AN IMPLEMENTATION OF DYNAMIC DATA ACQUISITION MEASUREMENTS

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ABSTRACT

As data acquisition systems evolve and begin utilizing new avenues of acquisition such as Ethernet, an entirely new range of flight test capabilities become available. These new capabilities, defined by acquisition, monitoring, and varying of test measurements, enhance previous operation as they can now be realized during flight. Achieving such high levels of integration between ground station and test vehicle involves complex network protocols. Implementing such systems from scratch would be a time consuming and costly proposition. Fortunately, employing Internet protocols (TCP/IP) over Ethernet provides a cornucopia of readily available technology. Using state-of-the-art integration techniques, modern data acquisition systems can leverage years of proven technology offered by the Internet Engineering Task Force (IETF) and the World Wide Web Consortium (W3C).

This paper discusses an implementation of dynamic data acquisition measurements for use in network data acquisition systems. The methodology used to determine whether or not a measurement can and should be variable during a flight test is examined in detail along with a discussion of the advantages of dynamically varying flight test measurements. Finally, an implementation is presented which successfully integrates Internet protocols with modern flight test equipment using the techniques described above for dynamic data acquisition measurements.

KEY WORDS

Dynamic Measurements, Network Acquisition, HTTP, DHTML, XML, XSLT, AJAX

INTRODUCTION

The process of configuring data acquisition systems for flight test has historically been a static process. A flight test engineer typically creates a detailed data acquisition configuration using the instrumentation vendor's system configuration. This configuration is converted into a set of instructions that is programmed into the acquisition hardware prior to flight. Once the system has been programmed it remains in a fixed state, with all specified measurements persistent until the hardware is reprogrammed on the ground after the flight test has concluded.

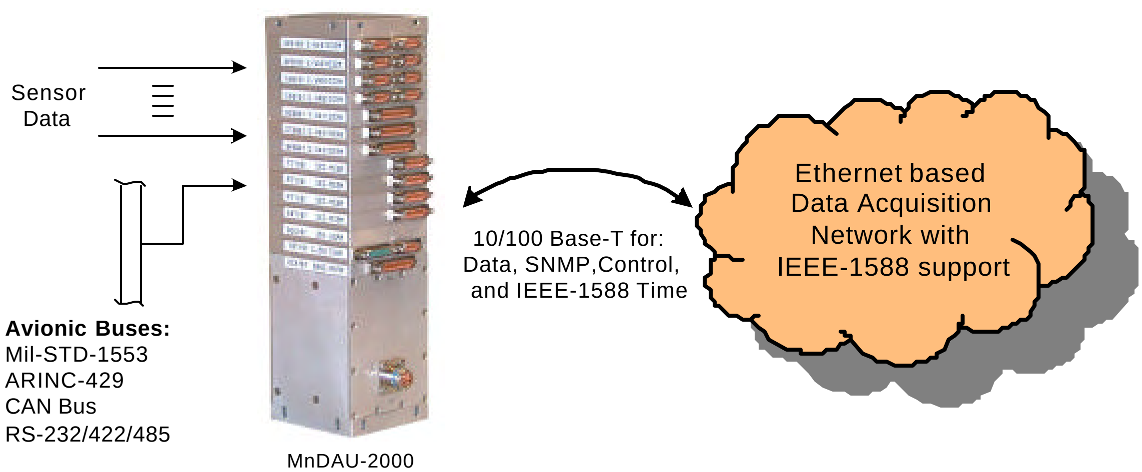
As data acquisition systems evolve and begin utilizing new avenues of acquisition such as Ethernet, an entirely new range of flight test capabilities become available. These new capabilities, defined by acquisition, monitoring, and varying of test measurements, enhance previous operation as they can now be realized during flight. Newer web technologies such as DHTML, XSLT, and AJAX can enable network acquisition systems to respond dynamically to requests from instrumentation engineers during flight. Using this increased flexibility, new types of flight tests can be conducted and the entire process of flight test can be accelerated and performed in a more cost effective manner.

This paper discusses an implementation of dynamic data acquisition measurements for use in network data acquisition systems. The methodology used to determine whether or not a measurement can and should be variable during a flight test is examined in detail along with a discussion of the advantages of dynamically varying flight test measurements. Finally, an implementation is presented which successfully integrates Internet protocols with modern flight test equipment using the techniques described above for dynamic data acquisition measurements.

NETWORK-BASED DATA ACQUISITION UNIT ARCHITECTURE

A Network Data Acquisition Unit (nDAU) is a system that conditions and acquires multiple input sensor channels with similar or dissimilar data types. The nDAU combines these input channels into data packets for transmission over the network fabric. The network interface also provides the unit with a gateway for setup and configuration, SNMP status and control, and time synchronization using the IEEE-1588 time standard. The unit acquires data from accelerometers, strain gages, various temperature sensors, pressure sensors, synchro/resolver sensors, LVDT, discrete signals, video, and many different types of avionics buses. Acquired IEEE-1588 time is distributed within the acquisition unit for time tagging sensor data and avionics bus data. Time can also be used to trigger time dependent events, such as simultaneous sampling, within the acquisition unit or across multiple acquisition units in the network.

Figure 1. Network Data Acquisition Unit



DYNAMIC ACQUISITION MEASUREMENTS

In traditional data acquisition systems, the configuration of the flight test instrumentation remains static over the course of a given flight test. Programming acquisition systems is typically done over a wired connection between a port on the master controller of the acquisition system and a PC that is running the instrumentation vendor's configuration software. Prior to programming the system, the test configuration must be created and compiled into loader files, which often consist of low-level hexadecimal instructions. After the instrumentation situation has been programmed, the programming cable is removed and the system is ready for data acquisition.

If a change to the configuration is required, the configuration must be modified and recompiled, the cable must be reconnected, and the system must be reprogrammed manually. As a result, it has historically been impossible to modify an acquisition system's configuration during an actual flight test. However, with the advent of network based acquisition systems, it becomes possible to vary measurements dynamically in flight.

BENEFITS

The ability to dynamically vary measurements in flight provides many benefits. The use of dynamic measurements can significantly reduce the cost of flight testing new aircraft. Consider the scenario where engineers in a control room who are telemetering data from a flight test via RF discover that an acquisition measurement, such as a gain, is programmed incorrectly. Instead of having to land the aircraft, reprogram its acquisition hardware, and take off again, the changes can quickly be made in flight.

Gain values and other similar settings can be corrected and updated in response to flight conditions without interrupting the test. For example, if a measured signal has unexpected amplitude, the corresponding analog conditioning module's gain can be adjusted so that the acquisition system properly captures the measurement. New tests can also be derived during a flight test based upon data that is acquired during previous parts of the test. The data acquisition hardware can be reprogrammed accordingly and the modified test can continue. This increased flexibility allows the data acquisition system to quickly adapt and respond to the changing needs of the flight test. This makes the entire data acquisition process more flexible and can greatly reduce the cost and time needed to flight test an aircraft.

Many acquisition modules have settings that apply to all data channels. As a result, multiple instances of such modules must be installed in the acquisition system if a flight test requires different values of this setting during a flight. Using dynamic measurements, only a single module is needed during a test since the value of such global settings (i.e. settings that affect all data channels) can be varied during flight. The usage of dynamic measurements in the abovementioned scenario actually eliminates the need for additional acquisition hardware.

DYNAMIC PARMAETER SELECTION CRITERIA

An analysis of the different types of programmable settings must be performed since not all data acquisition measurements can be varied dynamically. Some measurements must remain persistent while other measurements provide no additional capabilities when varied dynamic. Only certain measurements can and should be varied dynamically.

The simplest examples of parameters that must remain static are those that establish the core structure of the sampling format, including the sampling resolution, and the frame structure. Other such parameters that affect the core structure of the data acquisition system must likewise remain persistent and cannot be configured dynamically. In addition, some settings such as input source are fixed because they are determined by the physical wiring of the acquisition system.

As previously mentioned, changing flight conditions sometimes warrant a change to the acquisition system. One such example is the position of the time stamp on the output video, which is a dynamically variable measurement. An engineer may want to vary the position of the time stamp differently during different tests so as not to obscure the salient regions of the video for that particular test.

Another key usage of dynamic measurements is to change the mode of the acquisition system or the mode of a particular acquisition module. Great care must be taken when using dynamic measurements since the ramifications of changing mode are significant. For example, a synchro / resolver acquisition module measurement cannot be changed dynamically since there are too many interdependencies. Once the mode is switched, the entire character of the acquisition module is changed. The user must carefully consider these implications and such analysis often requires the graphical user interface of the instrumentation vendor's system configuration software. However, calibration is one such mode switch that can safely be made in flight and is fully supported using this dynamic measurement mechanism. Sensors can also be dynamically calibrated by varying strain gauge offset and trim count values in flight.

ENABLING TECHNOLOGIES

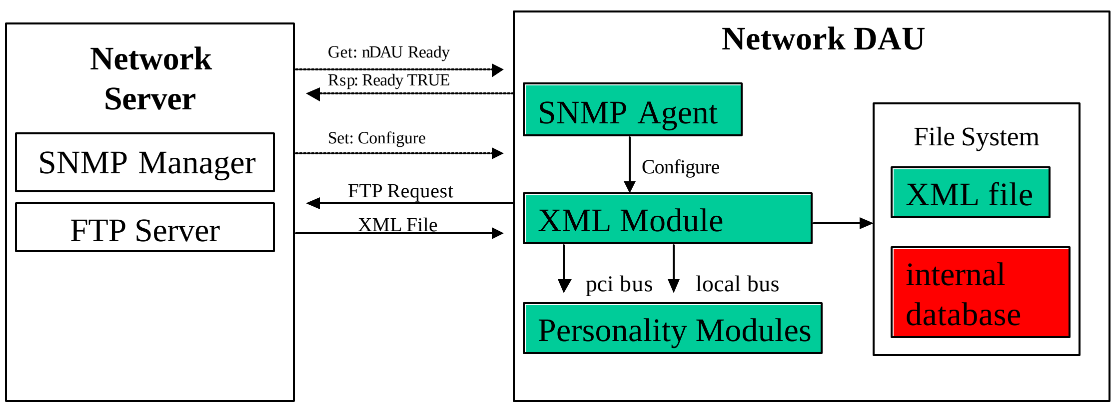
The bond between ground station and test vehicle may be described quite naturally as a client-server relationship. Broadly described as the web, global networks rely on the most widely accepted client-server protocol on earth, the Hypertext Transfer Protocol (HTTP). It is easy to see how HTTP quickly provides the reliable communications mandated by flight test. But HTTP merely facilitates the request/response paradigm for data exchange. To be useful, both parties must agree on the format of the data itself. Typical exchanges on the web between an HTTP client (commonly known as a browser) and a server involve documents formatted with the Hyper Text Markup Language (HTML). HTML is used exclusively for the exchange of static data. Unfortunately, HTML is not well suited for the dynamic environment of flight test. Fortunately, the Internet community has already risen to the challenges of dynamic data. New data formats such as Dynamic HTML (DHTML), eXtensible Markup Language (XML), XML Schema Language (XSL), and XSL Transformations (XSLT) provide exactly the type of flexibility demanded by dynamic environments. Building upon these formats, modern browsers now employ advanced techniques for data exchange such as Asynchronous JavaScript and XML (Ajax). A combination of new Internet technologies can be employed to dramatically influence the future of flight test.

APPLIED TECHNOLOGY IN THE NETWORK DATA AQUISITION UNIT

Traditional data acquisition systems require configuration prior to flight test. The nDAU is no different. However, it is distinguished by its comprehensive support for standard IP protocols. This includes, but is not limited to SNMP, FTP and HTTP. Combined with support for the enabling technologies described above, these protocols empower network DAUs with dynamic configuration capability.

As depicted in Figure 2, the nDAU is provisioned over an Ethernet interface by XML documents. The process, called static provisioning, supplies the nDAU with all information required for a complete configuration. Dynamic measurements are considered a subset of the static configuration and are included in the XML file.

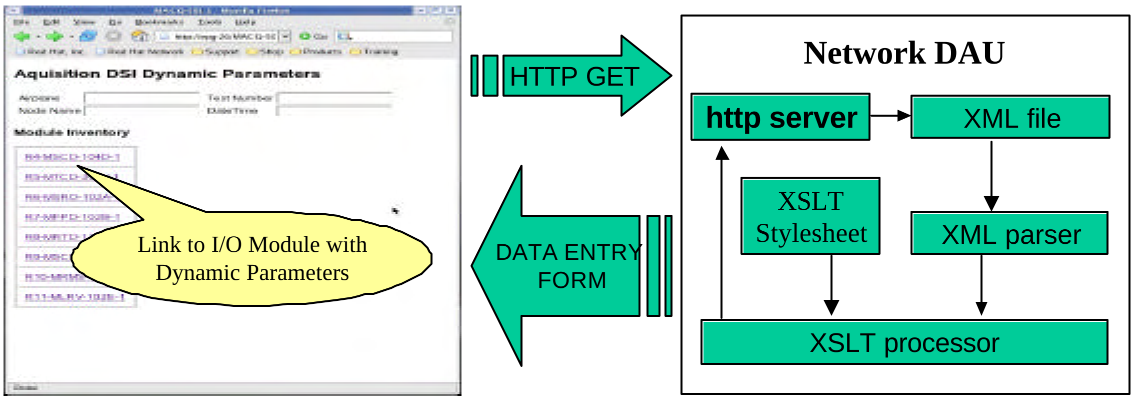
Figure 2. Static Provisioning Process



The XML file itself is created by a separate process. Typically, the file creation process involves a PC running the instrumentation vendor's system configuration software. This software provides all the functionality required to create appropriate XML files including data entry and compilation for both measurements and I/O formats. The resulting XML files contain human readable settings, as well as compiled machine readable settings and formats.

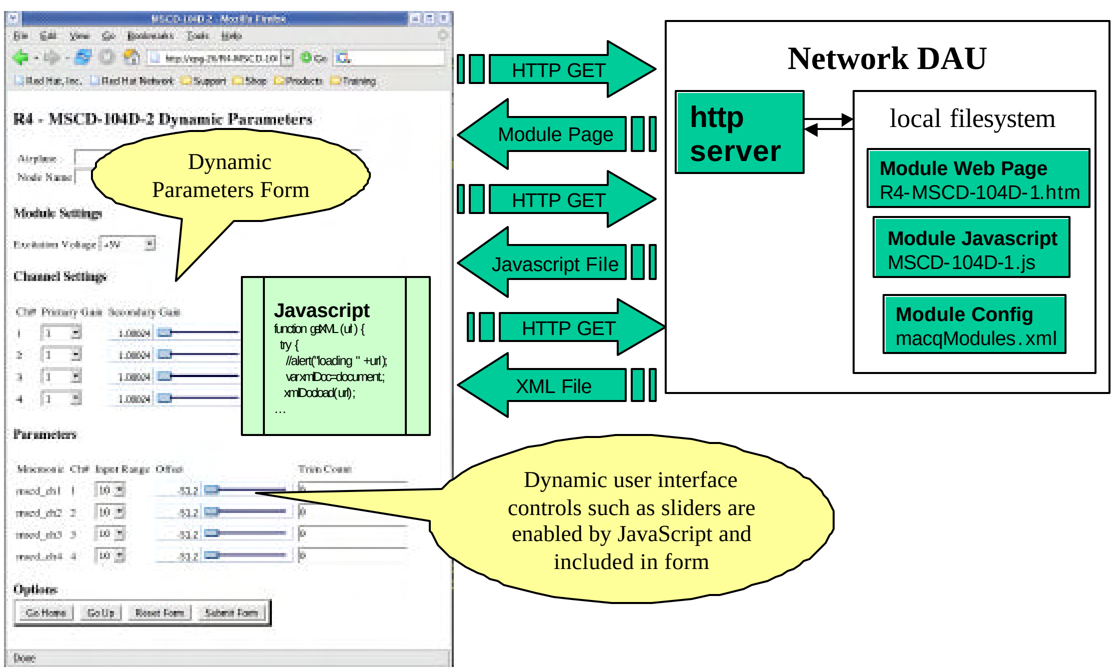
The XML-based static configuration technique leads quite naturally to the dynamic configuration process. In the static provisioning phase, the nDAU acts as a client to both SNMP and FTP servers. In the dynamic phase, its role is temporarily reversed and the nDAU acts as the server to web browser clients. The nDAUs run a specialized HTTP service to deliver files upon request. The HTTP service combines a server-side XML parser and XSLT processor to create dynamic web pages. Each page conforms to a common user interface, complete with a form for modifying dynamic measurements along with submission and navigation buttons. The nDAU always stores a copy of its current configuration in a local XML file. As depicted in Figure 3, when the link to an I/O module with dynamic measurements is accessed through a web browser, an HTTP GET request is generated and sent to the nDAU. In response, the nDAU combines its XML file with XSLT stylesheets to deliver the appropriate data entry form.

Figure 3. Dynamic Form Creation Process



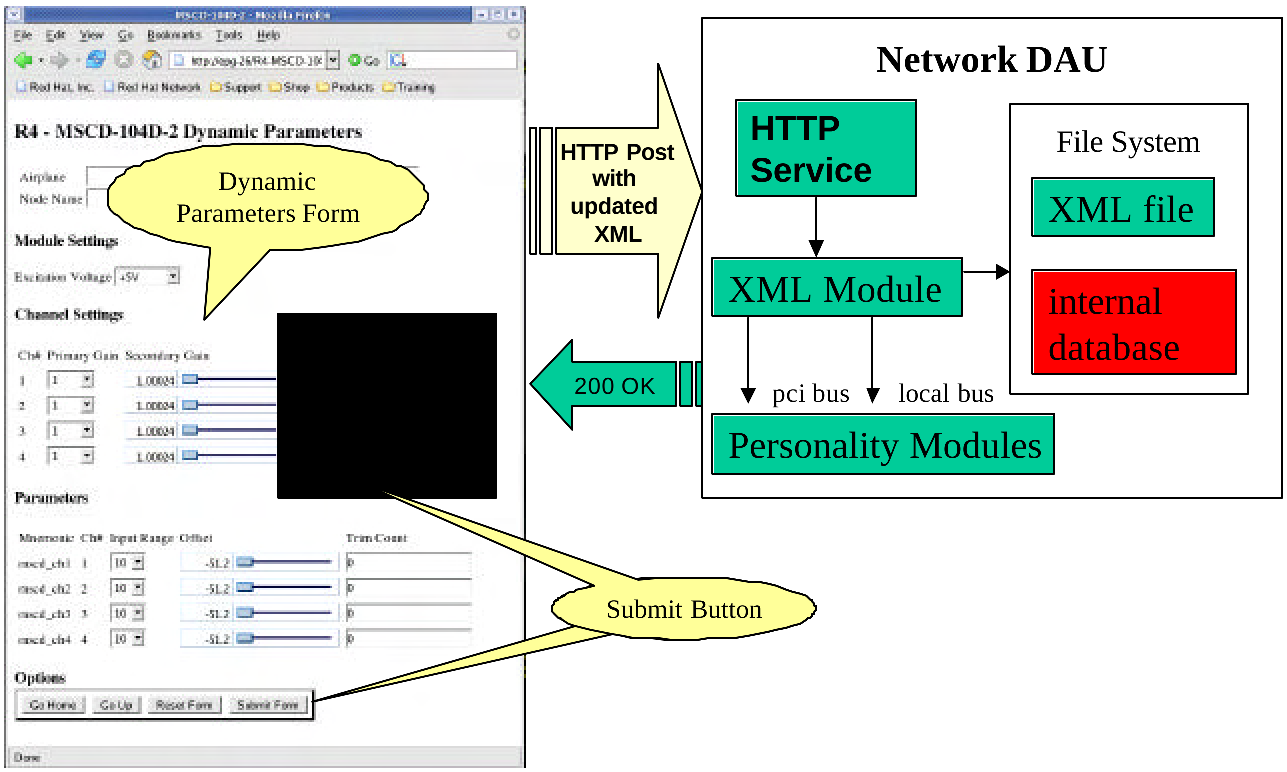
As shown in Figure 4, the resulting dynamic web page contains a mixture of external JavaScript, XML and XHTML. Using the DOM, the form is customized locally through JavaScript to reflect and enforce the boundaries of any given measurement. Through the use of JavaScript and CSS, the form may include dynamic user interface controls such as sliding bars and content sensitive fields. As the user modifies the form, JavaScript may update it in response to the current dataset. In this way, the form interacts more like a desktop application than a traditional static web page.

Figure 4. Interactive Data Entry Form



To accept modifications, the submit button is used. When clicked, JavaScript validates the form and confirms any changes with the user. Once confirmed, JavaScript uses the DOM to modify the XML, updating the dynamic measurement settings. The resulting XML file conforms to the same rules applied to the original static configuration file. With the updated XML, the web browser sends an HTTP POST message to the nDAU. The nDAU role flips again, back to client, and the XML file is processed as if it were a static configuration file. Figure 5 depicts the submission of a modified dynamic measurement form.

Figure 5. Submission Process



The diagrams used in this example depict a small portion of the power provided by this emerging technology. Many I/O modules in this system support dynamic measurements. Figure 6 shows a subset of those modules and the dynamic measurements supported.

Figure 6. Sample Dynamic Measurements and Modules

MSCD-104D-2		
Measurement Name	Range or variable	Scope
Excitation	0, +5 VDC, +10 VDC	Per Module
Primary Gain	1, 10, 100, 1000	Per Channel
Secondary Gain	1 to 10 in 3000 steps	Per Channel
Offset	±50%	Per Channel
Trim Counts	±4096	Per Channel
Input Range	10, 20 VDC	Per Channel

MTCD-208V-1		
Measurement Name	Range or variable	Scope
CJC Sensor Offset	-7.82 to 7.76 in 256 steps	Per Module
Scale	Full, Half, Quarter	Per Channel
Open Test	Enable, Disable	Per Channel
Lower Limit	IAW T/C tables	Per Channel
Upper Limit	IAW T/C tables	Per Channel

MLRV-102E-2		
Measurement Name	Range or variable	Scope
Excitation Frequency	Disabled, 400 Hz to 10000 Hz	Per Module
Excitation Amplitude	2.00 to 6.00 Vrms in 2174 steps	Per Channel
Reference Voltage	1.00 to 10.00 V in 1844 steps	Per Channel
L/RVDT Max Voltage	1.00 to 10.00 V in 3686 steps	Per Channel

MPSS-101-1		
Measurement Name	Range or variable	Scope
Primary Gain	1, 2, 4, 8	Per Module
Sample Averaging	1, 2, 4 Sample(s)	Per Module
Range Select	Full Scale, Half Scale, Quarter Scale	Per Channel
Offset	Not Applicable For Full Scale, ±50% For Half Scale, ±153.6% For Quarter Scale	Per Channel

CONCLUSION

Data acquisition systems are advancing at a rapid pace by melding emerging web technologies with traditional acquisition techniques. Systems that have traditionally been statically configurable are becoming dynamic. Ethernet is being used for data acquisition and networks of acquisition units are replacing conventional systems. The network acquisition system and the corresponding dynamic measurement mechanism presented in this paper provide great flexibility to engineers. By extending this system, engineers can realize the goal of having a truly dynamic and fully configurable system to meet all of their data acquisition needs.

GLOSSARY

eXtensible Markup Language (XML)
XML is a W3C recommended general-purpose markup language capable of describing many different kinds of data. It is a simplified form of the Standardized General Markup Language (SGML). In other words, XML is a document format. It can be used to carry content for web pages, books, articles, manuals, etc. All types of electronic files containing human readable content can be shared through the use of XML. In its more advanced applications, XML can be used to describe more specialized markup languages. Derivative languages such as, XHTML, XML Schema, XSL,

and MathML are all based on XML. The flexible nature of XML has led it to become an extremely popular document format. XML parsers are readily available on most computing platforms.

eXtensible Stylesheet Language Transformations (XSLT)
The eXtensible Stylesheet Language (XSL) is a family of W3C languages allowing one to describe how XML files may be (re)formatted or transformed. XSL Transformations (XSLT) are the member of this family that translates XML files from one format to another. The input to an XSLT processor is always an XML file and XSLT stylesheet. The output can be any text file and does not necessarily have to be XML-based. Many modern day Internet browsers have built-in XSLT processors. Both client (web browser) and server sides (web server) can take advantage of XSLT processing. Any XML file that references an XSLT stylesheet can be automatically transformed into an HTML document for display.

Cascading Style Sheets (CSS)
Though not required for the presentation of XML data, Cascading Style Sheets provide the means to display the data with formatting. CSS is specified by the W3C. However, it is not an XML format. CSS based stylesheets are far simpler than XSLT stylesheets, but can have a powerful impact. These stylesheets define rules for data elements, each containing a set of display properties. As data elements are processed by a web browser, the appropriate display properties are applied. The resulting web pages have a far richer appearance than those containing traditional HTML.

Dynamic HTML (DHTML)
DHTML is not a recommendation or standard by itself, but rather a term that implies the use of multiple technologies to create interactive web sites. Creating web pages dynamically is made possible by the use of XML and XSLT. Making those pages interactive is enabled by technologies such as JavaScript and the Document Object Model (DOM).

Document Object Model (DOM)
The Document Object Model is a set of W3C recommendations. Together, they define a platform and language neutral programming interface that facilitates dynamic access and updates to the content, structure, and style of documents. Documents can be processed and results incorporated back into the presented page. The DOM view of a document is that of a tree of nodes. This view leads to a natural representation of XML documents. Most modern day browsers provide Javascript bindings to XML file content through the use of the DOM.

JavaScript
JavaScript™ is a standardized scripting programming language supported by most modern day web browsers. Despite the name, the language syntax is more similar to the C programming language than Java. JavaScript is often used within web pages to provide a richer user interface than that provided by static HTML. These applications generally take advantage of the DOM to manipulate web page content and internal browser objects.

Asynchronous JavaScript and XML (Ajax)
Ajax is the term put forth in an article by Jesse James Garrett for a technique that employs multiple technologies to develop interactive web applications. The technique has sparked many popular web

sites such as Google Maps. Ajax incorporates XML, XSLT files, and the DOM using JavaScript to bind all of this technology together.

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