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Using XML to Network Distributed Analytical Instruments

Back to the Future?

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1. Abstract

There has been a paradigm shift in Medical Informatics standards in recent years from the message-oriented approach towards a more distributed-systems approach. However, despite all the early promise of distributed applications they haven't been widely adopted in the health domain for various reasons. As a result, despite an increasing need for a standardised distributed solution for analytical laboratory instruments, many implementers of instrument interfaces are still using proprietary serial interfaces, which do not support distribution. The emergence of the eXtended Markup Language (XML) specification in early 1998 revived the prospects of the message-oriented methodology.

This paper presents a partial return to the message-based solution. The first section describes the syntax of XML and it's impact in various healthcare areas. The next part outlines and compares the different aspects of a 'Standard Specification for Transferring Information Between Clinical Instruments and Computer Systems' (ASTM 1394-91) and its XML-compliant counterpart, while the third part presents one possible use of the XML version in a detailed and practical medical scenario. A provisional Document Type Definition (DTD) as well as an example of the resulting ASTM 1394-91/XML will be given in the last section.

2. Introduction

Important Note:

In this paper we use the expression **ASTM message** for messages based on the ASTM E 1394-91 messaging format. The so called **XML messages** or **XML documents** that are described in this work, are messages based on the ASTM E 1394-91 Markup Language (see also chapter 7.1) that follows the XML specification.

2.1. ASTM protocols for data exchange between host and instrument

Founded in 1898, ASTM (the American Society for Testing and Materials) is now one of the largest international voluntary standards organisations. ASTM is a non-profit organisation whose standards encompass metals, paints, plastics, textiles, petroleum, construction, energy, the environment, consumer products, medical services and devices, computerised systems, electronics, and many other areas.

In 1991 ASTM published two standards that dealt with the communications between clinical analysers and host computers.

- **E1381** Standard Specification for the Low-Level Protocol in Transferring Messages Between Clinical Laboratory Instruments and Computer Systems
- **E1394** Standard Specification for Transferring Information between Clinical Instruments

These standards were complementary and were intended for point-to-point connections (for instance a serial connection) between instrument and computer system such as a LIS or a validation workstation.

The first standard, **E1381**, described a low-level protocol to permit reliable bi-directional exchange of information between instrument and computer systems. Issues dealt with in this document included the low-level behaviour of the two systems when an error condition occurred, error checking, agreed low level message structure and other similar features. The second standard, **E1394**, which is the subject of this paper, described a mechanism for transferring the message content in a way that could be commonly 'understood' by both instrument and host. It described the positioning of agreed attributes within an ASTM message, so that sender could place information and receiver could know where to find it.

E1394 allows six different types of messages that can be arranged in a hierarchical fashion:

1. **Header record:**
   contains any information that is common to the entire message such as time of transmission.
2. **Patient Info record:**
   contains information about the subject of the request/results
3. **Order record:**
   contains information relating to an order for a test to be carried out by the instrument
4. **Result record:**
   contains information relating to a result that has been produced by the instrument.
5. **Request record:**
   contains information necessary to request the results of previously ordered tests

The standard also describes the following less frequently used record types; comment record, scientific record, manufacturer information record. An example of a fragment of an ASTM message that could be sent across a serial link is shown below*.

```
<STX>1H|\^&||PSWD|JungLabs|1 Zozimus St^Dublin||1850-
222222||||P|2.5|123456<CR><ETX><CS><CS><CR><LF>
       <STX>2P|1|2462|158|287-17-2791|BERRY^DAMON^Mr<CR><ETX><CS><CS><CR><LF>
              <STX>3O|1|0123456||^^^LIVER|S<CR><ETX><CS><CS><CR><LF>
                     <STX>4R|1|^^^TBILI|7.9<CR><ETX><CS><CS><CR><LF>
                     <STX>5R|2|^^^GGT|29<CR><ETX><CS><CS><CR><LF>
              <STX>6O|2|0123457||^^^GLU|S<CR><ETX><CS><CS><CR><LF>
                     <STX>6R|1|^^^GLU|91.5<CR><ETX><CS><CS><CR><LF>
       <STX>7L|1<CR><ETX><CS><CS><CR><LF>
```

This message conveys some results of a requested liver test and a glucose test for subject Damon Berry from instrument to host. In the following sections, we will see how an equivalent message suitable for multi-point connection (i.e. network connection) can be constructed using XML.

2.2. XML 1.0

XML is subset of the Standard Generalized Markup Language (SGML) defined in ISO standard 8879:1986. In 1996, members of the World-Wide-Web Consortium (W3C) published articles and early specifications which finally lead to the first approved and recommended XML specification in February 1998 [Xml98]. Described as being in between SGML and HTML, XML is a very flexible yet unrestricted means for the creation of hierarchically structured and logically organised documents. It addresses the engineering complexity of SGML and the limitations of the fixed tag set in HTML.

The main four parts of an XML document are the following:

1. **Document Type Definition (DTD):** A formal model to define the elements, it's attributes, relation and order between them on which an XML document is based. XML documents don't have to be conformant with a specific DTD, but if they are, validation is possible. A DTD might also be used to inform the receiver of a document's structure before they receive it. DTDs are normally stored as documents.
   The following example defines an ELEMENT 'Name' with one optional ATTRIBUTE 'type'. The content of the ELEMENT is parsable character data.
   ```
   <!ELEMENT Name (#PCDATA)>
   <!ATTLIST Name type CDATA #IMPLIED>
   ```

* The text in bold italics is dealt with in **E1381**, and the remainder is covered by **E1394**. In addition, the receiver would have to confirm the receipt of each frame (segment beginning with <STX>) by sending out a <ACK> acknowledge before the sender could send the next frame:

<STX>=start transmission, <ETX>=end transmission, <CR>=carriage return, <LF>=linefeed, <CS>=checksum.

2. **ELEMENT:** A logical part of an XML document. Each XML document must have exactly one root element. Each ELEMENT can contain zero-or-more ELEMENTs (children), depending on the DTD. ELEMENTs are syntactically bounded by opening ('<…>') and closing ('</…>') markup tags.
   Example:
   `<Name></Name>`
3. **CONTENT:** Syntactically, this is the part between the opening- and the closing-tag. It contains the content of the ELEMENT itself.
   Example:
   `<Name>Bill</Name>`
4. **ATTRIBUTE:** Property of an ELEMENT. ATTRIBUTEs are defined within the opening-tag of the related ELEMENT and specify more detailed the CONTENT of the ELEMENT.
   Example:
   `<Name type='first'>Bill</Name>`

It is important to mention that ELEMENTs and ATTRIBUTEs are not predefined as they are in HTML. The user is free to define their own set of ELEMENTs and ATTRIBUTEs and provide a DTD, in which the model of the document is defined. Various organisations and groups developed their own DTDs to use for specialised tasks or projects (e.g. MathML [MaML99], SynXML [JAA99]).

XML was only the first, but most important, recommendation from the W3C of the many 'children' of the X-family. A full list of statistics of actual work and ongoing activities can be found on the W3C web-site [W3C94].

3. General scenarios

3.1. XML in Healthcare

Jon Bosak, one of the designers and 'parents' of XML, envisioned the use of XML in Healthcare in his very early speeches and publications about XML [Bos96]. Instead of printing (e.g.) laboratory data or patient's medical history data on paper, then sending it from one hospital to another by postal mail and adding it manually into the receiving hospitals system, he demonstrated the following scenario:

1. Log into the hospital's Web site.
2. Become an authorised user.
3. Access the patient's medical records in a Web-based interface that represents the records for that patient with a folder icon.
4. Drag the folder from the Web application over to the internal database application.
5. Drop it into the database.

It is obvious that XML has many advantages over existing systems e.g. improvements speed, reduction of errors, easier use of distributed data.

Many of the steps described above are still only visions or implemented in very small prototypes. Due to the complexity of medical data and different legal regulations to handle the data within the various countries, XML hasn't yet taken off as it has in other areas. It is recognisable that the possible use of XML in healthcare was mentioned very early and it only become widely accepted now.

The following list will give a short summary of different European/international activities, where XML is used in Medical Informatics:

1. **CEN/TC251, Europe:** [CEN99]
   Since summer 1997, the XML Working Group with Prof. Joachim Dudeck (University of Gießen, Germany) as chairman met every 6 months to discuss to support adaptations of existing CEN/TC251 standards to XML. As a result of this a first DTD for 'Messages for the exchange of information' (prENV 13606-4) was published for formal vote. More activities in this direction are expected for the next months.

2. **SynEx, Europe:** [Syn99]
   The FHCR architecture group of the SynEx project mapped the existing and generic EPR object model straight forward into the SynXML DTD with site specific extensions. The Reference DTD represents the core structure, that is supported by all sites. Site specific extensions add local functionality. This flexibility led to an very fast development of the commonly agreed DTD, but showed it's weakness: this model is not strong enough to be used as the exchange structure. Future work requires a reduction in the specialisations to make the exchange more generic.
3. **Health Level Seven (HL7), USA:** [HL99]
   The HL7 organisation developed a very detailed and specific Reference Information Model (RIM) to express Patient Data. Work is undertaken to express the model as a DTD to make data exchange easier.
4. **CORBAmed, USA:** [Cor99]
   XML is one of the data content formats that is implicitly supported by CORBAmed's recently introduced clinical observation access service (COAS). In this respect CORBA could be considered as the conveyance mechanism and XML documents the payload.

4. Types of scenarios that might occur

4.1. ASTM 1394-91

To show how an ASTM based instrument would operate, let us consider the case of an imaginary blood-gas analyser that supports ASTM over an RS 232 serial interface. Typically, such an instrument would not support all ASTM record types as it requires a relatively unsophisticated communications interface. It is worth noting that this is a commonly cited reason why instrument interface implementers choose not to implement ASTM interfaces - it is difficult and thus expensive to implement the full specification.

Let us take the case where the instrument only sends information. In other words, the host computer is not permitted to use the request record to request particular results, nor to send any information to the instrument relating to a particular subject or result. The instrument merely sends all its result values to the host computer. In such a case it might be useful for the instrument to send information about the message itself using the header record. In fact, this information could be quite sparse. Perhaps it would send the date of transmission and the mode and name of the instrument. It would also be useful for the instrument to send some information to identify the subject of the tests. We could say that the instrument would require some numeric subject identifier which would be entered by a user before inserting a sample into the instrument. This identifier would be the main content required in the patient information record. Next we would require the results, where each result would comprise at least a test identifier, a measured value, the units and the measurement timestamp. This information in our scenario would be contained in result records, one result record per measured value.

Instrument Model Analyzer ABG32
SubjectID= 012345
SampleID 0000005(generated by the instrument)
Message time 13:01:56 09/09/1999

	TestID	**value**	**units**
Result 1:	pH	7.22	
Result 2	pCO2	30.8	mmHg

….

So a shortened version of the resulting message coming from the instrument could be something like.

```
H|\^&|Analyzer ABG32^SJH005||||||||||19990909130156<CR>
P|1||012345||
O|1|0000005|||||||||||<CR>
       R|1|^^^pH|7.22||||||<CR>
       R|2|^^^pCO2|30.8|mmHg||||<CR>
       …
L|1|N<CR>
```

It is interesting to note the following

1. The scenario only uses a small portion of the ASTM protocol but nevertheless the implementer of the host interface would need to develop "from scratch", code to manage both the low-level parsing and the logic to transform the message into another format, such as an entry in a database. In fact, because of the implementation cost, one might say that the use of ASTM is unjustified in this case.
2. The communication is point to point, single source-single destination so the source and destination of the message is implicit.
3. The use of delimiters means that there will be a certain amount of redundancy in the message
4. It is not easy to determine the exact meaning of the message, as there is no way to determine from the message itself, the purpose of the individual fields,
5. The serial connection is simple, reliable and relatively easy to maintain.
6. Because the connection is through a serial connection only a single host can receive the message
7. Because of practical limitations of RS 232 connections, one would expect the host to be situated quite close to the instrument.

Now let us now look at a similar scenario using XML and a network connection instead of ASTM and RS-232.

4.2. XML 1.0

The second scenario that will be presented here is more or less still only a vision. It's main purpose is to describe the functional use of XML to ease data exchange. Many of the required components are already in use in today's newly-build or refurbished Medical Informatics environments. Let us assume the following facts to take full advantage of the technical related issues after the introduction of XML:

1. Each single room, which might contain any kind of medical-related data-retrieving instrument (e.g. blood-gas analyser, but also the front-desk, where the patient data is entered) has connections to the local hospitals Intranet. It can be assumed that a secure connection to the Internet can be made using the local Intranet.

2. Each instrument will have it's own IP address, is equipped with a hardware/software data storage unit (e.g. hard-disk and database) and a network card with integrated web-server that can be connected to the local network. Alternatively, this functionality can be provided by a separate machine (computer), which then can be used as a bridge between the instrument and the network.

The easiest imaginable use-case is similar to the one described earlier in chapter 4.1. Each part of the original ASTM message is preserved. The main difference is a more readable and accessible structure for both, man and machine.

The following XML message/document based on the ASTM1394-91-DTD (see chapter 7.1) is equivalent to the ASTM message described in chapter 4.1.

```
<?xml version="1.0"?>

<!DOCTYPE ASTM SYSTEM "ASTM1394-91.dtd">

<ASTM Designation='E1394'>
  <MessageHeader>
    <Instrument>
      <Label>Analyzer ABG32</Label>
      <Extension Type='IntenalNumber'>SJH005</Extension>
```

```
 <DateTime>19990909130156</DateTime>
  </MessageHeader>
  <Message>
    <PatientInformation>
      <ID Type='LaboratoryAssigned'>012345<ID>
      <TestOrder>
        <Specimen>
          <ID>0000005<ID>
        </Specimen>
        <Result>
          <UniversalTestID>pH</UniversalTestID>
          <Value>7.22<Value>
        </Result>
        <Result>
          <UniversalTestID>pCO2</UniversalTestID>
          <Value Units='mmHg'>30.8<Value>
        </Result>
      </TestOrder>
    </PatientInformation>
  </Message>
</ASTM>
```

The use of the above mentioned components and techniques will gain the following advantages over the use of the RS 232 serial interface:

1. The location of the instrument doesn't influence the access. Through the use of the TCP/IP protocol, the instrument will have a unique identifier (IP address) within the local Intranet, uniqueness could be even gained within the global Internet. Moving the instrument from one room into another or from one building into the next doesn't effect the system. This makes the XML TCP/IP approach suitable for NPT instruments.
2. No long and proprietary physical connection is required to connect the instrument to the network.
3. The web-server functionality supports pull as well as push technology. Pull describes the situation when all data stored within the instruments storage system is send to another system on request. In contrary, push technology sends the data without request in specific time-intervals to predefined targets. Both methods will require CGI scripting on the instruments/web-server side. This scripting could be implemented through Active Server Pages (ASP), Java servlets or perl-scripts. It is likely that the situation would not correspond to each instrument having a web-site. It is more likely that each instrument would be similar to a channel source. The instrument would be more likely to "push" information at the workstation client. In this case it is possible that both, instrument and host/workstation, are in fact web servers.
4. Software to parse the XML document and provide a Document Object Model (DOM) for easy access of single elements or maintenance of the whole document are freely available. The source code as well as the binary files can be found for Java and C++. Dynamic Link Libraries (DLL) are also available for use in the Microsoft Windows environment.
5. Standard Tool support is very good and of a very high quality.
6. XML can support persistence, as XML files can be stored and retrieved from the file system. XML documents can also be merged easily using the DOM..
7. XML can be viewed in many different ways with comparative ease through the use of multiple style sheets. The processing of XML documents with stylesheets can take place on the server as well as on the client side. Stylesheets can be delivered from the default location (e.g. from the target source), but might be overwritten manually on the client side with local presentations rules. It only requires a modern Web browser to present reports coming from instruments.

5. Comparisons

5.1. General

The standard ASTM 1394-91 features a basic and very compact message format. However, because of the lack of tool support the standard is relatively difficult to implement and therefore isn't widely supported. On the contrary, the ASTM 1394-91 Markup Language features a much simpler message format with respect to human readability (clear separation of data and metadata) and data accessibility (DOM and SAX).

5.2. Cost / Implementation Time / Cost to implement from scratch

The following table outlines the main time and cost-differences in using XML or ASTM as the general message format between the instrument and the connected computer.

	XML	**ASTM**
Source side (Instrument): Adaptation of existing systems to the message format, e.g. creating and parsing documents, web connection , etc.	3 man-months [1] (high level programming)	5 man-months (low-level programming)
Target side (Host): Accessing the retrieved document and presenting it to the system/human.	1 man-month (high level programming)	3 man-months (low-level programming)
In Total:	Approx. 4 man-months = 50%	Approx. 8 man-months = 100%

[1] Development time will become even shorter, because many of the existing applications (like databases, web server, browser etc.) will support XML in the near future.

5.3. Memory Cost

Although most of the functionality is a available "off the shelf", a typical XML parser would be more complex than the equivalent ASTM 1394 parser. Therefore one could expect that the memory cost would be higher for the XML parser.

5.4. Security

Because ASTM 1394-91 is intended for point-to point connection, encryption is not necessary. Access control may be a problem on the workstation host side or on the instrument side. The ASTM standard does not recommend a procedure to explicitly prevent misidentification of patient or sample.

XML as it explicitly supports multi-point network connections requires encryption of messages. It also does not explicitly support access control but there is strong support from web-based access control. Using the hierarchy of XML documents, sub-tree (fragment-) encryption/decryption is easily imaginable and implemental.

5.5. Baud Rate / Bit Rate

Def.: The number of *signaling elements* that occur each second. The term is named after J.M.E. Baudot, the inventor of the Baudot telegraph code. At slow speeds, only one bit of information (signaling element) is encoded in each electrical change, i.e. ten bits represent a character. At higher speeds, it is possible to encode more than one bit in each electrical change. 4,800 baud may allow 9,600 bits to be sent each second. At high data transfer speeds, therefore, data transmission rates are usually expressed in bits per second (bps) rather than baud.

The ASTM standard, by its use of single character delimiters, leads to smaller message sizes. Assuming an RS232 interface transmits with 9.6 kbps (standard) over a serial line and up-to-date Ethernet networks transmit with (at least) 10Mbps. As long as the XML document is less than 1000 times bigger than the ASTM message, it will be transmitted faster. In fact, as can be seen from the previous example, the XML message would not normally be more than 10 times the size of the equivalent ASTM message. In addition, many conveyance mechanisms such as HTTP, support compression during transmission. Due to the high repetition rate of tags in an XML message, the approved longer descriptive tags that are a feature of XML do not present a significant transmission overhead.

5.6. Readability

ASTM uses single character delimiters to delimit fields and single characters to denote record types, while XML messages typically include descriptive tag names, that can be used to describe both element and attribute. As a result, a person attempting to understand the complete meaning of an ASTM message would need to refer to the instrument vendors document. An person reading a raw XML message could very easily, if the DTD was created with care, understand the content of the message.

6. Conclusion

Using XML instead of a proprietary ASTM format to structure ASTM 1394-91 messages doesn't change the semantic of the original data. Instead it changes the syntax dramatically and eases transfer and access to the data. Transfer advantages will be gained through the use of freely available web technology, whereas data-access is obtained by DOM and SAX. Despite the increase in message size for an XML message, the transmission speed and range would generally be improved because of the greater bandwidth and extended range of network technologies *"Higher, Faster, Further"* are attributes used in the sports and athletes area, but also fit perfectly in the medical XML scenarios:

- **Higher**
  Use high level programming languages and markup technologies to ease, speed up and fasten the access to data.
- **Faster**
  Cut down development time and therefore development costs. Maintenance work will also decrease by use of supporting development tools.
- **Further**
  Don’t rely on physical point-to-point connections, instead use Internet addresses. The use of the Intranet/Internet and it's transport protocols gives huge flexibility and transparency in connecting instruments to various computers.

7. Appendix

7.1. Document Type Definition (DTD)

```
<!-- ============================================================ -->
<!--                                                              -->
<!--      Name: ASTM 1394-91 DTD                                  -->
<!--   Version: 0.1                                               -->
<!--      Date: 11/09/1999                                        -->
<!-- Copyright: Benjamin Jung                                     -->
<!--                                                              -->
<!--    Editor:                                                   -->
<!--    Benjamin JUNG (TCD, <benjamin.jung@cs.tcd.ie>)            -->
<!--                                                              -->
<!--    Contributing editor:                                      -->
<!--    Damon BERRY (DIT, <dberry@docsee.kst.dit.ie>)             -->
<!--                                                              -->
<!--    Contributing authors:                                     -->
<!--                                                              -->
<!-- ============================================================ -->

<!ENTITY % Person 'ID*, Name?, Address?, Telephone*'>

<!ELEMENT ASTM
          ( MessageHeader?, Message+, MessageTerminator? )>
<!ATTLIST ASTM
            Designation    ( E1394 | CENTC251PT36 ) #REQUIRED
            AccessPassword CDATA                    #IMPLIED
            ProcessingID   ( P | T | D | Q )        #IMPLIED
            ControlID      CDATA                    #IMPLIED>

<!ELEMENT Message
          ( PatientInformation*, RequestInformation*, Scientific*,
            ManufacturerInformation? )
```

```
<!-- Message Header Record (ASTM 1394-91, Chapter 7)            -->
<!-- ============================================================ -->
<!ELEMENT MessageHeader
          ( Comment*, AccessPassword?, Sender+, Receiver,
            SpecialInstruction?, Version, DateTime )>

<!ELEMENT AccessPassword ( #PCDATA )>

<!ELEMENT Sender ( (Instrument | %Person;), Characteristics* )>

<!ELEMENT Instrument ( Label, Extension* )>
<ATTLIST  Instrument Type CDATA #IMPLIED>

<!ELEMENT Address ( Street?, City?, State?, Zip?, Country? )>

<!ELEMENT Receiver ( %Person; )>

<!ELEMENT Version ( #PCDATA )>

<!ELEMENT SpecialInstruction ( #PCDATA )>

<!ELEMENT DateTime ( #PCDATA )>
<!ATTLIST DateTime Type CDATA #REQUIRED>

<!ELEMENT ID ( #PCDATA )>
<!ATTLIST ID Type CDATA #IMPLIED>
```

```
<!ELEMENT Name ( Last, First?, Middle?, Suffix?, Title? )>

<!ELEMENT Street ( #PCDATA )>

<!ELEMENT City ( #PCDATA )>

<!ELEMENT State ( #PCDATA )>

<!ELEMENT Zip ( #PCDATA )>

<!ELEMENT Country ( #PCDATA )>

<!ELEMENT Telephone ( #PCDATA )>

<!ELEMENT Characteristics ( #PCDATA )>

<!ELEMENT Last ( #PCDATA )>

<!ELEMENT First ( #PCDATA )>

<!ELEMENT Middle ( #PCDATA )>

<!ELEMENT Suffix ( #PCDATA )>

<!ELEMENT Title ( #PCDATA )>
```

```
<!-- Patient Information Record (ASTM 1394-91, Chapter 8)       -->
<!-- ========================================================== -->
<!ELEMENT PatientInformation
          ( Comment*, %Person;, MothersMaidenName?,
            Birthdate?, Sex?, RaceEthnicOrigin?, Address?,
            AttendingPhysician*, Special*, Height?, Weight?,
            Diagnosis*, ActiveMedication*,  Diet?, Practice*,
            AdmissionDate?, DischargeDate?, Location?,
            ADCC*, Religion?, MaritialStatus?,
            IsolationStatus*, Language?, Hospital?, Dosage?,
            TestOrder* )>
<!ATTLIST PatientInformation
            AdmissionStatus ( OP | PA | IP | ER ) #IMPLIED>

<!ELEMENT MothersMaidenName ( #PCDATA )>

<!ELEMENT Birthdate ( #PCDATA )>

<!ELEMENT Sex ( #PCDATA )>

<!ELEMENT RaceEthnicOrigin ( #PCDATA )>

<!ELEMENT AttendingPhysician ( %Person; )>

<!ELEMENT Special ( #PCDATA )>

<!ELEMENT Height ( #PCDATA )>

<!ELEMENT Weight ( #PCDATA )>

<!ELEMENT Diagnosis ( #PCDATA )>
<!ATTLIST Diagnosis Type ( known | suspected) #IMPLIED>

<!ELEMENT ActiveMedication ( #PCDATA )>

<!ELEMENT Diet ( #PCDATA )>

<!ELEMENT Practice ( #PCDATA )>
```

```
<!ATTLIST AdmissionDate Status CDATA #IMPLIED>

<!ELEMENT DischargeDate ( #PCDATA )>

<!ELEMENT Location ( #PCDATA )>

<!ELEMENT ADCC ( #PCDATA )>
<!ATTLIST ADCC Nature CDATA #IMPLIED>

<!ELEMENT Religion ( #PCDATA )>

<!ELEMENT MaritialStatus ( #PCDATA )>

<!ELEMENT IsolationStatus ( #PCDATA )>

<!ELEMENT Language ( #PCDATA )>

<!ELEMENT Hospital ( Service, Institution )>

<!ELEMENT Service ( #PCDATA )>
<!ATTLIST Service ID CDATA #REQUIRED>

<!ELEMENT Institution ( #PCDATA )>
<!ATTLIST Institution ID CDATA #REQUIRED>

<!ELEMENT Dosage ( Category, SubGroup* )>

<!ELEMENT Category ( #PCDATA )>

<!ELEMENT SubGroup ( #PCDATA )>
```

```
<!-- Test Order Record (ASTM 1394-91, Chapter 9)                -->
<!-- ========================================================== -->
<!ELEMENT TestOrder
          ( Comment*, UniversalTestID, RequestDateTime?,
            Specimen?, OrderingPhysician?, Users?, Laboratory?,
            ResultsReportedDateTime?, InstrumentCharge?,
            InstrumentSectionID?, NosocomialInjectionFlag?,
            Result* )>
<!ATTLIST TestOrder
            Priority       ( S | A | R | C )            #IMPLIED
            ReportType     ( O | C | P | F | X | I | Y | Z | Q )
                                                        #IMPLIED>
<!ELEMENT UniversalTestID ( #PCDATA )>

<!ELEMENT Specimen
          ( ID, InstrumentID, Collection+,
            DangerCode?, RelevantClinicalInformation?,
            ReceivedDateTime?, Descriptor?, Type?, Source?,
            WardOfCollection?, Service?, Institution? )>
<!ATTLIST Specimen
          ActionCode ( C | A | N | P | L | X | Q ) #IMPLIED >

<!ELEMENT OrderingPhysician ( %Person; )>

<!ELEMENT Users ( AuxData* )>

<!ELEMENT Laboratory ( AuxData* )>

<!ELEMENT ResultsReportedDateTime ( #PCDATA )>

<!ELEMENT InstrumentCharge ( #PCDATA )>

<!ELEMENT InstrumentSectionID ( #PCDATA )>

<!ELEMENT NosocimialInjectionFlag ( #PCDATA )>
```

```
<!ELEMENT InstrumentID ( #PCDATA )>

<!ELEMENT Collection ( Collector?, DateTime+, Volume? )>

<!ELEMENT Volume ( #PCDATA )>

<!ELEMENT Collector ( %Person )>

<!ELEMENT DangerCode ( #PCDATA )>

<!ELEMENT RelevantClinicalInformation ( #PCDATA )>

<!ELEMENT ReceivedDateTime ( #PCDATA )>

<!ELEMENT Descriptor ( #PCDATA )>

<!ELEMENT Type ( #PCDATA )>

<!ELEMENT Source ( #PCDATA )>

<!ELEMENT WardOfCollection ( #PCDATA )>
```

```
<!-- Result Record (ASTM 1394-91, Chapter 10)                    -->
<!-- ========================================================== -->
<!ELEMENT Result
          ( Comment*, UniversalTestID, Value, ReferenceRange*,
            DOCInINV?, Identification?, DateTime* )>
<!ATTLIST Result
            Status ( C | P | F | X | I | S | M | R | N | Q | V )
                                                    #IMPLIED
            NatureOfAbnormality ( A | S | R | N )      #IMPLIED>

<!ELEMENT Value ( #PCDATA )>
<!ATTLIST Value
            Units CDATA #IMPLIED
            ResultAbnormal ( L | H | LL | HH | LLL | HHH | N | A |
                             U | D | B | W ) #IMPLIED>

<!ELEMENT ReferenceRange ( Value )>
<!ATTLIST ReferenceRange Type  ( upper | lower ) #REQUIRED>

<!ELEMENT DOCInINV ( #PCDATA )>

<!ELEMENT Identification ( InstrumentOperator?, Verifier? )>

<!ELEMENT InstrumentOperator ( #PCDATA )>

<!ELEMENT Verifier ( #PCDATA )>
```

```
<!-- Comment Record (ASTM 1394-91, Chapter 11)                   -->
<!-- ========================================================== -->
<!ELEMENT Comment ( #PCDATA )>
<!ATTLIST Comment ID     CDATA                #IMPLIED
                  Source ( P | L | I )        #REQUIRED
                  Type   ( G | T | P | N | I ) #REQUIRED >
```

```
<!-- Request Information Record (ASTM 1394-91, Chapter 12)       -->
<!-- ========================================================== -->
<!ELEMENT RequestInformation
          ( Comment*, UniversalTestID?, RangeID, RequestDateTime*,
            Physician*, AuxData* )>
```

```
            Status ( C | P | F | X | I | S | M | R | A | N | O |
                     D ) #REQUIRED>

<!ELEMENT RangeID ( PatientID?, SpecimenID?, AuxData*)>
<!ATTLIST RangeID Type ( start | end ) #REQUIRED>

<!ELEMENT PatientID ( #PCDATA )>
<!ATTLIST PatientID Type   ( start | end | all ) #IMPLIED
                    Source CDATA                #IMPLIED>

<!ELEMENT SpecimenID ( #PCDATA )>
<!ATTLIST SpecimenID Type   ( start | end | all ) #IMPLIED>

<!ELEMENT AuxData ( #PCDATA )>
<!ATTLIST AuxData Type CDATA #IMPLIED>

<!ELEMENT RequestDateTime ( #PCDATA )>
<!ATTLIST RequestDateTime
            Type   ( begin | end ) #REQUIRED
            Nature ( S | R )       #REQUIRED>

<!ELEMENT Physician ( %Person; )>

<!-- ========================================================= -->
<!-- Message Terminator Record (ASTM 1394-91, Chapter 13)      -->
<!-- ========================================================= -->
<!ELEMENT MessageTerminator ( Comment* )>
<!ATTLIST MessageTerminator
            Code ( Nil | N | R | E | Q | I | F ) #REQUIRED>
```

```
<!-- Scientific Record (ASTM 1394-91, Chapter 14)              -->
<!-- ========================================================= -->
<!ELEMENT Scientific
          ( Comment*, AnalyticalMethod?, Instrumentation,
            Reagents*, UnitsOfMeasure*, QualityControl?,
            SpecimenDescriptor?, SpecimenID?, Container?, Analyte?,
            Result?, CollectionDateTime?, ResultDateTime?,
            AnalyticalProcessingSteps?, Patient? )>

<!ELEMENT AnalyticalMethod ( #PCDATA )>

<!ELEMENT Instrumentation ( EMPTY )>
<!ATTLIST Instrumentation
            ManufacturerCode CDATA #REQUIRED
            InstrumentCode   CDATA #REQUIRED>

<!ELEMENT Reagents ( #PCDATA )>

<!ELEMENT UnitsOfMeasure ( #PCDATA )>

<!ELEMENT QualityControl ( #PCDATA )>

<!ELEMENT SpecimenDescriptor ( #PCDATA )>

<!ELEMENT Container ( #PCDATA )>

<!ELEMENT Analyte ( #PCDATA )>

<!ELEMENT ResultValue ( #PCDATA )>
<!ATTLIST ResultValue Unit CDATA #REQUIRED>

<!ELEMENT ResultDateTime ( #PCDATA )>

<!ELEMENT AnalyticalProcessingSteps ( #PCDATA )>

<!ELEMENT Patient ( Diagnosis?, Birthdate?, Sex?, RaceEthnicOrigin? )>
```

```
<!-- Manufacturer Information Record (ASTM 1394-91, Chapter 15) -->
<!-- ========================================================== -->
<!ELEMENT ManufacturerInformation ( Comment*, AuxData* )>
```

7.2. Examples

7.2.1. Scenario 1: ASTM 1394-91

ASTM 1394-91

This is an example from the 'ASTM Designation: E 1394-91' document.

Name: Results from Given Ordered Test Selections Shown in Various Formats

Reference: Figure 5c, Page 14

Size: 1.236 Bytes

```
H|\^&||PSWD|Harper Labs|2937 Southwestern Avenue^Buffalo^NY^73205||319 412-
9722||||P|2.5|19890314<CR>
        P|1|2734|123|306-87-4587|BLAKE^LINDSEY^ANN^MISS<CR>
                C|1|L|Notify IDC if tests positive|G<CR>
                O|1|032989325||^^^BUN|R<CR>
                        R|1|^^^BUN|8.71<CR>
                                C|1|I|TGP^Test Growth Positive|P<CR>
                                C|2|I|colony count >10,000|P<CR>
                O|2|032989325||^^^ISE|R<CR>
                        R|1|^^^ISE^NA|139\mEq/L<CR>
                        R|2|^^^ISE^K|4.2\mEq/L<CR>
                        R|3|^^^ISE^CL|111\mEq/L<CR>
                O|3|032989325||^^^HDL|R<CR>
                        R|1|^^^HDL|70.29<CR>
                O|4|032989325||^^^GLU|R<CR>
                        R|1|^^^GLU|92.98<CR>
                                C|1|I|Reading is Suspect|I<CR>
        P|2|2462|158|287-17-2791|POHL^ALLEN^M.<CR>
                O|1|032989326||^^^LIVER|S<CR>
                        R|1|^^^LIVER^AST|29<CR>
                        R|2|^^^LIVER^ALT|50<CR>
                        R|3|^^^LIVER^TBILI|7.9<CR>
                        R|4|^^^LIVER^GGT|29<CR>
                O|2|032989326||^^^GLU|S<CR>
                        R|1|^^^GLU|91.5<CR>
        P|3|1583|250|151-37-6926|SIMPSON^ALBERT^MR<CR>
                O|1|032989327||^^^LIVER|R<CR>
                        R|1|^^^AST|28<CR>
                        R|2|^^^ALT|49<CR>
                        R|3|^^^TBILI|7.3<CR>
                        R|4|^^^GGT|27<CR>
                O|2|032989327||^^^CHEM12|R<CR>
                        R|1|^^^CHEM12^ALB-G|28<CR>
                        R|2|^^^CHEM12^BUN|49<CR>
                        R|3|^^^CHEM12^CA|7.3<CR>
                        R|4|^^^CHEM12^CHOL|27<CR>
                        R|5|^^^CHEM12^CREAT|4.2<CR>
                        R|6|^^^CHEM12^PHOS|12<CR>
                        R|7|^^^CHEM12^GLUHK|9.7<CR>
                        R|8|^^^CHEM12^NA|138.7<CR>
                        R|9|^^^CHEM12^K|111.3<CR>
                        R|10|^^^CHEM12^CL|6.7<CR>
                        R|11|^^^CHEM12^UA|7.3<CR>
                        R|12|^^^CHEM12^TP|9.2<CR>
L|1<CR>
```

XML version

7.2.2. Scenario 2: CEN/TC251 PT36

CEN/TC251 PT36

This is an example from the 'CEN/TC251 PT36' document.

Name: Bi-directional communication with Order and Result Queries

Reference: WGIV/N99-12, Chapter A.3.5, Page 26

Size: 28 Bytes / 348 Bytes

```
(LIS)
H|\^&
Q|1|^ALL|||||||||F
L|1|N
```

```
(AI)
H|\^&
P|1|02095217784||OLSEN^CARL||19520902|M
O|1|99042123
R|1|^^^HB|14.5|g/dL||||F||BWD||19990316090200
R|1|^^^ERYT|6.5|10^12/L||||F||BWD||19990316090200
R|1|^^^LEUK|2.2|10^9/L||<||F||BWD||19990316090200
P|2|11126429753||DOE^WILLIAM||19641211|M
O|1|99046341
R|1|^^^HB|13.2|g/dL||||F||AS||19990316090800
R|1|^^^TROMB|354|10^9/L||||F||AS||19990316090800
L|1|N
```

XML version

Size: 277 Bytes (**989%**) / 2294 Bytes (**659%**)

```
<?xml version="1.0"?>

<!DOCTYPE ASTM SYSTEM "ASTM1394-91.dtd">

<ASTM Designation='CENTC251PT36'>
  <Message>
    <RequestInformation Status='F'>
      <RangeID>
        <PatientID Type='all'/>
      </RangeID>
    </RequestInformation>
  </Message>
  <MessageTerminator Code='N'/>
</ASTM>
```

```
<?xml version="1.0"?>

<!DOCTYPE ASTM SYSTEM "ASTM1394-91.dtd">
```

```
<Message>
  <PatientInformation>
    <ID Type='PracticeAssigned'>02095217784</PatientID>
    <Name>
      <First>Carl</First>
      <Last>Olsen</Last>
    </Name>
    <Birthdate>19520902</Birthdate>
    <Sex>M</Sex>
  </PatientInformation>
  <TestOrder>
    <UniversalTestID>99042123</UniversalTestID>
    <Result Status='F'>
      <UniversalTestID>HB</UniversalTestID>
      <Value Units='g/dL'>14.5</Value>
      <Identification>
        <InstrumentOperator>BWD</InstrumentOperator>
      </Identification>
      <DateTime Type='testComleted'>19990316090200</DateTime>
    </Result>
  </TestOrder>
    <Result Status='F'>
      <UniversalTestID>ERYT</UniversalTestID>
      <Value Units='10^12/L'>6.5</Value>
      <Identification>
        <InstrumentOperator>BWD</InstrumentOperator>
      </Identification>
      <DateTime Type='testComleted'>19990316090200</DateTime>
    </Result>
    <Result Status='F'>
      <UniversalTestID>LEUK</UniversalTestID>
      <Value Units='10^9/L'>2.2</Value>
      <Identification>
        <InstrumentOperator>BWD</InstrumentOperator>
      </Identification>
      <DateTime Type='testComleted'>19990316090200</DateTime>
    </Result>
  </TestOrder>
</Message>
<Message>
  <PatientInformation>
    <ID Type='PracticeAssigned'>11126429753</PatientID>
    <Name>
      <First>William</First>
      <Last>Doe</Last>
    </Name>
    <Birthdate>19641211</Birthdate>
    <Sex>M</Sex>
  </PatientInformation>
  <TestOrder>
    <UniversalTestID>99046341</UniversalTestID>
    <Result Status='F'>
      <UniversalTestID>HB</UniversalTestID>
      <Value Units='g/dL'>13.2</Value>
      <Identification>
        <InstrumentOperator>AS</InstrumentOperator>
      </Identification>
      <DateTime Type='testComleted'>19990316090800</DateTime>
    </Result>
    <Result Status='F'>
      <UniversalTestID>TROMB</UniversalTestID>
      <Value Units='10^9/L'></Value>
      <Identification>
        <InstrumentOperator>AS</InstrumentOperator>
      </Identification>
      <DateTime Type='testComleted'>19990316090800</DateTime>
    </Result>
  </TestOrder>
```

```
  <MessageTerminator Code='N'/>
</ASTM>
```

7.3. Index

7.4. Bibliography

[ASTM91] ASTM Designation: E 1394 – 91, *Standard Specification for Transferring Information Between Clinical Instruments and Computer Systems*, American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, U.S.A.

[Bos96] Bosak, Jon, *XML, Java, and the Future of the Web*, in: Conolly, Dan, World Wide Web Journal: *XML – Principles, Tools, and Techniques*, O'Reilly, Volume 2, Issue 4, Fall 1997, 219:227.

[CEN99] CEN/TC251 Homepage, http://www.centc251.org/.

[Cor99] CorbaMed Homepage, http://www.omg.org/homepages/corbamed/.

[CPT99] *Clinical Analyser Interfaces to Laboratory Information Systems*, First Working Document (FWD), CEN/TC 251 WG IV PT36, November 1999.

[HIG99] The Dublin Health Informatics Group Homepage, http://www.cs.tcd.ie/HIG/.

[HL99] Health Level Seven (HL7) Homepage, http://www.hl7.org/.

[JAA99] Jung, B., Austin, T., Andersen, E., *SynXML DTD (version 1.12)*, not publicly available at the moment, September 1999.

[MaML99] Ion, P., Miner, R., *Mathematical Markup Language (MathML™) 1.01 Specification*, http://www.w3.org/TR/REC-MathML/, W3C recommendation 7-July-1999.

[Meg98] Megginson, D., *SAX 1.0: The Simple API For XML*, http://www.megginson.com/SAX/.

[Syn99] SynEx Homepage, http://www.gesi.it/synex/.

[W3C94] World Wide Web Consortium Homepage, http://www.w3c.org/.

[Xml98] Bray, T., Paoli, J., Sperberg-McQueen, C. M., *Extensible Markup Language (XML) 1.0*, http://www.w3.org/TR/1998/REC-xml-19980210, W3C Recommendation 10-February-1998.