INET MDL FROM A USER PERSPECTIVE

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ABSTRACT

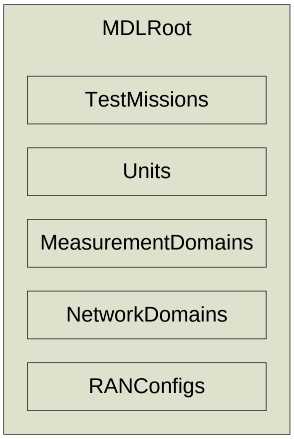
During concept development of a new core analog acquisition system, Boeing Flight Test identified a need for a set of more efficient and cost effective Test System configuration and setup tools, preferably supported by an industry standard. Like most big test organizations we support years and years of legacy tools. Currently all new functions are required to be hosted within the legacy environment. Legacy environments tend to be big, slow, and expensive to update and maintain. In searching for a better way to do business, we evaluated iNET/MDL, IHAL, and XidML standards. For a variety of reasons which will be discussed in this paper, we have chosen to focus on the iNET MDL standard as the means for producing a new vendor-agnostic, simpler and more cost-effective system interface. Our initial evaluation uncovered several gaps in the data structure and concept of operations. The iNET community acknowledged the gaps and encouraged us to work with them to enhance the standard. The iNET MDL concept of operations also represents a significant operational paradigm shift. Through an industry users group, we have been working to refine and enhance the data structures and concept of operations. This paper will describe the journey from a demonstration environment to an enterprise implementation of MDL as it relates to data acquisition setup and control.

INTRODUCTION

iNET is a standard being developed by the US DoD for use on US test ranges. The iNET standard includes the Metadata Description Language (MDL), a schema-controlled XML language to define the information necessary to describe a test scenario in an iNET system, including one or more test articles and locations. While its scope is quite comprehensive, Boeing's area of interest at this time is focused on a smaller piece of the language.

SCOPE OF INET MDL

iNET MDL encompasses the entire description of a test system, including the test-specific information, the entire data system network, and the telemetry system. As shown in the figure, this information is contained within several top-level elements: TestMissions, Units, MeasurementDomains, NetworkDomains, and RANConfigs.



The TestMissions element contains information describing a particular test. Units contains descriptions of derived units based on SI Units. Measurement Domains contains all of the information associated with measurement requirements and the transport of measurements within the system. NetworkDomains contains the description of one or more networks associated with the test article, as well as descriptions of each component of the network. RANConfigs contains information associated with the telemetry system.

While the MDL schema as a whole offers interesting possibilities for future enhancements, Boeing is at this time primarily concerned with those elements that are required for the setup of a data acquisition device.

USER BENEFITS OF INET MDL

iNET MDL is one of several attempts to define a language for vendor-agnostic setup and configuration of an acquisition system. Other existing standards include the Instrumentation Hardware Abstraction Language (IHAL) and eXtensible instrumentation definition Markup Language (XidML). Both have features that are attractive, but neither has as broad a scope as MDL. The potential for expansion of MDL usage to other areas of the flight test system make MDL stand out. In addition, MDL offers a new paradigm for setup and configuration that offers potential benefits.

IHAL is focused heavily on description of the hardware and its settings. Descriptions of measurements is borrowed from the MDL schema, but there is not a direct correlation between the measurement requirements and the device configuration. IHAL also defines an API through which vendor constraints and rules can be communicated. XidML describes the complete system as well as the measurements, and also offers a flexible file-based method of describing the vendor constraints and rules; however, it also does not offer a way to correlate measurement requirements to device setup. MDL is different in that it focuses heavily on measurement requirements, and provides the ability for a device to define a setup that will meet the user’s stated requirements. It currently has some gaps which will be discussed in more detail in this paper, but once those are addressed there is a great potential for increasing the efficiency and quality of the setup and acquisition system while also decreasing the implementation and maintenance costs.

INITIAL GAP ANALYSIS

In late 2013, when we began seriously looking into MDL as a possible solution for us, we performed a gap analysis to see how well it fit with our needs for describing an analog acquisition system setup and measurement configuration. At the same time, we explored the current iNET Concept of Operations to see how well it fit with our concept of operations. We identified some questions and some potential issues in both categories.

INET CONCEPT OF OPERATIONS

The iNET concept of operations represents a significant paradigm shift from the way the industry has historically accomplished setup of an acquisition system. It revolves around the idea that the device itself can, given a set of measurement requirements, set itself up and run to produce data that meets the requirements. While this idea is attractive and has the potential to increase efficiency and reduce errors, we believe there is still a use case for having user knowledge and control over all of the device's settings.

The main idea behind the differences in these two approaches centers on measurement requirements vs. setup definitions. In legacy systems, the focus is on setup definitions. That is, acquisition devices are configured by presenting an interface to the user which allows the assignment of values to each available hardware setting. The user is responsible for understanding the measurement requirement and what defining the settings as required to meet those requirements.

In the iNET system, the focus is instead on measurement requirements. The device vendor provides software that can receive the measurement definitions in a standard format and automatically provide the user with a configuration that meets those requirements, or prompt the user for more information if necessary.

MDL SCHEMA

In performing the gap analysis on the MDL schema, each element within our scope of interest was examined and evaluated based on its intended purpose, how well it can perform that purpose, and whether it fits within the existing and desired concept of operations. In addition we noted that there was some uncertainty about the nomenclature used, and the intended use of parts of the schema.

Elements

For our initial gap analysis, our focus was on elements contained within Units, MeasurementDomains, and, NetworkDomains. We are not considering TestMissions or RANConfigs elements at this time.

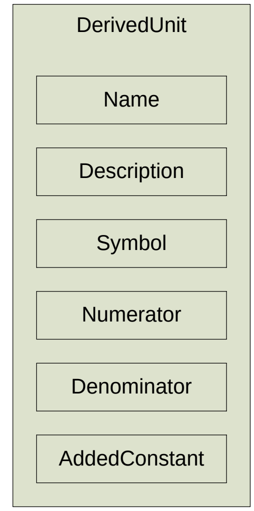
<u>Units</u> contains elements that are used to define any unit that can be derived from a standard SI unit. These derived units can be referenced throughout the rest of the schema. We did not find any gaps with these elements, but we did encounter a potential difficulty due to the way units are defined in our legacy system. This will be discussed in more detail in the following section.

<u>MeasurementDomains</u> contain elements that describe measurements and how they are processed and transported by the system. The Measurement element describes the properties of the measurement, both analog and digital. The DataOperation element describes EU conversion operations that can be performed on the measurement. DataStreams are used to describe the properties of a digital bus. Packages and Messages describe the way measurement data is transported through the network.

<u>NetworkDomains</u> contains elements describing the physical components of the network and the ways in which they are connected. A Device element describes a component that does not have a direct connection to the network, such as a transducer. A NetworkNode element describes a component that does have a network connection, such as a switch, recorder, or DAU. PortMapping elements describe the connection between a Device, a NetworkNode, and a DataStream or Measurement.

Units

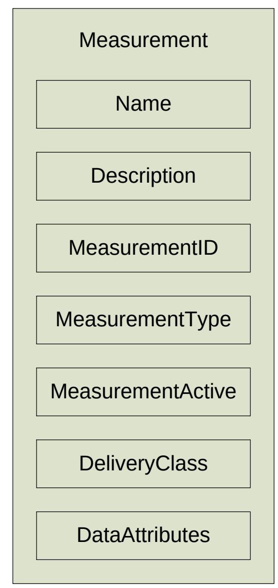
The concept of units in MDL is fairly straightforward, and our analysis did not uncover any gaps in the way units are defined or used. There is, however, a potential difficulty in describing information from a legacy system using MDL.



Derived units are defined as fractional expressions consisting of standard units of measure. The units used in the terms of the numerator and denominator elements can be either SI Units or other derived units. All elements within MDL that require units to be specified must reference either an SI Unit or a DerivedUnit. Thus, in importing measurements from legacy systems, all units must be able to be described using these concepts. This poses a difficulty for systems in which units may be entered as free-form text by the user. These legacy systems may contain units which are not described in terms of a standard unit of measure, or which are not described using standard abbreviations, thus requiring a manual translation to standard units.

Measurements

The Measurement element should describe all requirements for the measurement to be used in the configuration of a Test Article. Both analog and digital properties can be defined. The Measurement element is one of the places where the paradigm shift becomes most apparent, i.e. measurement requirements vs. setup definitions. Describing the requirements of the measurement as separate from any implementation details will likely require significant changes in the measurement description used in legacy systems.

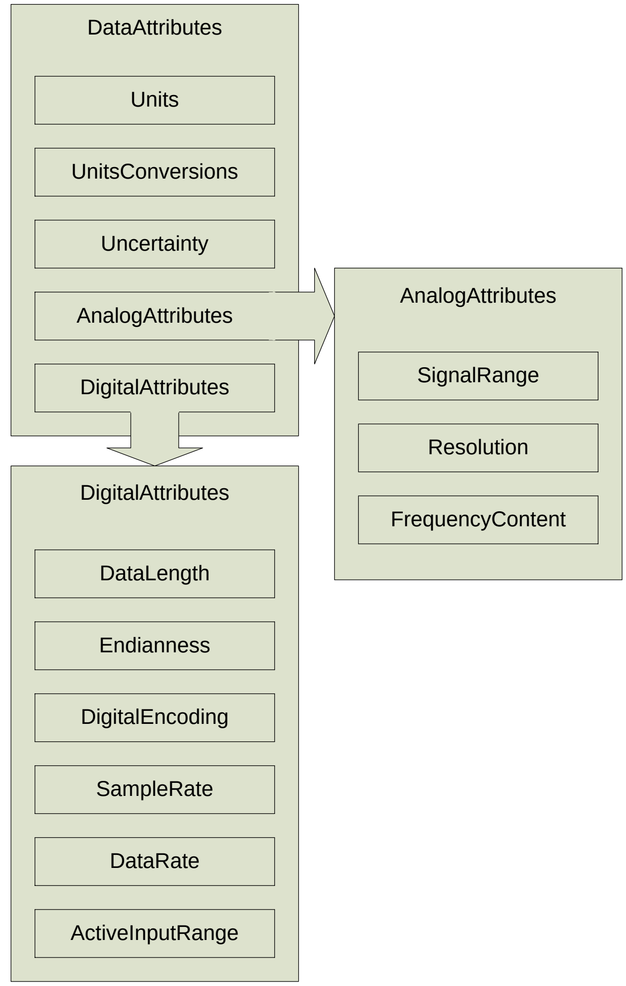


At the top level there are a few things that stood out initially. The MeasurementID field is a 32-bit hex or binary value, so is not useful for documenting the measurement identifier from a legacy system that may include decimal numbers or letters. The Name element may be used for this purpose instead and the MeasurementID would be a value used only by the system.

The MeasurementType is an enumeration that could be set to either Analog or Digital. In the initial evaluation, we noted that this element could be more useful if it was expanded to allow more specific types, e.g. temperature, or pressure. However legacy systems that have these detailed types can easily filter them down to the two basic types currently included in the enumeration.

MeasurementActive is a boolean value, indicating if the measurement is to be acquired in the configuration. This element could also be more useful if it allowed a greater variety of measurement statuses, such as “malfunction” or “questionable”. It may be that there should be a separate element for the status of the measurement, in addition to the existing “active flag.”

DataAttributes is a container within the Measurement element which has many more elements worth further discussion. Specification of units are done here as well as UnitConversions, which are specified as references to any number of DataOperation elements. As these are only references to other elements there are no issues to discuss at this point.



The Uncertainty element raises a few interesting questions. This element describes a confidence level over a confidence interval. Measurement definitions in a legacy system may not be as rigorously defined as this in terms of a requirement; often the specification includes only an accuracy value with no tolerance or confidence interval associated with it. There is often an implied or assumed confidence interval. While using the assumed values could allow this Uncertainty element to be used, it raises a number of questions about the extent and the quality of uncertainty analysis within an MDL-based configuration system. This issue will be discussed in more detail in a later section.

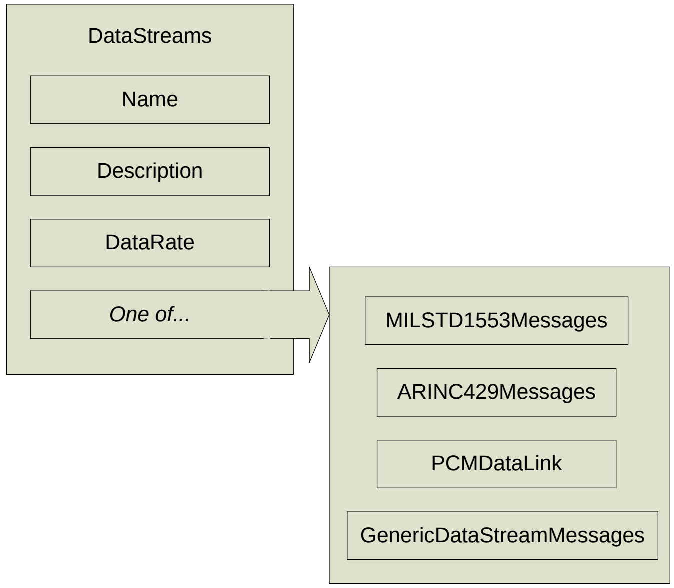
Within DataAttributes are two subcategories: AnalogAttributes & DigitalAttributes. Analog attributes are those characteristics that apply to the input signal to an acquisition device. Digital attributes apply to the processing and output of the signal.

Within AnalogAttributes are SignalRange, Resolution, and FrequencyContent. Signal range, representing the minimum and maximum values of the input signal, is straightforward. Resolution is included in the schema, but not clearly defined either in its definition or its use. FrequencyContent is the element where filtering requirements would need to be specified. In legacy systems, it is typical to simply call out a specific filter; however, in a vendor-agnostic system there must be a way to specify the requirement for filtering without mentioning a specific filter. FrequencyContent allows specification of frequency bands and attenuation ranges that can be combined to describe the user's desired filter characteristics. The initial gap analysis identified that this was likely not sufficient to select from a variety of possible filters; further discussions on the topic have drawn some conclusions that will be discussed in more detail later in the paper.

Within DigitalAttributes, many of the elements were not looked at in any detail, as our focus was on how the schema could be used to define the measurement requirements, and many of the elements here describe the implementation. SampleRate and DataRate were considered of some importance, as we are accustomed, in our legacy system, to specifying a sample rate. However, it was not immediately clear what each of these elements is meant to represent and whether either was useful for specifying a requirement rather than an implementation.

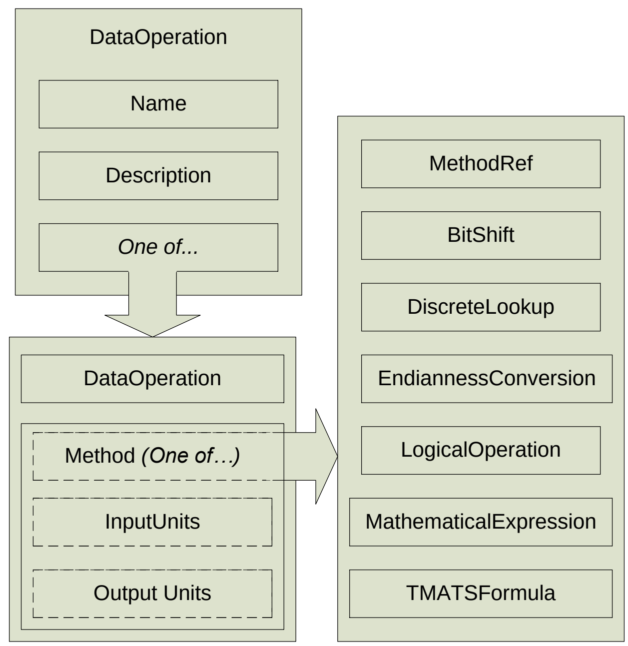
DataStreams

DataStreams was not looked at in any detail during the initial analysis, as our focus was on analog measurements. We did note, however, that only 1553, ARINC429, and PCM were explicitly defined. All other bus types are expected to fit into the Generic structure.



DataOperations

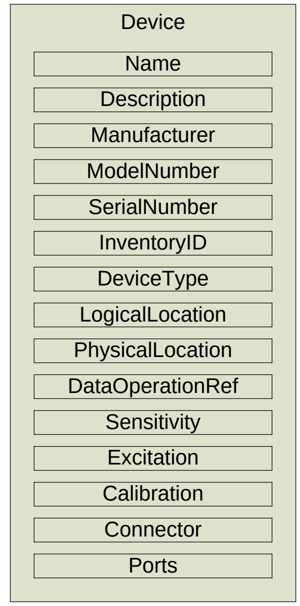
DataOperations are the containers for EU conversion information for a measurement. While not typically required for setting up the device, this information is a result of the selected setup parameters, and it is very important for data processing. A data operation may be constructed either as a single method, or as a chain of other data operations. This will allow documentation of each component that was used to produce the final transfer function for a measurement, as well as the transfer function itself.



We discovered two major concerns with DataOperations. The first is that this element supports only a single input. There are many use cases for a multi-variable transfer function. Also we noted that there is no support for multi-section polynomials, which are used frequently in our system, often in combination with multiple inputs. Some systems may use a lookup table for these types of conversions, and lookup tables are supported here.

Devices

Device elements are meant to represent anything on the system that does not have a direct connection to the network. Its contents, however, limit it to sensor devices.



The only significant issue with the Device element is the DeviceType, which is an enumerated list of transducer types. Currently this list is limited and does not cover the full range of possible transducer types. The enumeration will need to be expanded in order to be useful within large commercial flight test systems.

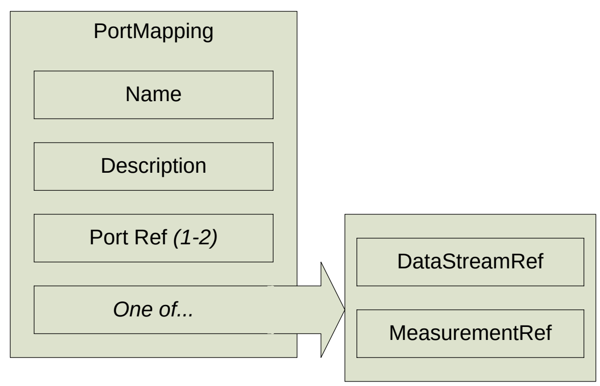
NetworkNodes

Network Node elements were not evaluated in detail for this exercise, as a vendor would be better suited to identifying gaps in the NetworkNode definition than a user. However, we did identify a couple of concerns that are more related to the concept of operations: initializing a DAU and communication of DAU settings (e.g. gain, offset, filter, etc.)

The current iNET Concept of Operations assumes that the setup and configuration system is connected directly to a DAU which reports its current configuration via an MDL file. There is also the concept of a "proxy," which is a software instantiation of a particular DAU. There was no concept of beginning with nothing but a knowledge of what building blocks are available and setting up the description of a device in software. Yet this is how our legacy systems work, and how we need to operate. In setting up a large data system, we often define the DAU descriptions well before the physical system is built up, and possibly even before we have the equipment available. In addition, it is important that we have a single, vendor-agnostic user interface for the entire setup and configuration process and do not need to access vendor-specific tools as part of the process. Much discussion has since taken place on this topic and an enhanced concept of operations is being proposed which will meet the need for a vendor-agnostic DAU initialization process.

PortMappings

PortMapping elements are meant to represent the physical connection between devices and network nodes and the logical mapping to their associated measurements or data streams. Devices and network nodes are referenced by their Port elements; multiple ports may exist on a device or network node, where each port would represent a single channel. The PortMapping may reference either a single DataStream or a single Measurement.



In some systems, it is possible to set up multiple measurements to be output from a single channel. The PortMapping element could easily accommodate this by allowing multiple MeasurementRefs but currently it does not. This could be worked around by using multiple PortMapping elements but does not seem to be as clean.

Naming and use

Often it is difficult to discern what exactly is meant by some of the elements in the MDL schema. The names used are generic and the comments do not adequately describe the element definition. Similarly, the intended use is not clear in many cases. The concept of operations has not been defined at a detailed level for setup of acquisition devices.

CURRENT STATUS

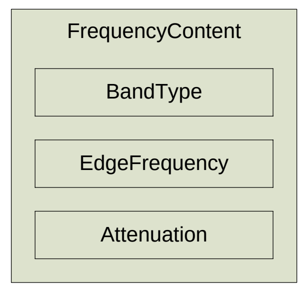
The MDL Users Group was formed in early 2014 and is made up of representatives from four potential users including Airbus, Airbus Helicopters, Boeing Test & Evaluation and Embraer as well as ten suppliers of DAUs and/or support hardware and software. Also included are representatives of the iNET program, Southwest Research Institute who is responsible for writing the iNET Standards and the RCC-TG who will be responsible for maintaining the standards once they are released. The group has made an effort to define a Concept of Operations that MDL would need to support to meet our needs. This concept of operations is discussed in more detail in the paper "DAU and Ground Station Setup - Concept of Operations."

Several items have been discussed in the group at some length, and conclusions or further questions have been formulated. The three primary discussion topics that have been covered are filtering, uncertainty, and resolution.

Filters

The filter characteristics are described in MDL today as a FrequencyContent elements consisting of a BandType (pass band, stop band, or transition band), an Edge Frequncy and an Attenuation. Multiple bands may be used within FrequencyContent to fully describe the filter characteristics.

The way that MDL today allows a filter to be described is in terms that MATLAB uses to define a filter. Most of the characteristics of the filter are defined. However, the phase response (delay) of the filter is not specified. MDL assumes that the delay can be accounted for in the time tags, however the time tags are associated with the package and the delays are associated with individual parameters. They may be combined with the time tag on the package to determine the time associated with the measurement. Knowing the delay is critical to the users.



Operationally, there are other problems with the way the filters are specified. The data analyst supplies the characteristics of the filter that is desired. The supplier's software can evaluate the requested filter characteristics and select the supplier-unique filter that most closely resembles what was requested. It will then notify the Instrumentation engineer if there is any mismatch. The instrumentation engineer must then consult with the analyst and decide if the filter selection is acceptable. If a filter mismatch occurs once or twice in a large system it is not a problem but if it happens hundreds of times it becomes an issue. This is not a necessarily a problem with the MDL schema but is an operational issue that the system will need to consider.

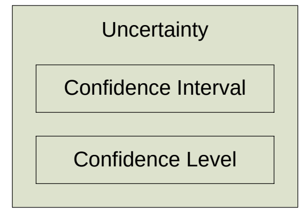
We believe that the MDL FrequencyContent element is adequate to describe the amplitude response of the filter. While this method of specifying frequencies of interest is functional, it is overly complex for an average user. Whether in the MDL schema or in a user system, there will likely need to be a method of abstracting the frequency definition and assigning a name or category to a particular FrequencyContent element. The average user can define measurement requirements by selecting the category that is appropriate for each use case and the MDL definition will be applied in the background without user interaction.

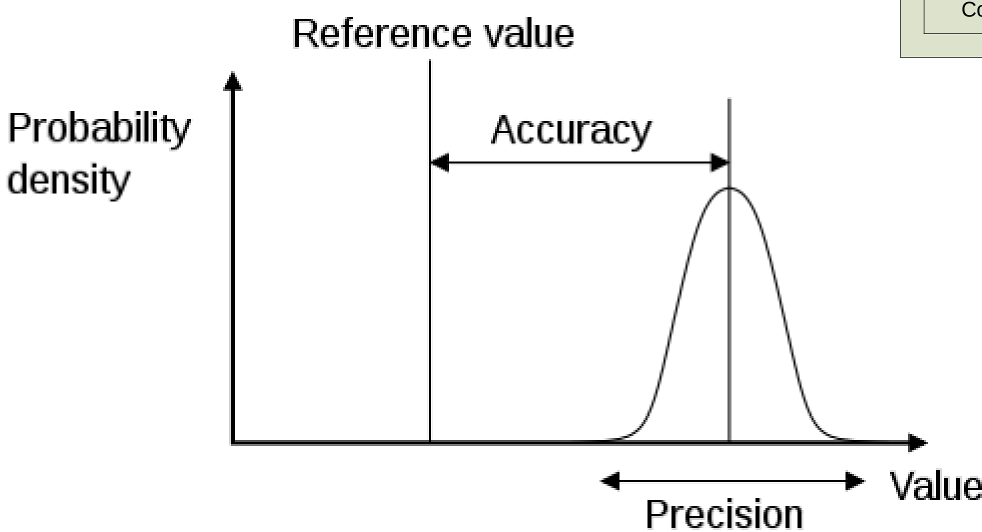
The phase response is currently not addressed, but future changes to the schema may address this. Those changes will need to be evaluated when they become available. While the MDL descriptions may be adequate there may be significant operational challenges in integrating this new paradigm into existing processes for measurement requirements definition.

Uncertainty

Uncertainty is specified in MDL as a confidence interval (a range of values with units), and a confidence level (a percentage value). It can be specified once for any Measurement element.

The first step in discussing Uncertainty was to come to an agreement on the definition of terms. The terms discussed are "uncertainty", "accuracy", and "precision" and the differences between them.





Precision, as demonstrated in the figure, represents the dispersion of values when repeated measurements are taken. The accuracy represents the proximity of the measurement values to the true value. Uncertainty includes both accuracy and precision as defined above and must be accompanied by a confidence interval to be of value.

Since the uncertainty for a measurement is specified as a combination of component uncertainties that each contribute to the overall measurement uncertainty, it must be recognized that the setup and configuration system may not have all of the information required to calculate a complete measurement uncertainty. Thus this value in MDL must generally be considered an "estimated" uncertainty. The acquisition hardware may have a known nominal uncertainty based on the selected setup parameters, and the transducer component may have a known uncertainty; however other factors such as installation method and environmental impacts will also have an effect and in many cases these components will not be known by the system. An uncertainty value for a Measurement can easily be computed based on the known factors and documented in MDL, but the user must be aware of what went into the computation to understand the fidelity of the final result.

Resolution

Resolution is specified in MDL as a value or range of values with a unit of measure. As there is no definition or intended use for this element documented with the MDL schema, the group agreed upon a definition. We defined resolution as referring to the difference in value of the input that is required to obtain a discernible change in the output; it should be expressed in the units of the input per one unit of the output.

Discussion has not yet progressed further regarding usage of this concept in MDL. Open questions remain about the effect of noise on resolution and whether the system should balance resolution against uncertainty when setting up a requested measurement. Resolution may be specified as a requirement, a goal, or a minimum/maximum. The schema does not offer any guidance on how the system will interpret "resolution".

NEXT STEPS

Discussions within the User Group are continuing to develop the proposed MDL schema updates and concept of operations by considering the interface points between vendor logic and the customer user interface. Topics under consideration relate to the interface point between the vendor configuration software and the user interface. From the vendor to the user, communication includes descriptions of vendor-unique settings, constraints and setup rules. From the user to the vendor, communication a notion of system and user constraints that may affect the vendor configuration system. Current status of these topics will be presented in more detail at the ITC presentation.

CONCLUSION

During concept development of a new system a need was identified for a set of more efficient and cost effective test system configuration and setup tools, preferably supported by an industry standard. We have chosen to focus on the iNET MDL standard as the means for producing a new vendor-agnostic, simpler and more cost-effective system interface. The iNET community has acknowledged gaps in their current schema and encouraged us to work with them via the industry User Group to enhance the standard. While the iNET MDL concept of operations represents a significant operational paradigm shift, we believe that it presents a significant opportunity for improving the reliability and repeatability of our test system setups.