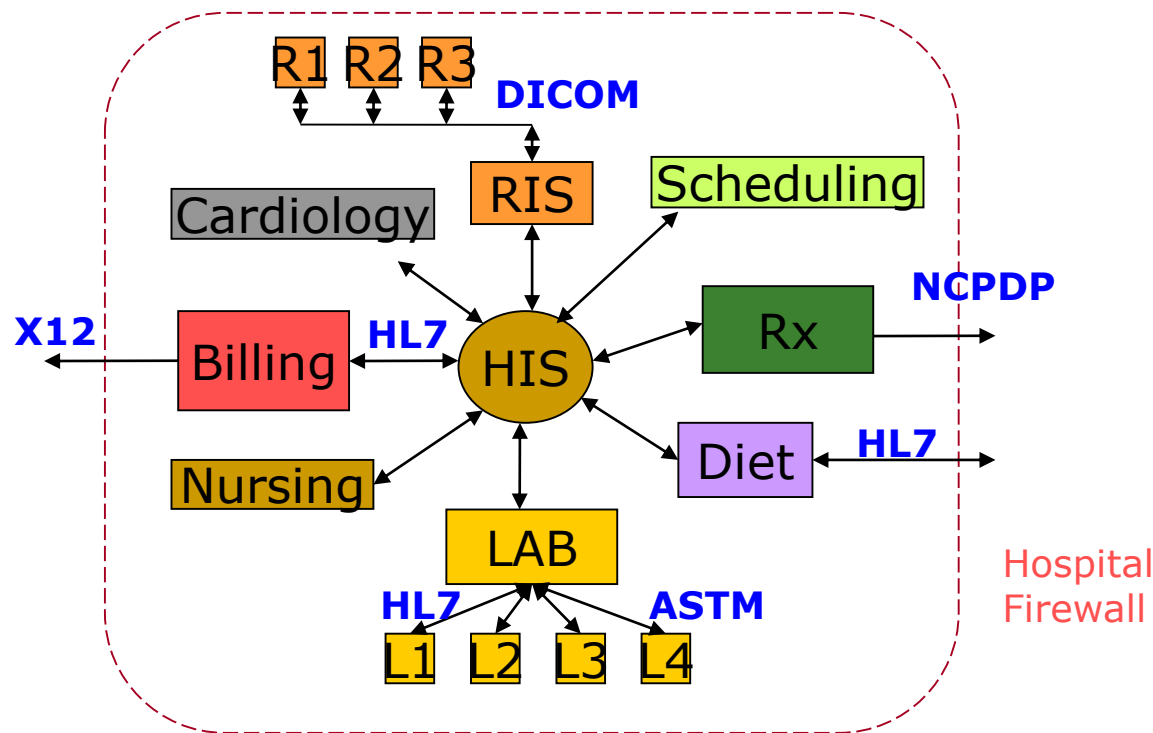


- ✓ Profile based
- ✓ Suite of test messages
- ✓ Suitable for conformance testing



- ✓ Tools to build messages
- ✓ Message Maker (NIST)
- ✓ Automated and adaptable

# HL7 and Healthcare Integration

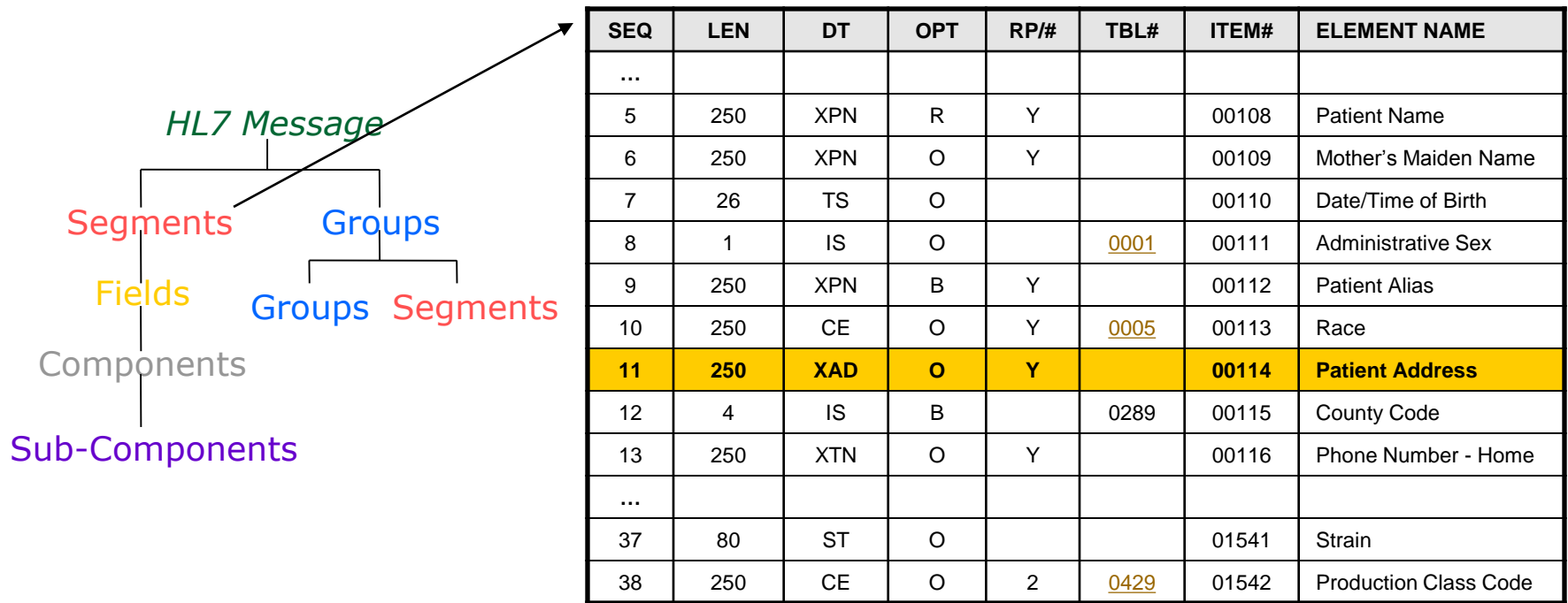


- HL7 (Health Level Seven) Messaging Standard (Application level)
- Standards for the exchange, management, and integration of data for clinical care
  - Messages model real world events
  - e.g., Messages for registering a patient or requesting a lab order
- HL7 provides a flexible framework to build messages
- Widely used; 90% of hospitals

# The Problem: Too Flexible

- Overwhelmingly large with many optional features
- Little agreement on how to define an interface
- Applications didn't know what to expect
- No two interfaces were alike

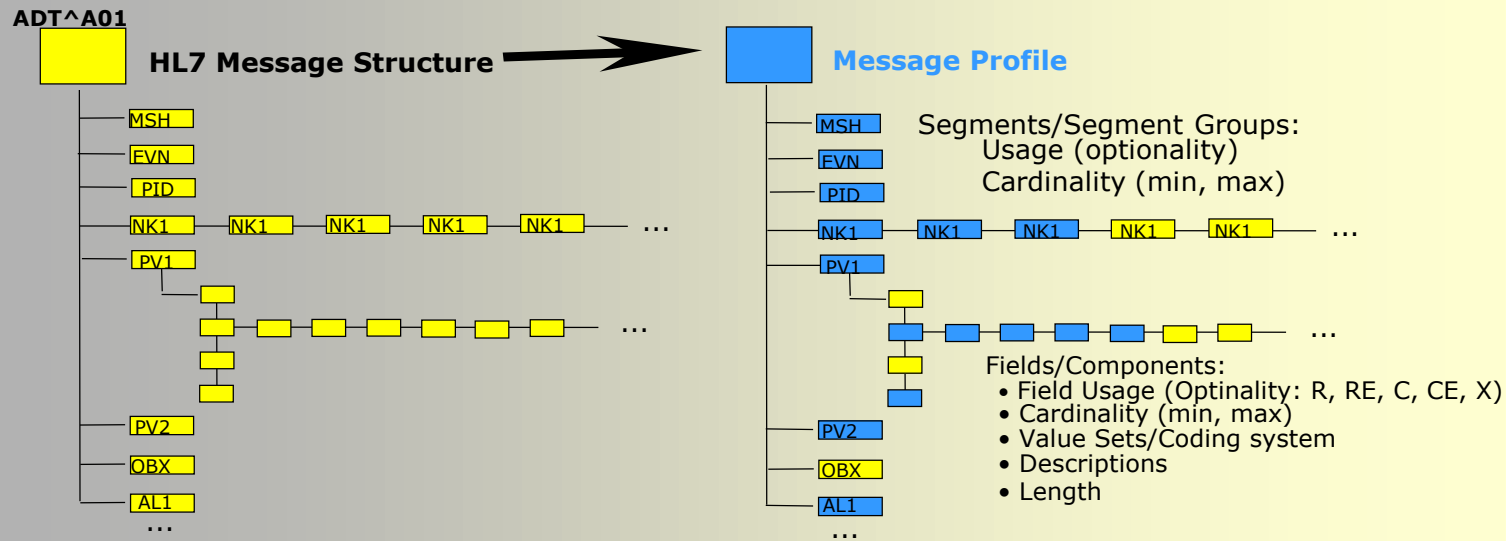
## Example: PID Segment



# The Solution: Message Profiles

- Refinement of the HL7 Standard (Eliminates Optional Items)
- Agreement between Trading Partners
- Represented as an XML document (HL7 defined schema)
- Tools to build message profiles

## Building a Message Profile



# Message Profile Example (XML)

## Snippet from PID segment

Value needs  
to be in  
table 0333

SSN not supported

License is required  
and must appear  
exactly one time

<Field Name="SSN Number - Patient" Usage="X" Min="0" Max="\*" Datatype="ST" Length="16" ItemNo="00122">  
 <Reference>3.4.2.19</Reference>  
 </Field>  
 <Field Name="Driver's License Number - Patient" Usage="R" Min="1" Max="1" Datatype="DLN" Length="250"  
 ItemNo="00123">  
 <Reference>3.4.2.20</Reference>  
 <Component Name="Driver's License Number" Usage="R" Datatype="ST" Length="100">  
 </Component>  
 <Component Name="Issuing State, province, country" Usage="R" Datatype="IS" Length="3">  
 Table="0333">  
 </Component>  
 <Component Name="expiration date" Usage="R" Datatype="DT" Length="30">  
 </Component>  
 </Field>  
 <Field Name="Mother's Identifier" Usage="X" Min="0" Max="\*" Datatype="CX" Length="250" ItemNo="00124">  
 <Reference>3.4.2.21</Reference>  
 <Component Name="ID" Usage="X" Datatype="ST" Length="3">  
 </Component>  
 <Component Name="Check digit" Usage="X" Datatype="ST">  
 </Component>  
 <Component Name="code identifying the check digit scheme employed" Usage="X" Datatype="ID"  
 Length="3" Table="0061">  
 </Component>

Value must  
be a valid  
date

1. Provides a roadmap for creating messages
2. Input into Message Maker

The diagram illustrates the relationship between Message Types, Message Events, Message Profiles, and Profile N. It shows how a specific message type (e.g., ACK) is mapped to a message event (A01) and then to a message profile (ADT^A01). The diagram also shows the structure of a message profile (HL7 Message Structure) and the resulting XML representation (Profile N).

**Message Types** (Left Column):

- ACK, ADR, ADT, BAR, CRM, CSU, DFT, DOC, DSR, EAC, EAN, EAR, EDR, EQQ, ERP, ESR, ESU, INR, INU, LSR, LSU, MCF, MDM, MFD, MFK, MFN, MFO, MFR, NMD, NMQ, NMR, OMD, OMG, OML, OMN, OMP, OMS, ORD, ORF, ORG, ORL, ORM, ORN, ORP, ORR, ORS, ORU, OSQ, OSR, OUL, PEX, PGL, PIN, PMU, PPG, PPP
- PPR, PPT, PPV, PRM, PRR, PTR, QBP, QCK, QCN, QRY, QSB, QSS, QVR, RAR, RAS, RCI, RCL, RDE, RDR, RDI, RDS, RDT, RDX, RER, RGV, ROR, RPA, RPI, RPL, RPR, RQA, RQC, ROI, ROP, ROQ, RRA, RRD, RRE, RRG, RRI, RSP, SIU, SPQ, SRM, SSR, SSU, SUR, TBR, TCR, TCU, UDM, VOQ, VXQ, VXR, VXX, VXX

**Message Events** (Middle Column):

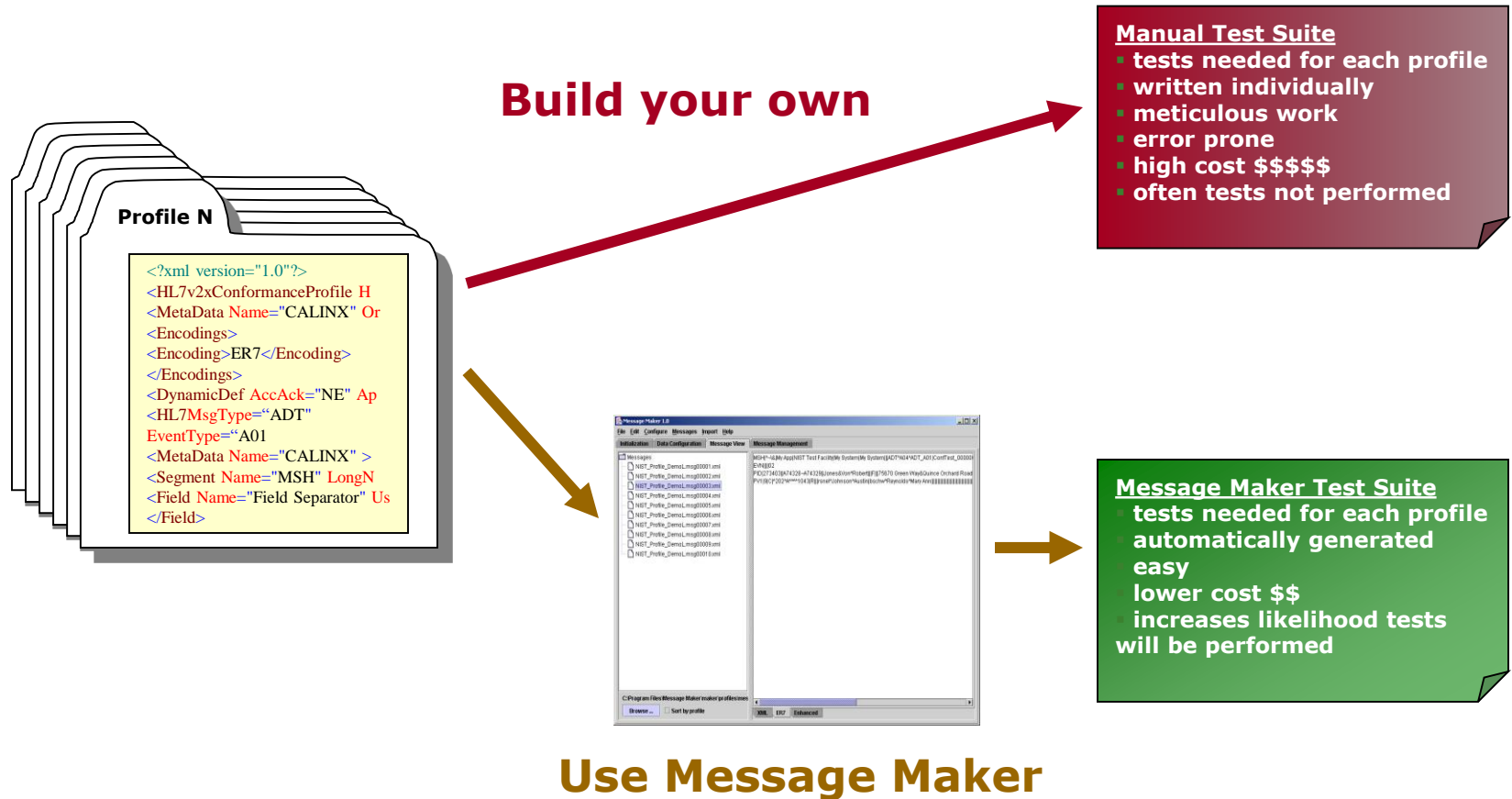
- A01, A02, A03, A04, A05, A06, A07, A08, A09, A10, A11, A12, A13, A14, A15, A16, A17, A18, A19, A20, A21, A22, A23, A24, A25, A26, A27, A28, A29, A30, A31, A32, A33, A34, A35, A36, A37, A38, A39, A40, A41, A42, A43, A44, A45, A46, A47, A48, A49, A50, A51

**Message Profile** (Top Right):

**ADT^A01** Message Profile

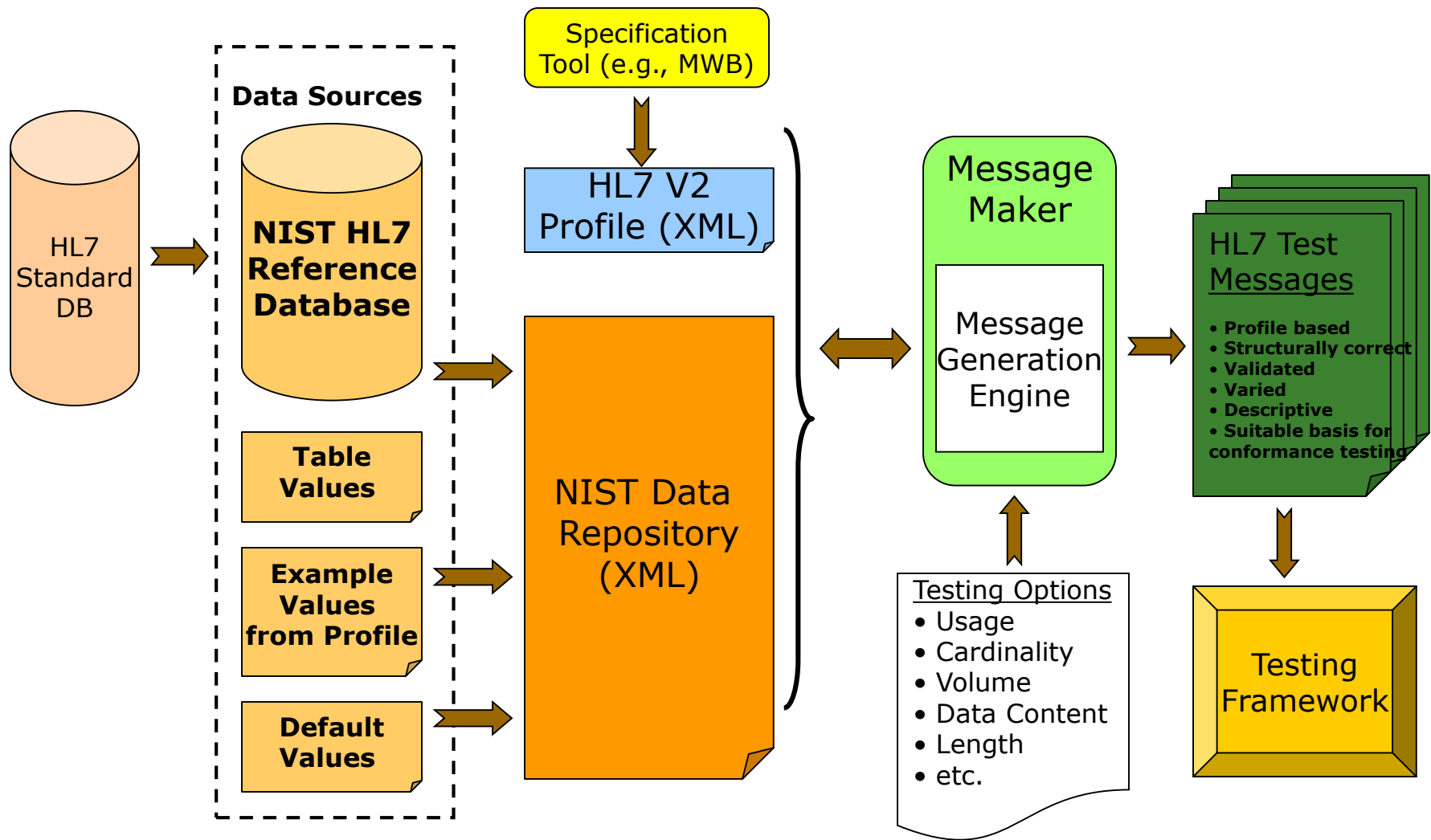
HL7 Message Structure: MSH, EVN, PID, NK1, NK2, NK3, NK4, NK5, NK6, NK7, NK8, NK9, NK10, NK11, NK12, NK13, NK14, NK15, NK16, NK17, NK18, NK19, NK20, NK21, NK22, NK23, NK24, NK25, NK26, NK27, NK28, NK29, NK30, NK31, NK32, NK33, NK34, NK35, NK36, NK37, NK38, NK39, NK40, NK41, NK42, NK43, NK44, NK45, NK46, NK47, NK48, NK49, NK50, NK51, NK52, NK53, NK54, NK55, NK56, NK57, NK58, NK59, NK60, NK61, NK62, NK63, NK64, NK65, NK66, NK67, NK68, NK69, NK70, NK71, NK72, NK73, NK74, NK75, NK76, NK77, NK78, NK79, NK80, NK81, NK82, NK83, NK84, NK85, NK86, NK87, NK88, NK89, NK90, NK91, NK92, NK93, NK94, NK95, NK96, NK97, NK98, NK99, NK100, NK101, NK102, NK103, NK104, NK105, NK106, NK107, NK108, NK109, NK110, NK111, NK112, NK113, NK114, NK115, NK116, NK117, NK118, NK119, NK120, NK121, NK122, NK123, NK124, NK125, NK126, NK127, NK128, NK129, NK130, NK131, NK132, NK133, NK134, NK135, NK136, NK137, NK138, NK139, NK140, NK141, NK142, NK143, NK144, NK145, NK146, NK147, NK148, NK149, NK150, NK151, NK152, NK153, NK154, NK155, NK156, NK157, NK158, NK159, NK160, NK161, NK162, NK163, NK164, NK165, NK166, NK167, NK168, NK169, NK170, NK171, NK172, NK173, NK174, NK175, NK176, NK177, NK178, NK179, NK180, NK181, NK182, NK183, NK184, NK185, NK186, NK187, NK188, NK189, NK190, NK191, NK192, NK193, NK194, NK195, NK196, NK197, NK198, NK199, NK200, NK201, NK202, NK203, NK204, NK205, NK206, NK207, NK208, NK209, NK210, NK211, NK212, NK213, NK214, NK215, NK216, NK217, NK218, NK219, NK220, NK221, NK222, NK223, NK224, NK225, NK226, NK227, NK228, NK229, NK230, NK231, NK232, NK233, NK234, NK235, NK236, NK237, NK238, NK239, NK240, NK241, NK242, NK243, NK244, NK245, NK246, NK247, NK248, NK249, NK250, NK251, NK252, NK253, NK254, NK255, NK256, NK257, NK258, NK259, NK260, NK261, NK262, NK263, NK264, NK265, NK266, NK267, NK268, NK269, NK270, NK271, NK272, NK273, NK274, NK275, NK276, NK277, NK278, NK279, NK280, NK281, NK282, NK283, NK284, NK285, NK286, NK287, NK288, NK289, NK290, NK291, NK292, NK293, NK294, NK295, NK296, NK297, NK298, NK299, NK300, NK301, NK302, NK303, NK304, NK305, NK306, NK307, NK308, NK309, NK310, NK311, NK312, NK313, NK314, NK315, NK316, NK317, NK318, NK319, NK320, NK321, NK322, NK323, NK324, NK325, NK326, NK327, NK328, NK329, NK330, NK331, NK332, NK333, NK334, NK335, NK336, NK337, NK338, NK339, NK340, NK341, NK342, NK343, NK344, NK345, NK346, NK347, NK348, NK349, NK350, NK351, NK352, NK353, NK354, NK355, NK356, NK357, NK358, NK359, NK360, NK361, NK362, NK363, NK364, NK365, NK366, NK367, NK368, NK369, NK370, NK371, NK372, NK373, NK374, NK375, NK376, NK377, NK378, NK379, NK380, NK381, NK382, NK383, NK384, NK385, NK386, NK387, NK388, NK389, NK390, NK391, NK392, NK393, NK394, NK395, NK396, NK397, NK398, NK399, NK400, NK401, NK402, NK403, NK404, NK405, NK406, NK407, NK408, NK409, NK410, NK411, NK412, NK413, NK414, NK415, NK416, NK417, NK418, NK419, NK420, NK421, NK422, NK423, NK424, NK425, NK426, NK427, NK428, NK429, NK430, NK431, NK432, NK433, NK434, NK435, NK436, NK437, NK438, NK439, NK440, NK441, NK442, NK443, NK444, NK445, NK446, NK447, NK448, NK449, NK450, NK451, NK452, NK453, NK454, NK455, NK456, NK457, NK458, NK459, NK460, NK461, NK462, NK463, NK464, NK465, NK466, NK467, NK468, NK469, NK470, NK471, NK472, NK473, NK474, NK475, NK476, NK477, NK478, NK479, NK480, NK481, NK482, NK483, NK484, NK485, NK486, NK487, NK488, NK489, NK490, NK491, NK492, NK493, NK494, NK495, NK496, NK497, NK498, NK499, NK500, NK501, NK502, NK503, NK504, NK505, NK506, NK507, NK508, NK509, NK510, NK511, NK512, NK513, NK514, NK515, NK516, NK517, NK518, NK519, NK520, NK521, NK522, NK523, NK524, NK525, NK526, NK527, NK528, NK529, NK530, NK531, NK532, NK533, NK534, NK535, NK536, NK537, NK538, NK539, NK540, NK541, NK542, NK543, NK544, NK545, NK546, NK547, NK548, NK549, NK550, NK551, NK552, NK553, NK554, NK555, NK556, NK557, NK558, NK559, NK560, NK561, NK562, NK563, NK564, NK565, NK566, NK567, NK568, NK569, NK570, NK571, NK572, NK573, NK574, NK575, NK576, NK577, NK578, NK579, NK580, NK581, NK582, NK583, NK584, NK585, NK586, NK587, NK588, NK589, NK590, NK591, NK592, NK593, NK594, NK595, NK596, NK597, NK598, NK599, NK600, NK601, NK602, NK603, NK604, NK605, NK606, NK607, NK608, NK609, NK610, NK611, NK612, NK613, NK614, NK615, NK616, NK617, NK618, NK619, NK620, NK621, NK622, NK623, NK624, NK625, NK626, NK627, NK628, NK629, NK630, NK631, NK632, NK633, NK634, NK635, NK636, NK637, NK638, NK639, NK640, NK641, NK642, NK643, NK644, NK645, NK646, NK647, NK648, NK649, NK650, NK651, NK652, NK653, NK654, NK655, NK656, NK657, NK658, NK659, NK660, NK661, NK662, NK663, NK664, NK665, NK666, NK667, NK668, NK669, NK670, NK671, NK672, NK673, NK674, NK675, NK676, NK677, NK678, NK679, NK

# Automated and Adaptable Message Creation





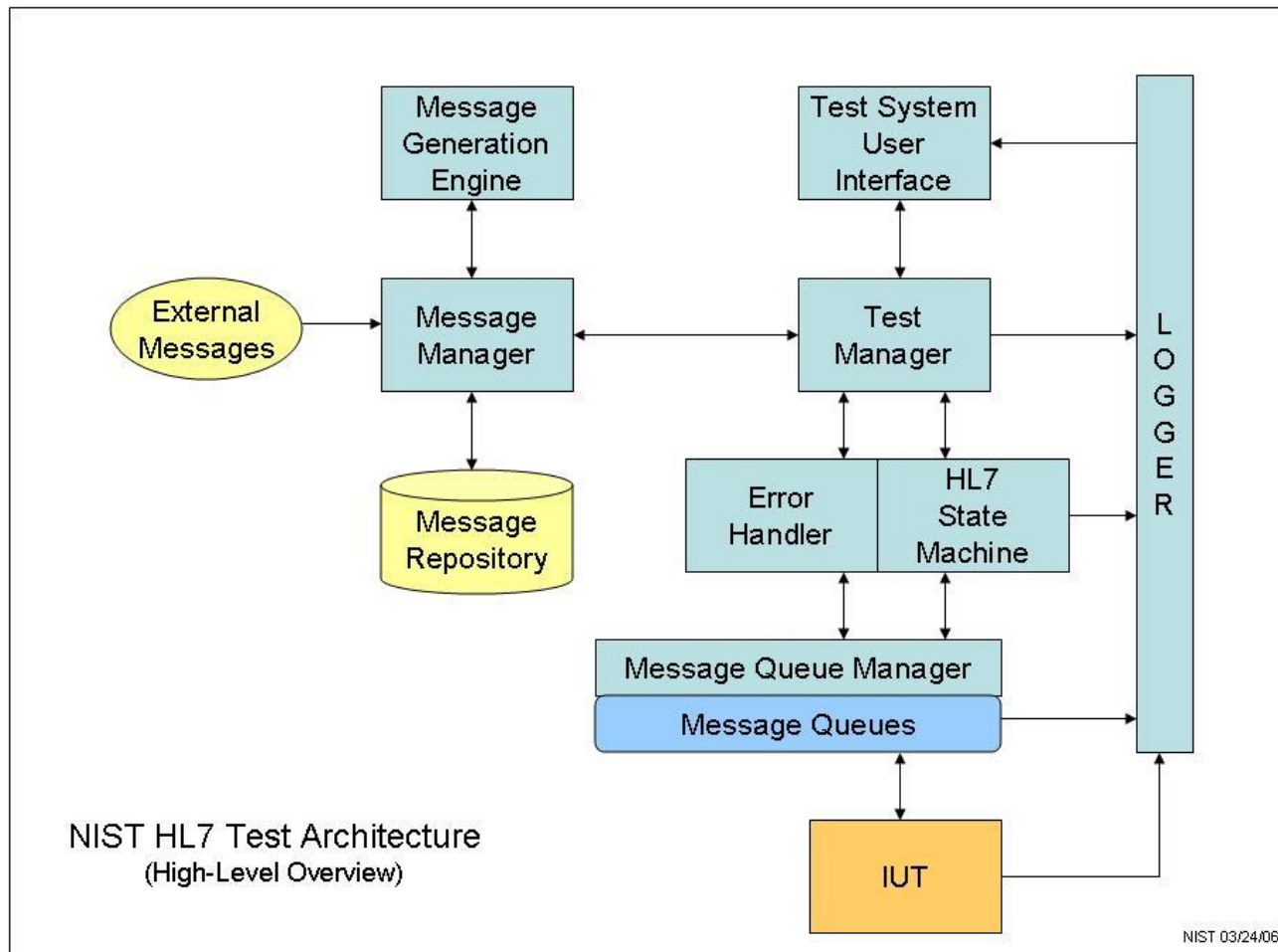
# Message Maker Design



# Approach to Message Generation

- XSLT Engine
  - Create *base* message
  - Combines XML Profile, Rules, Data
- Modify the profile
  - Message Structure
  - Element attributes (e.g., cardinality, usage)
- Modify existing message content
  - XPath expression and data value
  - Element content (length, data, value set)
- Used in combination

# NIST HL7 Test Framework



# Initial Setup

The screenshot shows the 'Message Maker 1.3' application window. The 'Messages' menu is open, and the 'Initialization' tab is selected. The interface is divided into two main sections: 'Test Message Set Initialization' and 'Test Message Options'.

**Test Message Set Initialization:**

- Profile:** C:\Program Files\Message Maker\maker\testing\Simple\NIST\_SampleA. A callout points to the 'Browse ...' button, stating: "Load a valid HL7 XML Message Profile".
- Message Path:** C:\Program Files\Message Maker\maker\testing\Simple\messages. A callout points to the 'Browse ...' button, stating: "Location to save the messages".

**Test Message Options:**

- Volume:** 5. A callout points to the input field, stating: "Set number of messages to be created".
- Select the type of messages you want to create:** A callout points to the radio button options, stating: "Select the type of messages you want to create". The options are:
  - ☒ Create a set of valid test messages
  - ☐ Create a set of invalid test messages
  - ☐ Create a set of both valid and invalid test messages
  - ☐ Create a sample message (randomly populated)
  - ☐ Create a sample message (minimally populated)
  - ☐ Create a sample message (maximally populated)
- When generating messages:**
  - ☒ Ignore length constraints
  - ☐ Enforce length constraints
- Customize Settings:** More Options >>> (radio button)
- Manual test selection:** Set (radio button)

A callout points to the sample message options, stating: "Options to create sample messages".

# Define Specific Test Location and Type

The screenshot shows the 'Manual Test Selection' dialog box. The 'Type of messages' dropdown is set to 'INVALID'. The left pane shows a tree view of the profile elements. The right pane shows a table of selected elements with columns for Element, Cardinality, Usage, and Value.

**Annotations:**

- Request either valid or invalid:** Points to the 'Type of messages' dropdown.
- Navigate to specific location in the profile:** Points to the tree view on the left.
- Not supported element is populated with a value:** Points to the '0001' value in the 'Value' column.
- Required element is NOT populated with a value:** Points to the '0333' value in the 'Value' column.
- Vary the cardinality of this element such that it is outside the valid cardinality range:** Points to the '1..1' cardinality in the 'Cardinality' column.

Element	Cardinality	Usage	Value
Set ID - PID	1..1	R	
Patient ID	1..1	R	
Patient Identifier List	1..1	R	
Alternate Patient ID - R	1..1	R	
Patient Name	1..3	X	
Mother's Maiden Name	1..1	X	
Date/Time Of Birth	1..1	X	
Administrative Sex	1..1	R	
Patient Alias	1..1	X	
Race	1..1	X	
Patient Address	1..1	X	
County Code	1..3	R	
Phone Number - Home	1..1	X	
Phone Number - Business	1..3	R	
Primary Language	1..1	X	
Marital Status	1..1	X	
Religion	1..1	X	
Patient Account Number	1..1	X	
SSN Number - Patient	1..1	X	
Driver's License Number - Patient	1..1	X	
Driver's License Number	1..1	R	0001
Issuing State, province, country	1..1	R	
expiration date	1..1	R	
Mother's Identifier	1..1	X	
Ethnic Group	1..1	X	
Birth Place	1..1	X	
Multiple Birth Indicator	1..1	X	
Birth Order	1..1	X	
Citizenship	1..1	X	

Number of Message Variants: 5

Buttons: Apply, Undo Modification, Clear All, Close

**Description:** The Manual Test Selection allows you to pick a specific location in the profile and the type of test you'd like. Tests can be valid or invalid. A number of error messages have been requested above.

# Browse and Edit Repository Data

The screenshot shows the 'Message Maker 1.3' application window, specifically the 'Data Configuration' tab. The window is divided into three main sections:

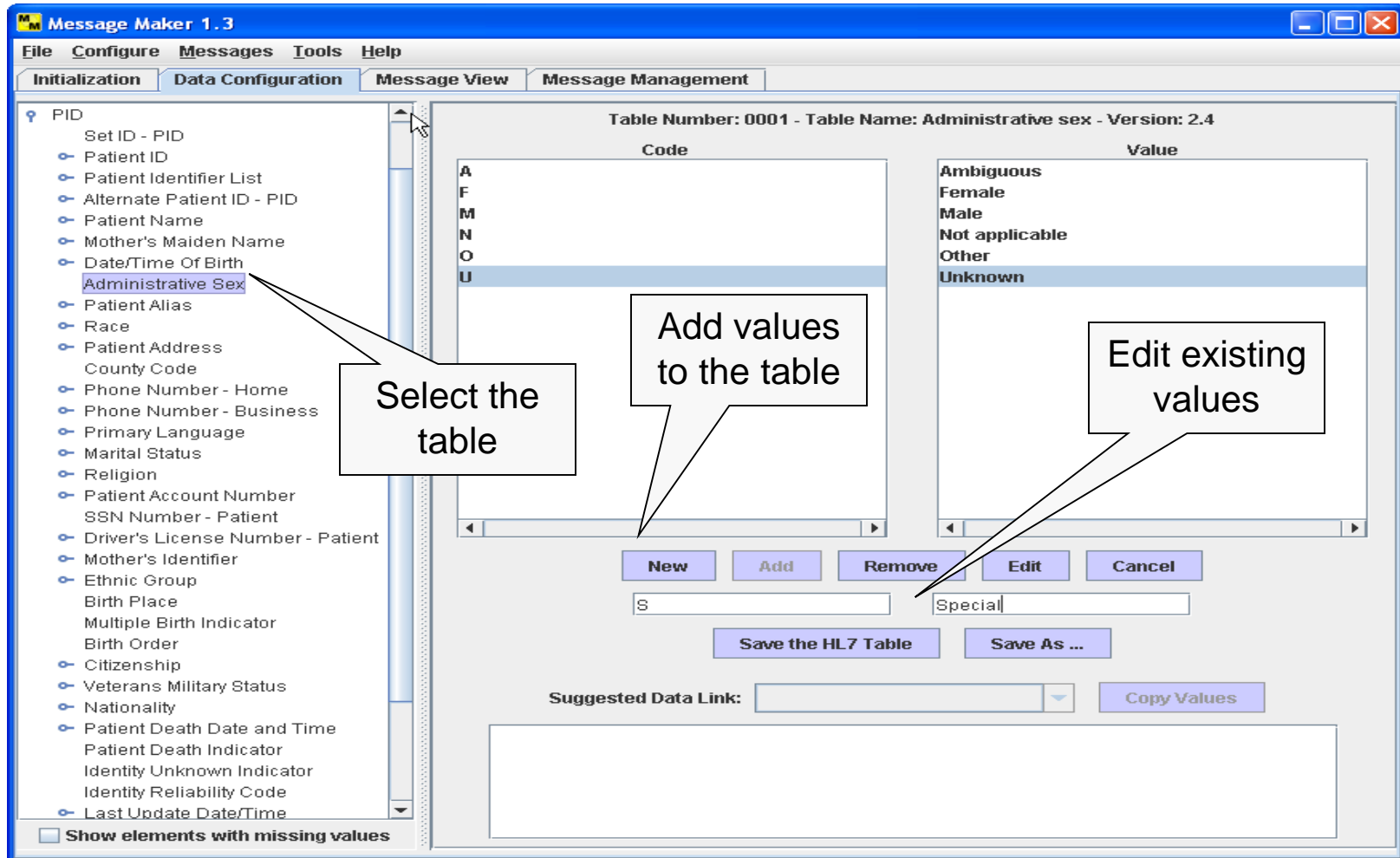
- Left Panel (Tree View):** A list of data elements. The 'Phone Number - Home' element is selected, and its sub-elements are expanded, showing a list of phone number formats like '[(999)] 999-9999 [x999999][C any text]'.
- Center Panel (Values List):** A list of values for the selected element. The values are: (608)885-2312, (240)765-1455, (972)444-2222, (972)765-1994, (240)222-1212, (214)444-5473, (301)191-9999, (412)287-7733, (240)765-1214x5924, (972)233-1992x63741, (972)666-1992x6444C Press 2, 233-4422, 221-0548, (412)221-7218, (814)284-9218, (703)463-9900, (301)392-6372, (214)444-5471x7342, (412)446-5423x123, (814)442-5473x22C After 6:00, (301)444-5473B951, 834-5473, 221-4753C local number, 693-3432, 818-6438x44, and 49 (301)444-5473.
- Right Panel (Form):** A form to add new values. It includes fields for 'Name', 'Segment', 'Field', 'Component', '# Sequence', 'Datatype', 'Category', and 'Description'. The 'Name' field is populated with '[(999)] 999-9999 [x999999][C any text]'. The 'Segment' is 'PID', 'Field' is 'Phone Number - Home', 'Component' is empty, '# Sequence' is '13.1', 'Datatype' is 'TN', 'Category' is 'Valid: Typical', and 'Description' is empty. There are buttons for 'New', 'Add', 'Remove', 'Edit', 'Save the repository', 'Save As ...', and 'Copy Values'.

Callout boxes provide additional context:

- Top Right:** 'Add values to the repository' (pointing to the 'Add' button).
- Left:** 'Browse the data repository' (pointing to the tree view).

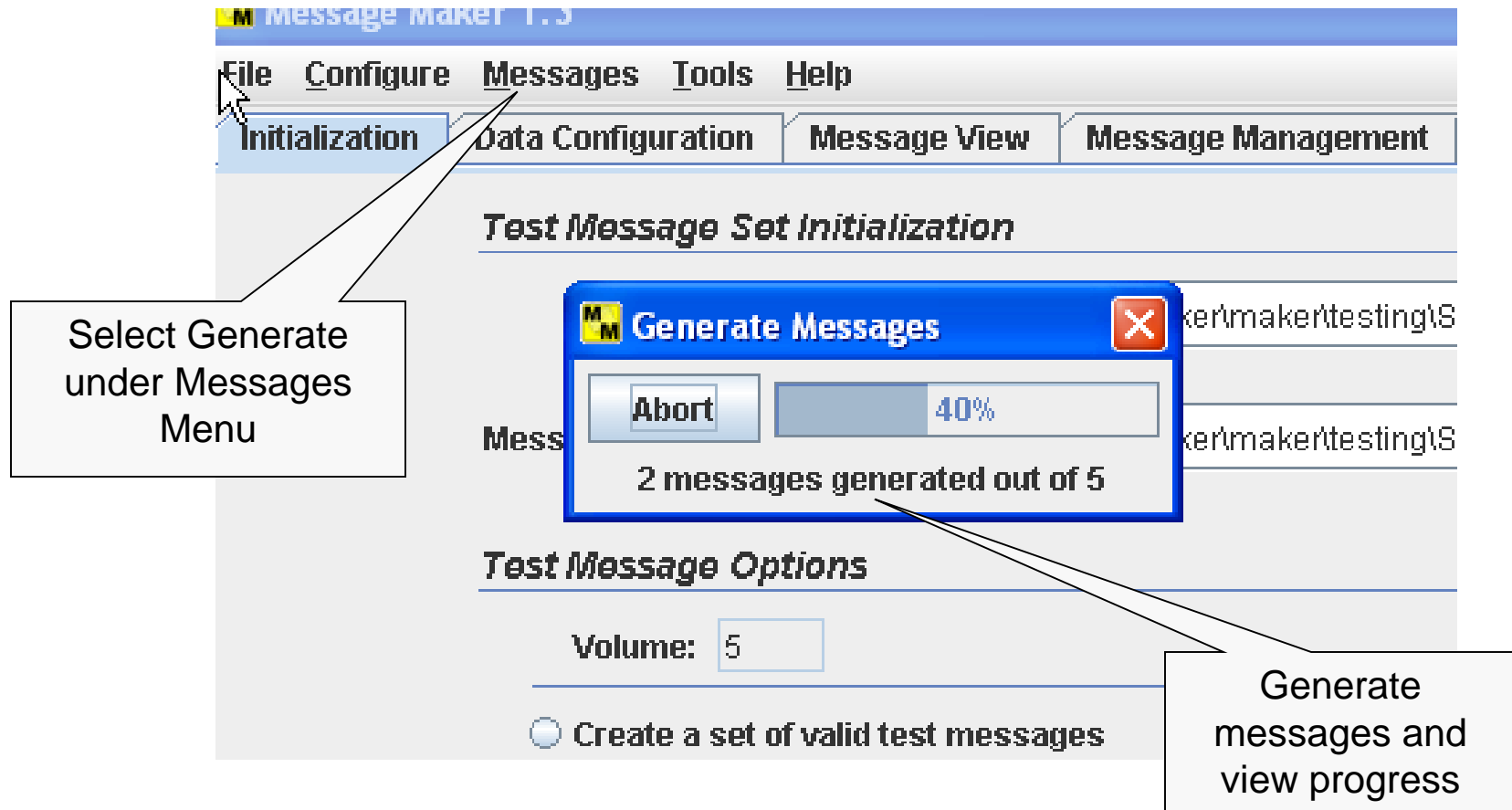
**Description:** The Data Repository is a collection of data items for each HL7 primitive element. Users can browse and edit the values in the repository.

# Table Data



**Description:** Table data can be browsed and edited. Tables can also be viewed from a table centric view by selecting Table Viewer item under the Configure menu.

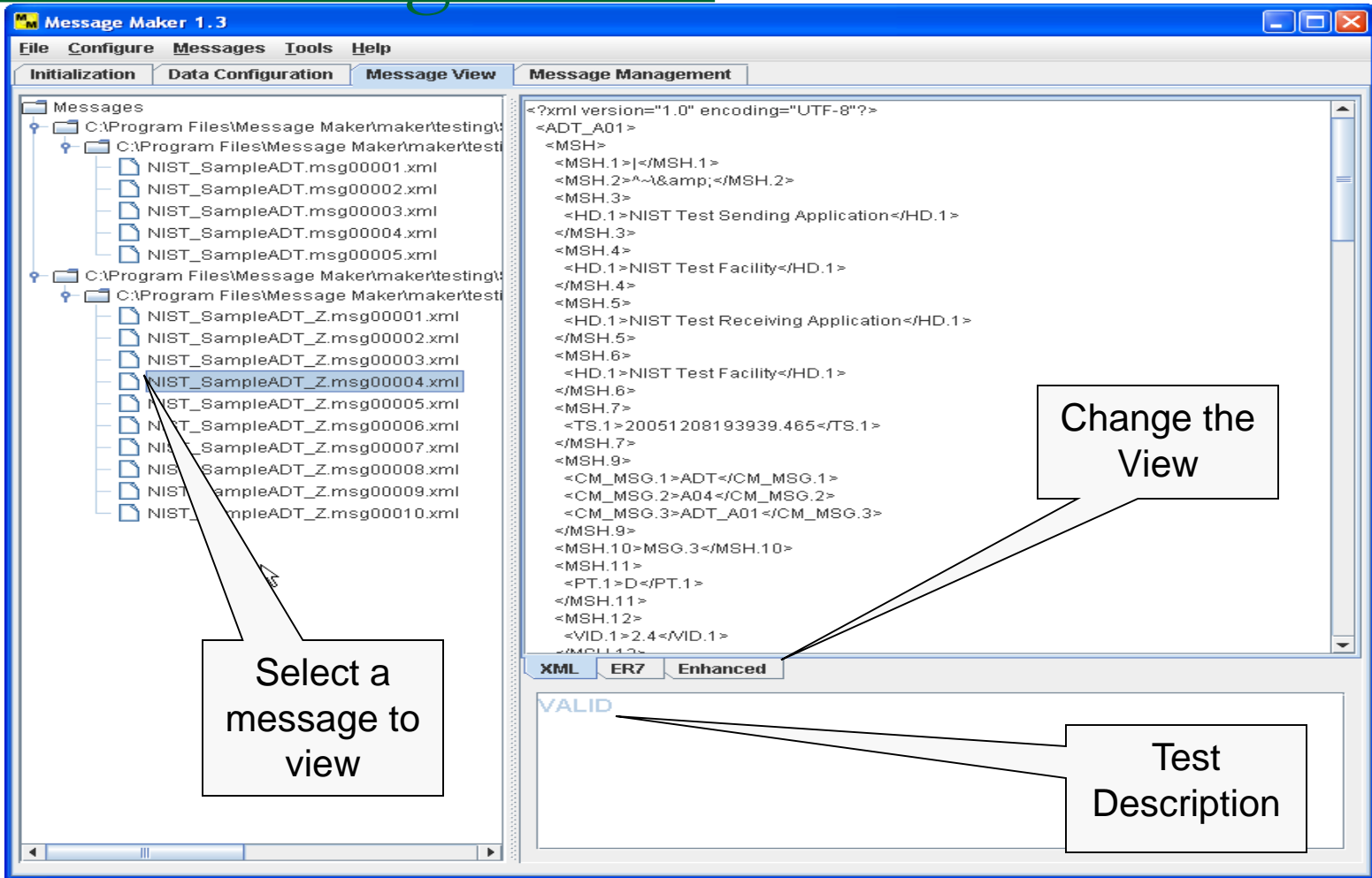
# Generate Messages



**Description:** Once initialization has been completed messages can be generated.

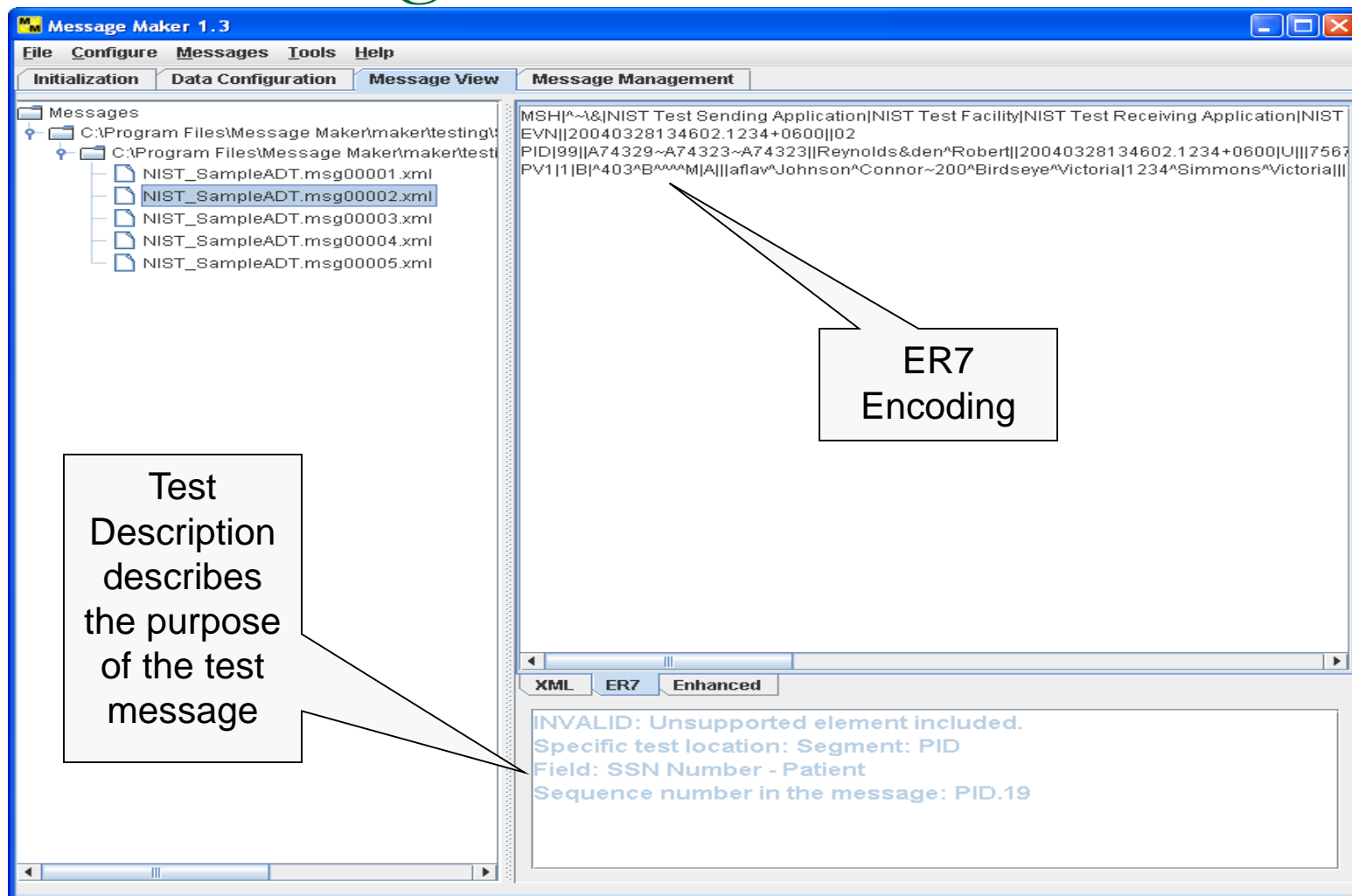


# XML Message View



**Description:** Message Maker provides three views of the messages (XML, ER7 and Enhanced ER7). For each message a Test Description is given that describes the purpose of the test message.

# ER7 Message View



**Description:** ER7 view with a detailed test description.

# Enhanced Message View

Message Maker 1.3

File Configure Messages Tools Help

Initialization Data Configuration Message View Message Management

Messages

- C:\Program Files\Message Maker\maker\testing\
- C:\Program Files\Message Maker\maker\test\
- NIST\_SampleADT.msg00001.xml
- NIST\_SampleADT.msg00002.xml
- NIST\_SampleADT.msg00003.xml
- NIST\_SampleADT.msg00004.xml
- NIST\_SampleADT.msg00005.xml

ADT\_A01

- MSH
- EVN
- PID
  - PID.1 99
  - PID.3
  - PID.5
  - PID.7
  - PID.8 N
  - PID.11
  - PID.13
  - PID.18
  - PID.20
    - DLN.2 GA
    - DLN.3 2004
- PV1
  - PV1.1 4
  - PV1.2 C
  - PV1.3
  - PV1.4 N
  - PV1.7
  - PV1.8
  - PV1.18 G
  - PV1.19
  - PV1.44
  - PV1.45
  - PV1.46 2567.87
  - PV1.47 78.99
  - PV1.49 14.85

Missing data element PID.20.1

Required element error injected at location PID.20.1

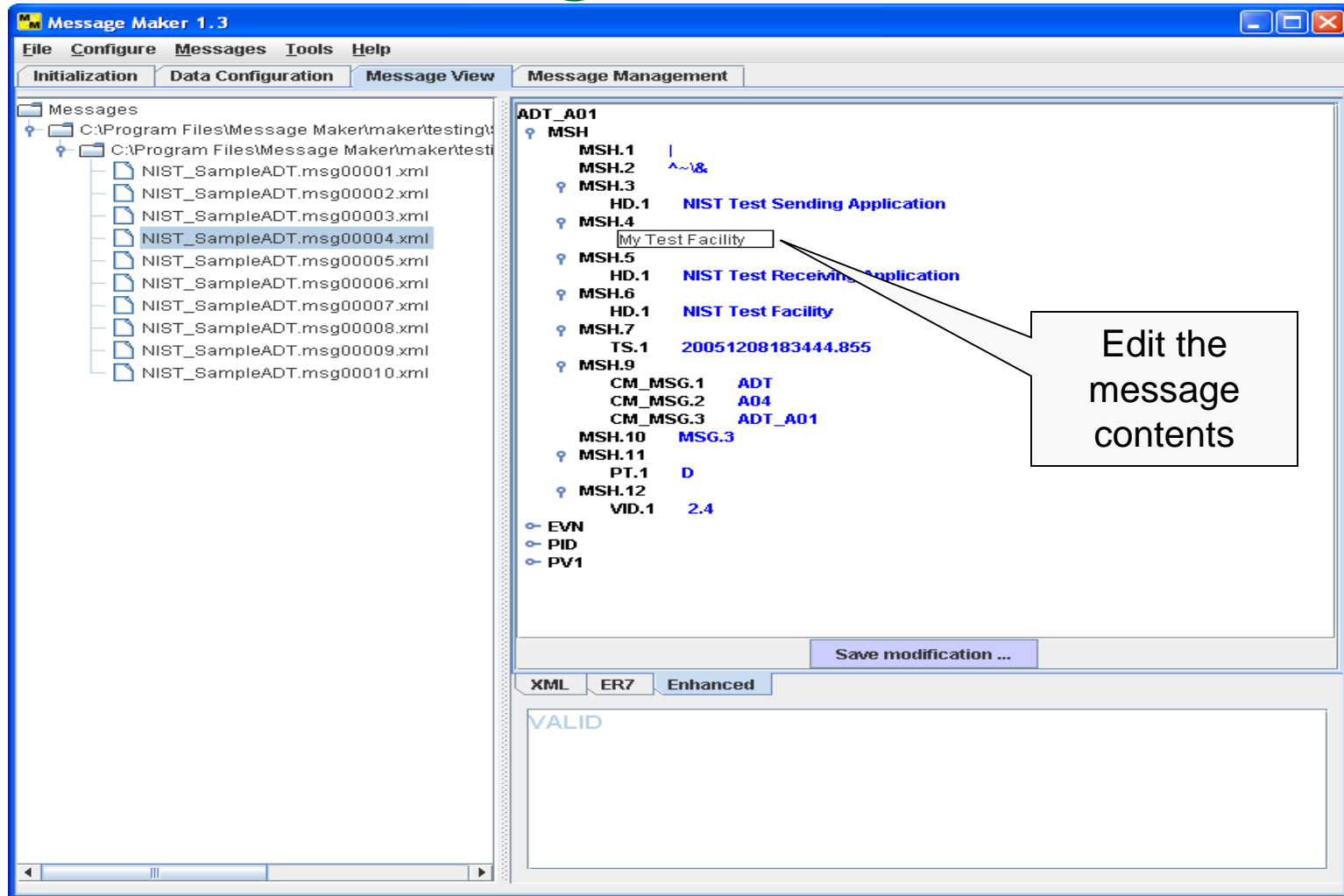
Save modification ...

XML ER7 Enhanced

INVALID: Required element not present.  
Specific test location: Segment: PID  
Field: Driver's License Number - Patient  
Component: Driver's License Number  
Sequence number in the message: PID.20.1

**Description:** The enhanced ER7 view presents the message in a tree structure that can be navigated. The above call outs shows the injected error description and the location in the message.

# Post Edit Message



**Description:** The enhanced ER7 view allows messages to be edited and saved.

# Summary

- Methodology and tool to create test messages
- Automatically and dynamically generate messages for any given profile
  - Account for site-specific characteristics and options
  - Can be used to produce self-adapting test suites
- Capabilities:
  - Message Variation
  - Data Configuration
  - Methods to automatically determine test message set
  - Multiple encodings (XML, ER7)
  - Test Descriptions (metadata)
- <http://www.nist.gov/messagemaker>
  - Public domain
  - Source code available