

IADC Rig Sensor Stewardship Guidelines

IADC ADVANCED
RIG TECHNOLOGY
COMMITTEE

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Version 1.0, November 2020

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TABLE OF CONTENTS

1. Summary	3
2. Purpose and Scope	3
3. Rig Sensor Stewardship	3
3.1 Acronyms and Definitions	3
3.2 Relevant Standards	4
3.3 Useful Sources of Knowledge	5
3.4 Preface	5
3.5 Rig Sensor Stewardship Process	6
3.6 Simple Concepts for Sensor Data Quality	6
3.7 Principles for Sensor Data Quality	6
3.8 Data Road to User	7
3.9 Criticality Levels	7
3.10 Duplicate Sensors	8
3.11 Sensor Inaccuracies	8
3.12 Basic Calibration and Validation Principles	9
3.13 Sensors and Specifications	14
3.14 Sensor Accuracy for Rig State Detection (RSD) Algorithms	16
Acknowledgements	18

1. SUMMARY

The IADC Data, Controls & Sensors (DCS) subcommittee has identified the need for a set of guidelines with regards to the stewardship of sensors used for drilling control systems and rig state detection algorithms.

These guidelines provide a structure to address and define the following:

- a) Proper sensor functioning
- b) Accuracy of a data point measurement

The guidelines do not provide required accuracies and/or service intervals, as these can be defined by the individual stakeholders. However, where appropriate, suggestions are provided.

The stakeholders of this document include but not limited to:

- Owners of quality management system
- Rig manager/supervisor
- Drilling engineer
- Quality personnel
- Field personnel
- Maintenance personnel

2. PURPOSE AND SCOPE

The role and importance of sensor-generated data during the well construction process is undergoing a transformation as drilling contractors, service companies, and operators consume increasing amounts of this data for monitoring, analytics, and automation. However, the promise of a valued output can only be delivered when the measured data is a reliable image of the real drilling process.

The IADC Advanced Rig Technology DCS subcommittee has launched an initiative together with the IADC Maintenance Committee to develop sensor stewardship guidelines to enable drilling contractors and service providers to deliver high integrity and reliable data.

This initiative is also complementary to the Operators Group for Data Quality (OGDQ) and the API to ensure a broad level of support. For drilling contractors and service providers who wish to align with the Field

Verification process set forth by the OGDQ and API, this document is a first step to adhere to its recommendations.

These guidelines do not define actual verification or calibration procedures but instead focus on the following:

- Understanding applicable standards
- Providing a common framework and set of definitions
- Concept of sensor stewardship philosophy for rig owners
- Types of sensor errors
- Set of critical sensor accuracy framework tables
- Metadata sensor formats

It is important to recognize that these are guidelines. As a result, this document does not have any requirements or standards, nor does it include any "shall," "must," or "will" statements.

These guidelines use the following normative language:

- Should/should not: indicates a recommendation
- May/need not: indicates permission
- Can/cannot: indicates ability or inability
- Typically/typical: indicates most common cases

Please refer to the following for more discussion of the use of normative language:

- <http://www.iso.org/iso/how-to-write-standards.pdf>, page 4
- <http://www.iso.org/iso/foreword>
- http://www.iec.ch/members_experts/refdocs/iec/isoiec-dir2%7Bed6.0%7Den.pdf

3. RIG SENSOR STEWARDSHIP

3.1 Acronyms and Definitions

Acronyms:

ANSI – American National Standards Institute
 ART - Advanced Rig Technology (committee)
 DCAS – drilling control alarm system
 DCS – drilling control system
 DPM – drilling performance monitoring/management

DQM – data quality management
 IADC - International Association of Drilling Contractors
 IEC – International Electrotechnical Commission
 IEEE – Institute of Electrical and Electronic Engineers
 ISA – International Standards Association
 ISO – International Organization for Standardization
 MOC – management of change
 NPD – Norwegian Petroleum Directorate
 OGDQ – Operators Group on Data Quality
 PMBOK – Project Management Body of Knowledge
 RSD – rig state detection
 SPE – Society of Petroleum Engineers

Definitions:

Accuracy: In ISO 8000-2:2018, accuracy is defined as “closeness of agreement between a property value and the true value, where property value is defined as the instance of a specific value together with identifier for a data dictionary entry that defines a property, and where true value is defined as a value that characterizes a characteristic perfectly defined in the conditions that exist when the characteristic is considered.” The term “inaccuracy” and “error” are used interchangeably in this document.

Calibration: Calibration is an in-depth procedure that is usually reserved for laboratory or factory settings. Calibration will be addressed later in this document.

Criticality: A critical sensor is a sensor which must be highly reliable and retain this reliability throughout operation to mitigate high-impact risks.

Derived data point: A computed (or derived) value from measurements is a value that is not directly measured but requires other system specifications to be determined.

Measured data point: A measurement data point is a data point that is directly measured, such as pressure or length, and can be used with only unit conversion and/or number of digits change.

Primary sensors: Primary sensors are defined as ones that contain the most trusted source of measurement. There can only be one sensor measuring a variable dedicated as primary sensor at any given time. All other sensors measuring the same variable are designated as secondary sensors.

Redundancy: Redundancy means there is a backup sensor to the main (primary) sensor. Redundancy increases reliability of the sensor data (to maintain

accuracy) and improves the availability of the sensor data (uptime). For reliability, the challenge is to identify which sensor is out of specification if both do not agree. In some higher redundancy situations, both sensors use different physics to improve this comparison ability.

Stewardship: The process to ensure sustainability and long-term integrity of a sensor’s function and measurement (or calculation) within the industry-accepted error margin. Good stewardship is creating internal systems and cultivating the necessary self-discipline to check and maintain the performance of sensors and the quality of data they generate.

Secondary sensors: All sensors for a certain variable that are not designated as primary sensor.

Validation: Validation is the assurance that a product, service, or system meets the needs of the customer and/or other identified stakeholders. It often involves acceptance and suitability with external customers. This term is contrasted with “verification” according to the Project Management Body of Knowledge (PMBOK).

Per the Systems Engineering Body of Knowledge, validation is the confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.

Verification: Verification is the evaluation of whether a product, service, or system complies with a regulation, requirement, specification, or imposed condition. It is often an internal process. This term contrasts with “validation” according to the PMBOK.

Verification is the confirmation, through the provision of objective evidence, that specified requirements have been fulfilled, as per the Systems Engineering Body of Knowledge.

3.2 Relevant Standards

The committee identified the following standards that could be of use in the scope of this document:

- IEEE 2700-2017: IEEE Standard for Sensor Performance Parameter Definitions
- ISO 8000: Data Quality Standard
- ISA 51.1: Process Instrumentation Terminology

3.3 Useful Sources of Knowledge

The following resources provide examples from the field that could provide useful:

- Neufeldt, A.C. Lai, S. W. Kristjansson, S.D. An Algorithm to Automatically Zero Weight on Bit and Differential Pressure and Resulting Improvements in Data Quality. Presented at the IADC/SPE Drilling Conference and Exhibition, Fort Worth, Texas, USA March 2018. SPE 189636-MS
- Zenero, N., IADC IoT Data Quality and Sensor Stewardship
- Zenero, N., Koneti, S., & Schnieder, W. (2016, March 1). Iron Roughneck Make Up Torque - It's Not What You Think! Society of Petroleum Engineers. doi:10.2118/178776-MS
- Flow Measurement Engineering Handbook, R.W. Miller, 1983
- De Wardt, J., Wood, P., (2020, March 3). Verification and Validation of Sensors and Systems Using Systems Engineering Methods. Society of Petroleum Engineers. SPE 199589
- "Basic Calibration and Validation Principles," provided by Nathan Zenero

3.4 Preface

Drilling rigs generate enormous volumes of data each day. The data is processed and stored locally, then transmitted and retrieved remotely. Companies use this data in varying ways, including remote monitoring and analysis. Traditionally, rig data has been collected and meticulously reviewed manually. This time-consuming process was fraught with errors, as it relied primarily on the human beings on the rig understanding the data and accounting for inaccuracies. Over the past 10 years, continued advancements in automation and data analytics have necessitated better initial quality when data is collected. Particularly in an environment where persistent cost constraints are an issue, it is more critical than ever that sensor data be accurate and that it provide a solid foundation upon which to optimize performance and scale improvements across comparable rigs.

For the purpose of proper rig sensor stewardship, i.e. the careful and responsible management of something entrusted to one's care, it is important to note that sensors will always provide some mismatch with respect to true value; a 100% true measurement does not exist.

The challenge is to ensure that sensors operate to the highest integrity of their design. When sensors are used in many different applications and/or are of the "highly critical class," accuracy requirements should be higher compared to other sensors that are only used in a few applications and/or are of a "low criticality" class.

For the purpose of these guidelines, a distinction is made between measured data points and derived data points. An example of a measured data point is the pressure measured in the deadline anchor line tension measurement sensor. The derived data point, using the measured data, is the hookload.

In all cases, IADC recommends using sensors that provide measured data points for the process value over derived data points, or, if that is not possible, a minimum of conversion steps.

As stated in the definitions, a measurement data point is a data point that is directly measured, such as pressure or length, and can be used with only unit conversion and/or number of digits change. An example is pressure in a hydraulic system, which can be measured in bar/psi and presented with various levels of accuracy.

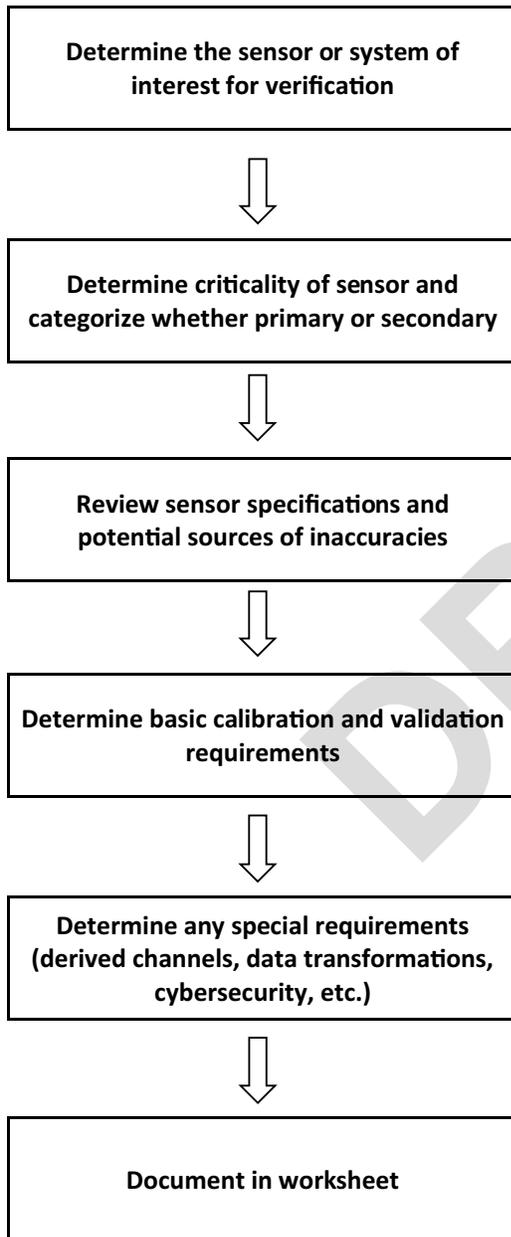
A computed (or derived) value from measurements is a value that is not directly measured but requires other system input to be determined. An example of this is tank volumes. A level measurement or a weight measurement is needed, as well as the size of the tank, to come to the volume value. However, if the tank volumes are presented as levels on the screens, this can be considered a measured data point again.

There is a difference between direct and derived data points when it comes to ensuring correct data generation. Measured data point accuracy is determined by the sensor itself or the processing on the sensor. Ensuring that the data points are correct will involve working directly on the sensor itself, and no further steps can be taken. On the other hand, derived data points use additional calculation steps that might be used to enhance the accuracy, especially bias and sensitivity errors. However, these additional calculation steps could introduce errors as well if not carefully applied.

During calibration work as part of the sensor stewardship process, great care should be taken to differentiate between direct data points and derived data points.

IADC recommends limiting the sensors to the absolute minimum to achieve the goals of the individual stakeholders. That something can be measured does not mean it needs to be measured.

3.5 Rig Sensor Stewardship Process



3.6 Simple Concepts for Sensor Data Quality

1. Data should come from mutually agreed upon, trusted sources only
2. Data should be immutably stored — the original data should always be available

3. Sensor data can contain errors for many reasons, and we should be able to determine if, when, why, and how a sensor is in error. If possible, we should correct the source of the error.
4. IADC recommends storing the processed data in separate fields, such that the original (raw) data is left unaltered.

3.7 Principles for Sensor Data Quality

The following principles can be read as guidelines and recommendations describing an ideal DQM system.

1. A person or system should have access to information that uniquely describes a sensor.
2. A person or system should have access to the configuration of a sensor or collection of sensors and their orientation with respect to the following:
 - a. The machine, tool, or instrument (or collection thereof) for which measurements are provided
 - b. Influencing vector fields such as gravity, magnetic flux, radiation, pH, etc.
 - c. Correlated, covariant, dependent, redundant, or otherwise related sensors, machines, tools, or instruments
3. A person or system should have access to sensor documentation describing:
 - a. Operational ranges
 - b. Corrections such as temperature, pressure, etc.
 - c. Bias, hysteresis, or other forms of systemic error
 - d. Measurement capability such as sigma-level or other measure
 - e. Master calibration date and type
4. A person or system should be able to establish a consensus, or synchronization, of time for time-series or other data sets whether or not they use the same clock.

IADC recommends installation of a time server or, alternatively, designating one system as the timekeeper for all other systems to follow. Time should preferably be rig based to facilitate synchronization with other methods of record keeping on the rig.

5. A person or system should be able to validate the conformance of data to its defined syntax (format, type, range).
6. A person or system should have the ability to verify the consistency of a data item across data sets and databases.

7. A person or system should be able to check the accuracy of a sensor measurement with a secondary trustworthy source of data in a similar condition when the comparison is made.
8. A person or a system should be able to verify the completeness for a given sensor data in terms of the following:
 - a. Rules that define a complete set of data (including metadata)
 - b. Amount of missing value(s)
 - c. Presence of value when no value is expected
9. A person or system should have access to documentation that establishes the lineage of the data describing the following:
 - d. Origin of the sensor data (direct, transposed, derived, or estimated)
 - e. Transformation of data (if any)
 - f. Transportation of data (between databases)
 - g. How data is stored
10. A person or system should be able to provide raw or unaltered sensor data and associated metadata. That is, manipulation of any form (filtering, smoothing, decimation, compression, scaling, fitting, modeling, or any other adjustments or modifications) should be stored in separate fields or described such that it can be reversed.

3.8 Data Road to User

There are several steps that should be addressed when providing data from a source to end user, though these steps are not sequential or unique. For all data points the following steps can influence the accuracy:

1. Proper installation of the sensor or instrumentation
2. Measuring of the data
3. Deriving data points (if applicable)
4. Data transmission on the rig

----- End of scope of Rig Sensor Stewardship Guidelines -----
5. Data Storage on the rig
6. Data Processing on the rig
7. Data Transmission from the rig to external storage (cloud based or normal servers)

8. Data Processing at the External Storage
9. Data Visualization

Scope of this document is to cover steps 1 – 4 in this list, in addition to some external forces and source of inaccuracies. Other documents may address further steps. Reference is also made to the IADC Cybersecurity guidelines in this aspect.

IADC recommends mapping this so-called “data road” in an easy-to-understand way so it is accessible for all stakeholders.

For steps 4-8 it is important to ensure that historical sensor data not been altered by

- h. Compression
- i. Transmission
- j. Transformation/conversion or other mathematical or data operations
- k. Database ETL
- l. Third-party or other external manipulation by system(s) or person(s) - Cybersecurity

3.9 Criticality Levels

It is important to assess and understand the risk associated with inaccurate sensor measurements. Operator and contractor companies should risk assess the failure or inaccuracies of a specific sensor and plot the risk on their internal company risk matrix. Setting criticality levels is important to define proper stewardship activities and ensure efficient use of available resources. This list provides one way of defining criticality levels for each sensor using a rate of failure and severity of an incident. Equipment owners should determine their own criticality levels and take appropriate action to maintain the data quality feed.

System level	Failure consequence	Failure rate example
A	Catastrophic	Remote – will not fail within 5 years
B	Hazardous	Unlikely – will not fail within 1 year
C	Major	Possible – will not fail within 6 months
D	Minor	Quite likely – will not fail within 3 months
E	No effect	N/A

Source: International standard DO-178C – Software Considerations in Airborne Systems and Equipment Certification (RTCA)

- Catastrophic – Failure may result in multiple fatalities, extensive asset damage, or significant impact on the license to operate. An example of this incident type could be a major accident hazard such as a high-level blowout.
- Hazardous – Failure may have a significant negative impact on safety or performance, leading to the possibility of serious or fatal injuries, major asset damage, or environmental impact.
- Major – The failure would be significant with limited personal injuries.
- Minor – The failure would be observable, leading to changing drilling plans with loss of income and project delays.
- No effect – The failure would have no impact on safety, assets, environment, or operator workload.

3.10 Duplicate Sensors

In cases of duplicate sensors on location (meaning more than one sensor measuring the same task or process), it is up to the rig owner and service providers to communicate with the client which sensors are treated as primary sensors and which are secondary backup sensors. Sensor duplication could be due to multiple parties connecting to the same input or for secondary backup in automation as a failsafe measure. All stakeholders should agree on which sensor is being used for which purpose and reach an agreement on which sensors are designated as “primary sensors.”

To prevent and potentially mitigate against well control situations, sensors used to monitor and control the well’s primary, secondary and further barriers should be risk assessed and assigned a criticality ranking.

Voting is used to eliminate failing sensors or bad measurements. In this case, the outcome of the voting algorithm shall be the primary sensor value. It is outside the scope of this document to define the details of the voting algorithm. The outcome of the voting algorithm should be classified as a derived measurement.

IADC recommends sensors used for well control not to be in the A or B criticality group.

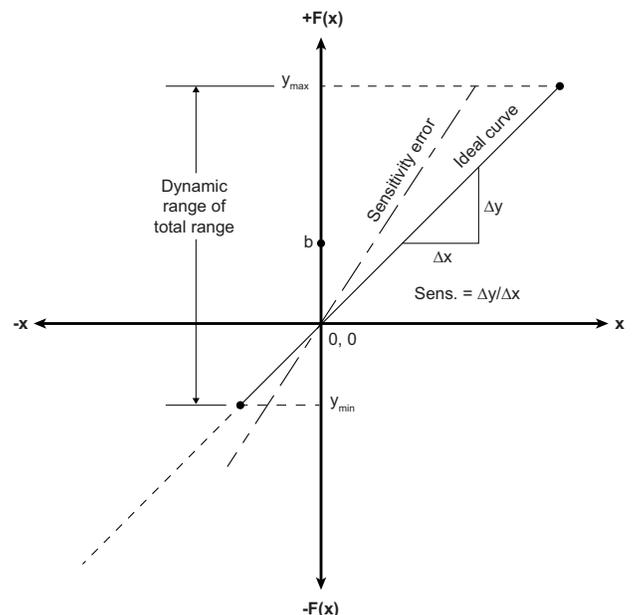
3.11 Sensor Inaccuracies

Since sensors cannot replicate an ideal transfer function, several types of deviations can occur which limit sensor accuracy. Some of these deviations can be mitigated as part of the sensor stewardship process; however, some are part of the sensor characteristics that cannot be changed.

Care should be taken to define those deviations that can be mitigated by procedures performed by the rig crew. If specialized personnel and/or tools need to be used, it could pose undue burdens on the cost effectiveness of the drilling rigs.

Typical list of sensor deviations based on <https://en.wikipedia.org/wiki/Sensor>

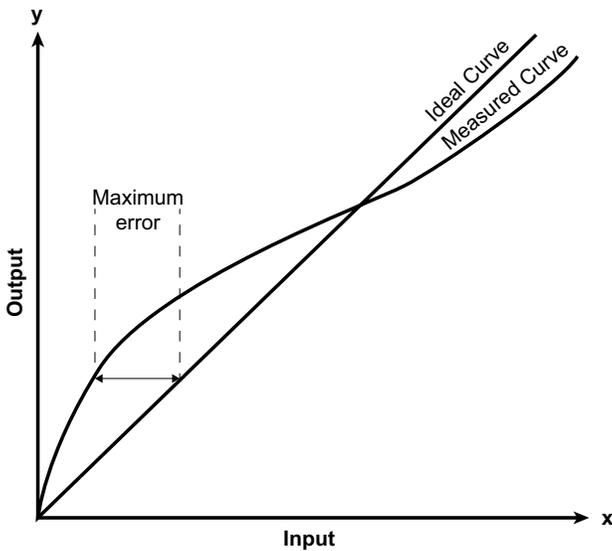
- The range of the output signal is always limited and will eventually reach a minimum or maximum when the measured property exceeds the limits. The **full-scale range** defines the maximum and minimum values of the measured property.
- The sensitivity may in practice differ from the value specified. This is called a **sensitivity error**. This is an error in the slope of a linear transfer function.



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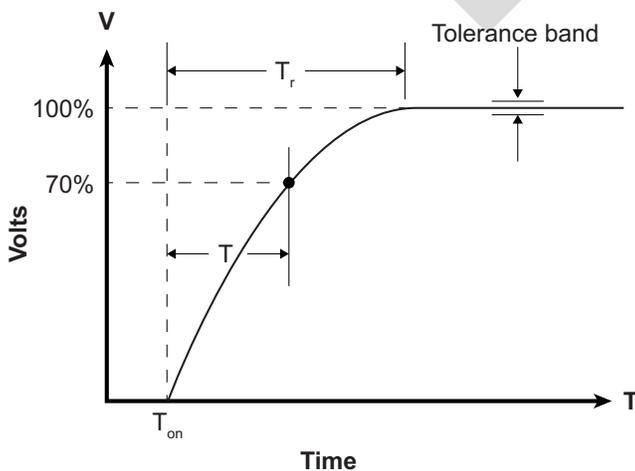
- If the output signal differs from the correct value by a constant, the sensor has an **offset error** or **bias**. This is an error in the y-intercept of a linear transfer function.

- **Nonlinearity** is deviation of a sensor's transfer function from a straight-line transfer function. Usually, this is defined by the amount the output differs from ideal behavior over the full range of the sensor, often noted as a percentage of the full range.



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- Deviation caused by rapid changes of the measured property over time is a **dynamic error**. Often, this behavior is described with a Bode plot showing sensitivity error and phase shift as a function of the frequency of a periodic input signal.



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- If the output signal slowly changes independent of the measured property, this is defined as **drift**. Long-term drift over months or years is caused by physical changes in the sensor.

- **Noise** is a random deviation of the signal that varies in time.
- A **hysteresis error** causes the output value to vary depending on the previous input values. If a sensor's output is different depending on whether a specific input value was reached by increasing versus decreasing the input, then the sensor has a hysteresis error.
- If the sensor has a digital output, the output is essentially an approximation of the measured property. This error is also called **quantization error**.
- If the signal is monitored digitally, the sampling frequency can cause a dynamic error, or if the input variable or added noise changes periodically at a frequency near a multiple of the sampling rate, **aliasing errors** may occur.
- The sensor may to some extent be sensitive to properties other than the property being measured. For example, most sensors are influenced by the temperature of their environment.

These deviations can be classified as systematic or random errors. Systematic errors can sometimes be compensated for by means of a calibration strategy. Noise is a random error that can be reduced by signal processing, such as filtering, usually at the expense of the dynamic behavior of the sensor.

Errors can also be used to determine sensor degradation and/or other problems. For example, increasing or a sudden increase in noise levels could point to shielding failures in signal cables.

3.12 Basic Calibration and Validation Principles

There are two methods to check the process capability of sensors—calibration and validation. Calibration is typically infrequent and laboratory-based, while validation is frequent and field-based.

3.12.1 Calibration

Calibration is an in-depth procedure that is usually reserved for laboratory or factory settings. Proper calibration requires controlled environments, rigorous procedures, highly trained technicians, and sensitive instruments to establish trust. Reputable calibration labs and factories use traceable by the National Institute

of Standards and Technology (NIST) equipment when possible and practical. Doing so furthers the level of confidence in the instruments being used.

Calibration should be performed using methods that will expose potential bias introduced through expected environmental and operating conditions such as temperature, pressure, strain, background radiation, vibration, or any other factor to which the sensor will be reasonably subjected. Records should indicate the influence of bias factors and if the device has been adjusted or programmed to correct them. If possible and practical, calibration labs should perform combined load testing where multiple variables can be changed at once.

3.12.2 Validation

Field operations typically preclude the use of calibration tools and methods. Moreover, calibration does not always occur in the specific environmental and operational conditions that exist in the field. Thus, validation is a much less rigorous yet much more practical approach to establish or perpetuate trust in oilfield sensors.

Validation will yield positive results if performed with the following concepts in mind:

- Validate to direct measurements when possible and practical. Use known loads, volumes, rates, or other metrics, and avoid the use of indirect measurements such as current or voltage when possible.
- Validate measurements in load/flow path or as close thereto as possible.
- Validate measurements on sensors that are at steady-state operating conditions or are operating across the range of values that are reasonably expected during planned operations.
- No fewer than three observations should be performed at any setpoint.
- Always check to make sure that sensors are properly installed and maintained. Leaks, shorts, electrical noise, and vibrations are common causes of measurement error.
- Exact readings are not possible with continuous measurements, and care should be taken not to introduce error by reading or estimating accuracy that is not present.

3.12.3 Induced (Special Cause) Errors

Filtering and smoothing

Many digital gauges and/or associated aggregation systems can manipulate data in a variety of ways. The most common include smoothing, filtering, normalization, cutoff limits, band-pass, down/up-sampling, scaling, and formulae. With the advent of inexpensive processing power, signal processing plays a larger role in the total accuracy of the measured signal. This role is expected to grow even more in the future.

Filtering and smoothing are very common methods of data manipulation. In most cases, these methods are used to reduce noise or perceived noise. These tools are particularly useful when data is interpreted visually, as it helps to identify trends without being confounded by random variations present in most data. The most used filtering and smoothing methods are moving average and moving floor/ceiling. Examples are shown below.

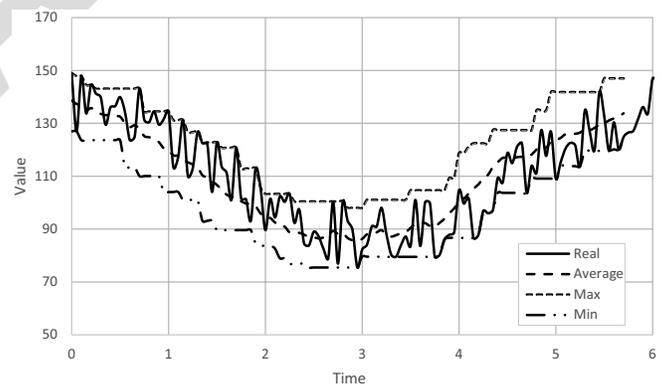


Image courtesy of Nathan Zenero

Figure 7: Effects of simple filters on signal data

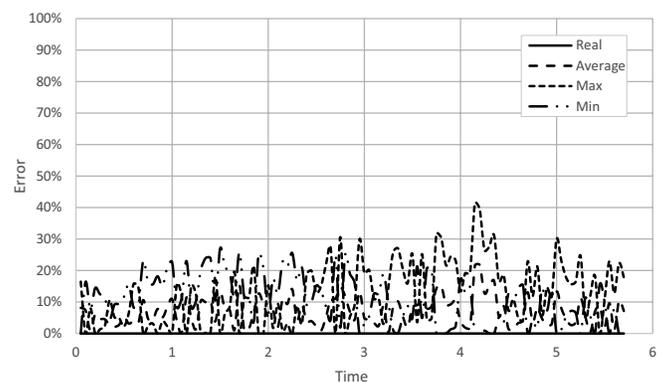
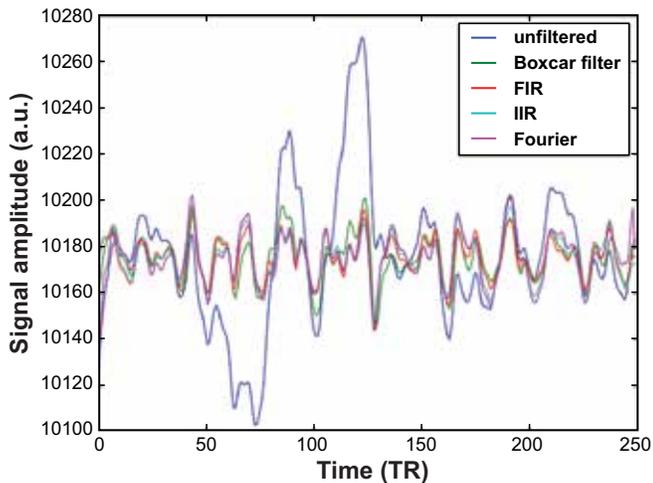


Image courtesy of Nathan Zenero

Potential errors (residuals) induced by filtering and/or smoothing

The following figure shows the results of more complex linear and nonlinear filters and smoothing functions.



Source: http://nipy.org/nitime/examples/filtering_fmri.html

Example of effects of several complex filters

Most filters represent a loss of information. It is important to understand the types and magnitude of the losses that occur. The figure above is an example of information that may be lost. While it may be convenient for a user to remove what may be reasonably considered an outlier or noise, these data points may, in fact, be true and indicate a fault in the measurement or in the sensor. Moreover, when combined with other methods, such as formulae or algorithms, propagation of error should be considered.

Filtering and smoothing are generally done with respect to a single variable of interest and are done so without respect to the physical system associated with the system. More advanced methods, however, consider physical and virtual relationships between and among groups and subgroups of sensors that comprise a network. This process leverages unique knowledge of the underlying systems to more accurately and reliably filter and smooth data in a physically consistent way.

Filtering and smoothing should not be used to hide or mask bad signals. If signals are noisy, it is recommended to first rule out physical causes such as grounding, crosstalk, harmonics, ambient/background radiation, or other sources of interference or noise.

Filters should only be used if the original data is also stored, as it can be difficult or impossible to

reconstruct an original signal from a filtered one. There are some notable exceptions to this, especially if the raw data sets are too large to be stored or if the processed value is the only value of interest. Vibration analysis is an example of this.

When considering when and/or how data is manipulated, one should consider the unique nature of oilfield sensors. The magnitude of forces regularly applied or resisted by oilfield equipment is large in comparison to other industries. Additionally, the mobile and flexible nature of oilfield equipment does not lend itself to the types of safety and control features typically available in fixed installations. Consequently, catastrophic failure modes are potentially more numerous and severe, and it is recommended that error in measurements (or the corrections/manipulations) be accounted for and propagated through engineering, planning, and analysis.

Formulae

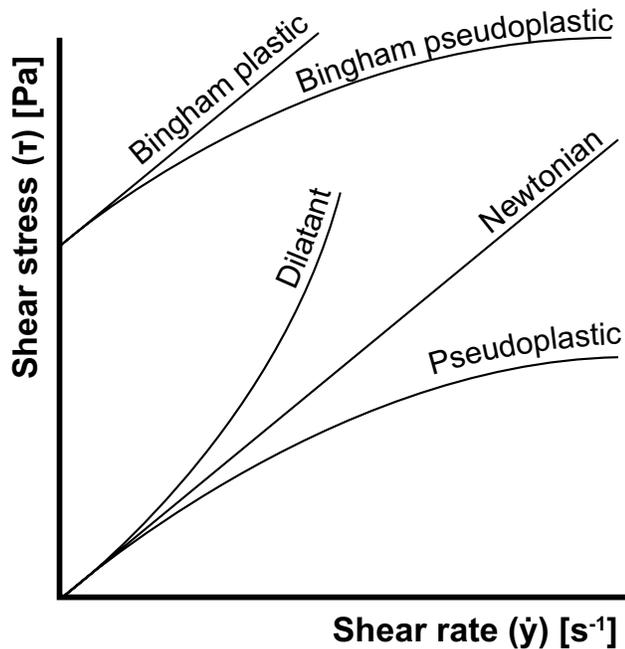
The common use of multiple third parties is to provide operational data that is critical to oil and gas.

There should be a high level of transparency in the methods used to derive calculated channels or values. This is particularly important considering that many important values used to analyze oilfield operations are derived. For instance, weight on bit is derived from hookload.

Assumptions, constants, formulae, algorithms, and other information necessary to define a derived value or channel should be made available to data owners and data users as long as intellectual property is respected.

It is important to note that it is not uncommon for physical models or other methods to diverge significantly when small changes to assumption or constants are introduced.

A classic example is rheological behavior, as shown in the next figure. Significant differences in calculated frictional pressure losses will occur depending on the chosen rheological model, assumed constants, and other inputs or measurements. It is not difficult to imagine how this may also be expressed in other commonly used calculated values such as torque and drag, mechanical-specific energy (MSE), hole cleaning, rate of penetration (ROP), and many more.



Source: https://commons.wikimedia.org/wiki/File:Rheology_of_time_independent_fluids.svg

Divergent behavior as a function of choice of model

3.12.4 Other Errors

Environmental factors

Sensors can also be affected by environmental or other induced transients such as waves, wind, sun, or other factors. Extrinsic loading, thermal effects, radiation influences, and other factors should be addressed and mitigated through failure analysis and engineering practices. When necessary, these factors should be corrected for.

For example, it is common for the fluid level in mud pits to be significantly influenced by the motion of offshore rigs due to wave action. In such instances, controls such as additional sensors can be used to mitigate such effects.

Orientation

Sensor orientation is particularly important when:

- Measuring in a moving or rotating reference frame. The orientation of sensors influences how they can cancel or multiply error or how forces will be interpreted in the moving frame(s).
- Measuring in a field which has an influence on the measurement—this is particularly common in magnetic and gravitational measurements

where the effect of the field is a function of position and orientation of the sensor.

- Combined or covariant measures are likely, such as when measuring tension, torsion, pressure, and buckling, all of which may be present in combined forms.

Installation

Errors resulting from inaccurate structural measurement during installation such as undefined offsets of deadline tension anchor or undefined placement of sensors in bottomhole assembly tools.

Redundancy

Modern sensors have high reliability and repeatability, but no sensor is fail-proof. It is incumbent on engineers to address the risk of a sensor fault or failure and determine the level (if any) of required redundancy. There are many analytical approaches that may be used. In the event redundancy is present, rules for agreement and/or reference should be defined such that errors can be easily identified and rectified/mitigated. Refer to the section on criticality and the definition of primary and secondary sensors.

Sensor location – out of scope in this document

IADC encourages organizations to use necessary and sufficient taxonomies, topologies, and ontologies to describe systems, locations, configurations, and their respective relationships. Though useful, it is outside the scope of this document.

Compression (data reduction) – out of scope in this document

Data compression is frequently used to maximize available bandwidth from remote locations when the cost or availability of telemetry is limited. Recent advances in telemetry have made compression less necessary; however, the proliferation of high sample-rate, and ‘smart’ sensors, required for analytics and automation, have begun to outpace networks. Thus, compression will likely be required in certain circumstances.

Compression algorithms can be lossy (i.e. there is a loss of information) and should be chosen carefully if their use is required. There are several methods that can help limit the need for compression. For instance, not all data generated locally is required remotely for analysis and many systems can be managed by exception. That is, systems report

data only when a fault is detected, or intervention is required. Additionally, very dense data used solely for post-process analysis can be transferred to physical media locally for manual delivery or in a non-real-time queue when network performance allows.

If lossy compression is used, it should be limited. Multiple applications of the same or different algorithms can lead to data that is of insufficient quality to perform necessary tasks.

Conversion – out of scope in this document

Conversion of data from one measuring system to another, or from one data type to another, can introduce error if the precision of the conversion constants is not greater than or equal to the precision of the values being converted. Conversion should be avoided if possible, and it should be considered best practice to maintain a consistent measurement system to avoid confusion.

Database operations – out of scope in this document

Database transformation between variable types (i.e. string to integers or integers to double precision) can introduce error and should be avoided. All other database ETL, query, and scrubbing processes should also be demonstrably loss-less and reversible.

Networking (automation) protocols – out of scope in this document

There are a wide range of network protocols for industrial data collection, command, and control. Each system has features that may offer benefits for certain applications and limitations that may make it unsuitable for others. Regardless of the protocol used, data collection should be strictly limited to a read-only layer and should have user permission management to prevent unauthorized access.

Time synchronization – out of scope in this document

Time synchronization is of concern for operations where multiple vendors may use independent clocks and timekeeping. Time synchronization is also of concern for operations that are monitored from a significant distance, such as RTM for offshore operations.

Data providers should regularly sync clocks to an agreed upon standard such as the NIST clock at www.time.gov or similar.

Devices that are not continuously attached to a common network should be time synced to surface equipment before being passed through the rotary table (inbound) and should be checked for synchronicity again after being returned to surface (outbound). Any difference in time should be explicitly stated as part of data delivery, analysis, or manipulation.

Improper resolution

A common source of error is over- or under-resolution in analog-to-digital conversion. The rise of inexpensive analog-to-digital digitizers have enabled many instruments with low sensitivity to be paired with converts with high bit counts. This results in reported significant digits that are outside the capability of the instrument and are, therefore, spurious. The converse, under-resolution, leads to a condition known as machine epsilon, whereby the digitizer cannot recognize a change reported by the instrument because it is limited by the number of available significant digits in memory registers.

Cybersecurity

Cybersecurity considerations vary widely as a function of risk. RTM operations that strictly consume and visualize data have much lower security requirements than ones that are integrated with controls systems.

ISO 27001 and the IADC Guidelines on Cybersecurity are excellent foundations for cybersecurity, though they may not be suitable for all applications.

Cybersecurity programs should be tailored to the risk and needs of each individual organization but should include at least the following:

- Physical security
 - o Physical security focuses mainly on prevention of intrusion.
 - o Methods to physically secure areas that contain data or controls systems and to prevent unauthorized users from accessing, manipulating, damaging, or otherwise influencing sensor and data systems.
 - o Methods to secure networks and prevent malicious access. This may include hardware/software combinations, physical lockout/tagout systems, or other methods to mitigate intrusion.
- Virtual security – out of scope in this document
 - o Virtual security focuses mainly on detection and mitigation of intrusion.

- o Where appropriate and/or required, data providers should employ methods to detect and mitigate unwanted intrusion or damage caused by malicious actors.

3.13 Sensors and Specifications

IADC has listed below some specific measurements that are key to monitoring the rig and understanding its performance. We do not intend this list to be exhaustive. We expect that users of the guidelines will take this format and apply it to other sensors that are important to the individual data consumer. Our intent is to provide the structure for a conversation between data generator and data consumer.

Hookload Measurement	
Criticality	A
Direct measurement type	Load pins
Derived measurement type	Deadline tension measurement Drawworks torque
Derived data points	Weight on bit Maximum specific energy Bit depth Rig state
Safety considerations	Hookload measurements are used to ensure the tension in the drillstring and the weight on the tools does not exceed the maximum allowable values. This also includes the structural load on the mast.
Overall sensor accuracy	This will be determined with operational requirements and equipment limitations in mind.
System data typically needed	Number of falls Type of sensor Equipment weight in load path Application offshore/onshore Location of the sensor
Calculations to be provided	For derived measurements, the equations need to be provided to show how the hookload data point is calculated from the direct measurement.

Deadline tension measurement inaccuracies				
#	ERROR TYPE	SOURCE	RECOMMENDED REMEDIATION	RECOMMENDED INTERVAL
1	Full scale range	<ul style="list-style-type: none"> Change in number of falls of the block Incorrect settings in the PLC 	<ul style="list-style-type: none"> Check the values when minimizing the bias. Expected values in the system matching measurements 	
2	Sensitivity error	Sensor not functioning properly and/or wrong conversion factor used.	Adjust conversion factor	During commissioning or after replacement of a sensor
3	Offset error or bias	<ul style="list-style-type: none"> The weight of the moving installed equipment needs to be subtracted from the reading to obtain a true load hoisted. Sensors need to be calibrated to ensure zero reading at zero load 	<p>Using the control system, the offset due to fixed equipment can be removed (any offsets should be applied to the original value, not change the original value)</p> <p>The signal of the sensor needs to be set at zero when no line tension is present.</p>	<p>After each slip and cut procedure</p> <p>After each change in weight of moving equipment</p>
4	Nonlinearity	<ul style="list-style-type: none"> Inherent component mismatching Unaccounted variations due to operations outside specified ranges 	<ul style="list-style-type: none"> Assure sensors are well set up inside the operational ranges via regular checks of offsets and gains Ensure capture of data points associated to health checks is implemented as part of any embedded platform 	Carry out every time a rig is started
5	Dynamic error	This is not likely to occur		
6	Drift	Drift will be likely when using a clamp on sensor and will be visible as a varying static hookload over time when no load is present	Zero out the sensor using either the sensor adjustment or (not both) changing the static value in the PLC. Care should be taken not to influence the maximum range.	Check at the start of every well section
7	Electrical magnetic interference	Noise will typically occur using analog, electrical signal sensors.	Proper shielding and grounding Proper routing of sensor cables	To be decided between contractor/service provider and operator
8	Hysteresis error	<p>This error is common for the derived value of the sensor due to sheave losses in the system, etc.</p> <p>There is a difference in static and dynamic friction values.</p>		
9	Quantization error	Using a digital pressure sensor output.	Use the correct signal bits. For a 1,000-t maximum value: 8 bit = 256 values = 4.9 t/step 16 bit = 65,536 values = 0.01 t/step	
10	Aliasing errors	This is not likely to occur for the hookload measurement.		
11	Outside errors	On offshore platforms the heave motion will influence the reading of the hookload due to inertia of the loads hoisted.	Averaging over time can be used to minimize this effect during calibration. It is not recommended to remove this error during normal operations.	
12	Hydraulic drift	Using hydraulic fluid-based sensors, environmental temperature could affect the readings	Use equipment that is temperature compensated Remedy examples can be either from conversion tables or electronic DLA sensors (CCE wagon wheel style) rather than pressure transducers. This is a very easy way to improve measurement fidelity and reliability with low cost impact	
13	Other error	Susceptible to large shifts due to thermal changes causing expansion/contraction of the hydraulic fluid	Address as needed	

Typical methods of calibrating the hookload readings include the following:

1. Using a calibrated load shackle and pulling at several different loads
2. Moving the block upwards/downwards with a known load and measuring the average hookload

Digital accuracy data to be provided if supported by the measurement system – The following table provides an example of metadata fields that could be added to each datapoint to ensure the end user has all necessary information to quantify sensor performance. Reference is made to WITSML standards and the IADC digital Daily Drilling Report structure that can be used as examples. It is outside the scope of this document to provide the actual structure.

#	Error type	Error metadata
1	Full scale range	FS_Max FS_Min
2	Sensitivity error	NA
3	Offset error or bias	Bias
4	Nonlinearity	
5	Dynamic error	N/A
6	Drift	N/A
7	Noise	
8	Hysteresis error	Hyst_Min Hyst_Max
9	Quantization error	Quant
10	Aliasing	NA
11	Outside errors	

3.14 Sensor Accuracy for Rig State Detection (RSD) Algorithms

Sensor data quality, in all its dimensions, is critical for the proper functioning of rig state detection algorithms; therefore, sensor data quality is critical to the systems that rely on accurate rig states, such as automated activity reporting and drilling performance monitoring. The following data are generally considered as critical for achieving quality rig states:

- Bit depth
- Hole depth
- Hook position
- Hookload
- Mud flow rate in

- Pump stroke rate
- Rotary speed
- Motor RPM
- Standpipe pressure
- Weight on bit

Examples of unreliable real-time sensor data that has led to failure in the RSD algorithms can be seen below:



Image courtesy of IDS

Negative block height – the block is below the drill floor

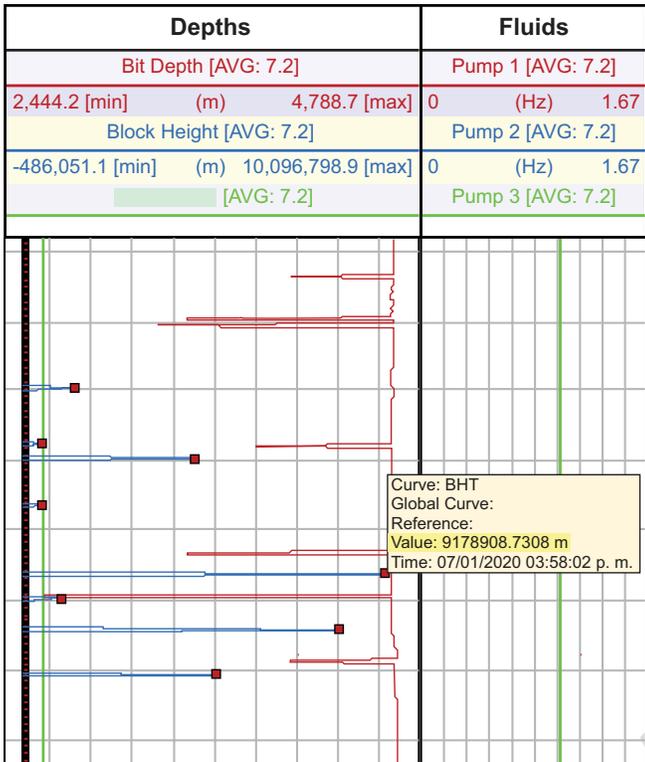


Image courtesy of IDS

Very large block heights, with irrelevant numbers of 'significant figures'

DRAFT

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