WMO OMM

World Meteorological Organization
Organisation météorologique mondiale
Organización Meteorológica Mundial
Всемирная метеорологическая организация
المنظمة العالمية للأرصاد الجوية
世界气象组织

WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

ONE GLOBE
ONE INDUSTRY
ONE VOICE

AWS TENDER SPECIFICATION

Version: 1.31

Summary and purpose of document

This document contains guidance material to enable a NMHS to procure all, or components of, an Automatic Weather Station Network.

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1 TABLE OF CONTENTS

2 AWS TENDER SPECIFICATION

This document consists of two main sections:-

- Preamble
  The aim of this section is to provide guidance to both NMHS and Tenderers as to the items that should be considered when tendering for all, or part, of an Automatic Weather Station Network.
- Tender Clauses
  This section contains example tender clauses that can be modified by the NMHS to meet the Requirements of their Data Users. Where possible, the tender clauses have been referenced to the relevant Guidance material

2.1 Key Reference Documents

1. **World Meteorological Organisation.** *Guide to the Global Observing System: WMO-No. 488.* Geneva, Switzerland : WMO, 2010 [Updated in 2013].
2. **International Civil Aviation Organisation.** *Annex 3 to the Convention on International Civil Aviation: Meteorological Service for International Air Navigation.* Montreal, Quebec, Canada : ICAO, 2016.
3. **World Meteorological Organisation.** *Manual on the Global Observing System: WMO-No. 544.* Geneva : WMO, 2015 [updated 2017].
4. —. *Guide to Meteorological Instruments and Methods of Observation [WMO-No. 8].* Geneva, Switzerland : s.n., 2014.
5. —. *Manual on the WMO Integrate Global Observing System (WMO-No. 1160).* Geneva : WMO, 2015.
6. **International Organization for Standardization.** *Solar energy - Specification and classification of instruments for measuring hemispherical solar and direct solar radiation (ISO/DIS 9060).* Geneva : ISO, 2017.
7. **WMO.** *Classification of initial and ongoing surface measurement quality.* s.l. : WMO, 2018.
8. **M. Lacombe, D. Bousri, M. Leroy, M. Mezred.** *WMO Field Intercomparison of thermometer screens/shields and humidity measuring instruments (Ghardaia, Algeria, November 2008-October 2009).* s.l. : WMO, 2011.
9. **World Meteorological Organisation.** *Manual on Codes: WMO-No. 306.* Geneva Switzerland : WMO, 2011 [Updated in 2016].
10. **International Civil Aviation Organization (ICAO).** *Manual on Automatic Meteorological Observing Systems at Aerodromes (Doc 9837).* Montreal, Canada : ICAO, 2011.

In this text, the relevant sections of these documents will be referred to whenever possible, rather than quoting or paraphrasing the text – this aims to ensure that this AWS Tender Specification can more easily maintain currency with the relevant guidelines/references.

3 RESILIENT AWS NETWORKS

In this document, the Tender Specifications have been broken up into 3 Aspects:-

- Automatic Weather Station and Sensors – the hardware that is typically placed in the location where the measurement is made.

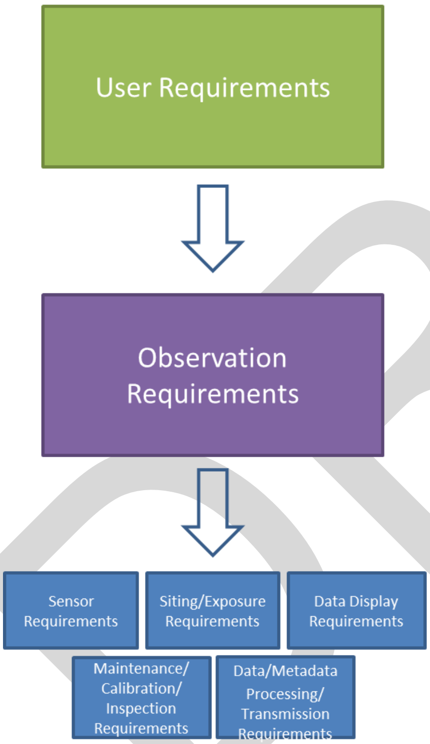
- Meteorological Information Processing System (MIPS) – the IT systems, often placed in the NMHS Head Office or other centralised location, that process, manage and store the data provided by the field equipment

- Lifecycle Management – the (largely administrative) processes, often requiring supporting hardware, facilities and training, that ensure that the AWS network meets the User Requirements from the first day and well into the future.

Too often an AWS Network Tender concentrates on obtaining new hardware (AWS/Sensors/MIPS) and invests too little in its future (lifecycle) management. The outcome is that, soon after the network is commissioned, the hardware is out of calibration and/or broken and there is no knowledge or resources to fix it.

4 ESTABLISHING REQUIREMENTS

Any AWS procurement should ideally start, not with the specification of the hardware but, with an analysis of the user requirements. That is:-



What is the main use: Examples include

- Public Weather Forecasting?
- Numerical Weather Prediction?
- Improve Agricultural Forecasting?
- Establish a climate reference?
- Early Warning System?

Leads to:

- Functional specifications
- Uncertainty/performance figures for observations
- Data/Message Outputs

Leads to:

- Tender Content

Figure 1: Steps in producing a Specification

4.1 User Requirements

The user requirements can be based on several sources of information, either in isolation or in combination, so that the best overall set is achieved for the specific user. Typical information sources include, but are not limited to, the following:-

a) Many National Meteorological and Hydrological Services (NMHS) have user requirements established over many years of discussion with end users, and refinement based on available hardware and lessons learnt from previous procurements.

b) In addition, the World Meteorological Organisation (WMO) has an ongoing Rolling Requirements Review (RRR). As described in (1) Part II 2.3, the RRR process has 4 stages:-

1) A review of user requirements for observations, within an area of application covered by WMO Programmes;
2) A review of the observing capabilities of existing and planned observing systems;
3) A Critical Review of the extent to which the capabilities (2) meet the requirements (1);
4) A Statement of Guidance based on 3)

The RRR outcomes are available from the Observing Systems Capability Analysis and Review (OSCAR) Tool. This currently lists Requirements for the following Application Areas[1]:

- Aeronautical Meteorology
- Agricultural Meteorology
- Global NWP
- High Res NWP
- Hydrology
- Nowcasting/Very Short Range Forecasting (VSFR)
- Ocean Applications
- Sub-Season to Longer Prediction (SSLP)
- Space Weather

It is expected that this list will grow over time to include a broader range of applications.

c) Many meteorological services have as a key information source some form of Numerical Weather Prediction (NWP) model (either produced by the NMHS or sourced from another agency). The NWP model data input requirements (either Global NWP or High Res NWP) may form a good starting point for user requirements, particularly in the absence of specific RRR guidance for an application are.

Ideally, User Requirements should be Hardware Agnostic – that is, they are about the End User data performance requirements, not specifying the equipment/sensors required.

4.2 Observation Requirements

User Requirements are often in terms of outputs/products at the end of the measurement/processing chain. In the Observation Requirements step, the performance of the upstream components which are needed to deliver the outputs are examined/unpacked.

For example:-

- The User Requirement is "Observational data sufficient to produce a SYNOP"
  Unpacking this leads to:
  - A required list of sensors to meet (at least) the mandatory content
  - A reporting frequency for sensors
  - Algorithms that need to be applied to the data
  - AWS/IT Infrastructure (new or existing) where these algorithms are applied
  - AWS/IT Infrastructure (new or existing) where SYNOP message content is generated
  - IT Infrastructure (new or existing) where data is archived

[1] The following Application Areas are also listed, but currently contain no data: Providing Atmospheric Composition Information, Monitoring Atmospheric Composition, Forecasting Atmospheric Composition, Climate Applications, Climate Science, Climate Monitoring (GCOS)

  - Communications requirements to get data from sensors to IT Infrastructure
  - Staff, appropriately trained and equipped, to maintain the equipment so that it continues to produce the data.
  - Facilities and staff to calibrate the equipment.

- The User Requirement is “Temperature measurements to support a Climate Archive” Unpacking this leads to:
  - Performance requirements for temperature sensors
  - Siting hardware requirements for temperature observations
  - QC/QA processes [automated or manual]
  - Data storage requirements
  - Training, equipment and calibration requirements
  - Staff to support the processes above.

4.3 Tender Specifications

The final stage, involves translating the individual components into statements that can be included in tender content – that is, statements that :

- specify a requirement clearly
- contain only the essential information for that requirement
- are written in a way that enables the response to be evaluated. For example:-
  - Yes/No: Does the tendered equipment/service have the required capability?
  - Performance Measure:
    - Values in a particular range are acceptable
    - Values in another range are good, ….

4.4 Layout of this Specification Document

Each AWS Network Tender will be different – different User requirements, different political climate, different existing NMHS infrastructure, different budgets…..

To make a specification that is useful to the most people, the guidance/requirements are grouped by:-

- Hardware [Table 1]: The “things” that make up an AWS Network
- Function [Table 2]: The “functions” that are required in an AWS Network

Table 1: AWS Network Specification Hardware Modules

Hardware	Definition	Hardware Symbol
AWS Network Management	Centralised Control/Management of AWS Network	ANM
AWS/Smart Sensors	Applies to datalogger in traditional AWS or Smart Sensors where appropriate	AS
Air Temperature		T
Cabling & Wiring		CW
Communications	Primarily between field equipment and MIPS	C
Direct Solar Radiation		DSR
GUI		GUI
General	Applies to All/Any Module	G
Global/Diffuse Sky/Reflected Radiation		GDR
IT Infrastructure	General IT Hardware wherever used	IT
Long Wave Radiation		LWR

Hardware	Definition	Hardware Symbol
MIPS All	Meteorological Information Processing System - covers AWS Network Control, Central Metatdata Storage, Measurement Data Storage, National Measurement Generation	MIPS
Measurement Data Archive	Centralised storage of observations and processed observations	MDA
National Message Generation	Generation of Products to meet WMO/RA/National Requirements	NMG
Network Metadata Management	Centralised management/storage of Metadata	NMM
Precipitation Amount		PA
Precipitation Intensity		PI
Pressure		P
Relative Humidity		U
Snowfall/Snow Cover		SSC
Software	General Software Requirements	S
Soil Temperature		ST
Solar Tracker		ST
Sunshine Duration		SD
Wind Direction		WD
Wind Speed		WS

Hardware Symbol is used to identify the Hardware (type) in the Tender Clause documents.

Table 2: AWS Network Specification Functionality

Function Name	Function Description	Code	AWS Network Aspect
Sensor/Hardware Performance	What the actual sensing equipment needs to do.	SP	AWS_Sensors
Sensor Siting	Sensor location/housing so as to provide the best performance	SS	AWS_Sensors
Measurement/Functional Requirements	Output requirements, often these are to match up with User Requirements	MR	AWS_Sensors
Observation Statistics/Algorithms	Processing of Raw Sensor Output	OS	AWS_Sensors
Observation/Site Metadata	What do we need to know about the sensor in addition to its output	OM	AWS_Sensors
Power/Site Infrastructure	What do we require of the equipment and the local infrastructure	PSI	AWS_Sensors
Derived Parameters Calculations	For example, Dew Point, QNH, Fire Indices	DPC	AWS_Sensors
Regulatory/Standards	Any requirement associated with National Regulation or International Standards	R	AWS_Sensors
HSE	Health Safety & Environment	HSE	AWS_Sensors
Message/Report Generation	Message generation to meet requirements for WMO/RA/National Users	RMG	MIPS
Metadata Storage	Stores Metadata for whole network	MS	MIPS
AWS Network Management	Controls/Manages AWS Network	ANM	MIPS
Meteorological Data Storage	Stores Measurement Data for whole network	MDS	MIPS
Alarms/Warnings/Logging	Information about the system state/status	AWL	MIPS
IT Security	IT Security/Functionality	IT	MIPS
Data Communications-AWS	Data communications to/from the AWS	DCA	MIPS
Data Communications Other	Data communications with other external data sending or receiving systems	DCO	MIPS
Meteorological Data Processing	Processing of Meteorological Parameters, including error handling	MDP	MIPS
QA/QC	QA/QC Processes [automated or manual]	QAQC	MIPS

Function Name	Function Description	Code	AWS Network Aspect
Configuration Management for AWS	Configuration Management/tools for the AWS Stations	CMA	MIPS
Configuration Management for MIPS	Configuration management/tools for the MIPS itself	CMS	MIPS
Technical Monitoring (for) AWS		TMA	MIPS
Technical Monitoring (for) MIPS		TMS	MIPS
Maintenance/Support/Training	What do we need to make this work into the future	MST	Lifecycle_Management
Capacity/Planning/Performance	Current and Future Performance	CPP	Lifecycle_Management
Financial	Any Requirement associated with costs	F	Lifecycle_Management
Tender Requirements	General Tender Requirements. Will standardly be replaced by the NMHS's own clauses	TR	Lifecycle_Management

AWS Network Aspect is described in Section 5

This grouping recognizes that, as Observation networks evolve, the hardware in which the function occurs may change.

For example, many existing Observation networks utilize a variant of the following design [Figure 2]:-

- At the site of the observation is a collection of sensors [analog and intelligent[2]].
- These sensors are attached to equipment that does local processing of the data [sometimes referred to as the datalogger or local processor].
- The output of this local processing is sent to a central/common location [often the NMHS Head Office or main computer centre], where additional processing may occur. In Figure 2, this is called the Meteorological Information Processing System (MIPS), and consists of:
    - National Message Generation
    - AWS Network Management/Control
    - Network Metadata Management
    - Measurement Data Archive
- The NMHS infrastructure then facilitates access to the data to meet local, national and international requirements.

The value of an AWS having sensors and processing co-located enables the sharing of power and communications infrastructure.

In Figure 2, each coloured rectangle represents an AWS module from **Table 2** and shows their usual locations for a Function for a "Traditional" AWS configuration.

In contrast, Figures 3 to 5 show a range of other AWS Network layouts. In each of these, there is the same deliverables functionality as in Figure 2, but the equipment and network topology changes. These Figures are indicative, but not totally inclusive of all the AWS network layout variations in use around the world.

Similarly, it is also likely that an AWS network may not require all the modules or functions listed in Table 2. Alternatively, a NMHS may already have some of the pieces in place.

[2] Throughout this document, sensors which make the measurement and provide a 'human-readable' character/text based output containing the observation are described as "intelligent" – for example, an instrument that contains a platinum resistance thermometer, but outputs a message containing a temperature in Kelvin is "intelligent". This nomenclature is used to differentiate from a "digital sensor" which may only output a value in binary.

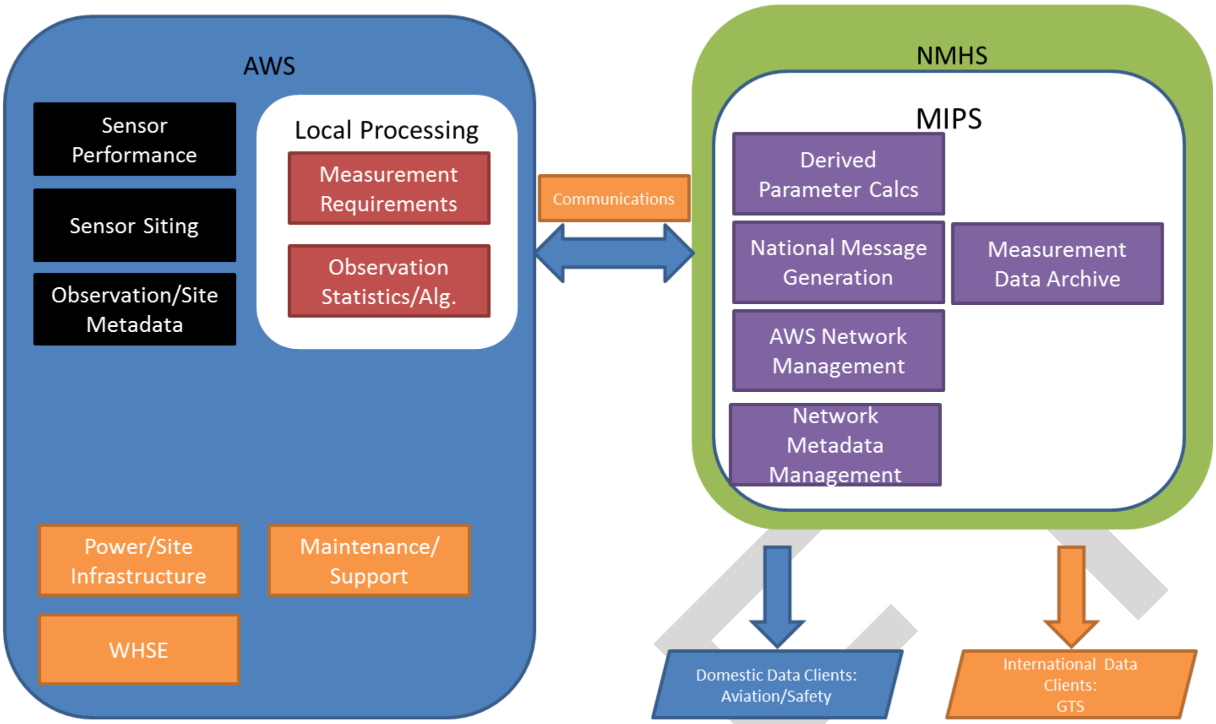


Figure 2: “Traditional” AWS with data logger and central MIPS

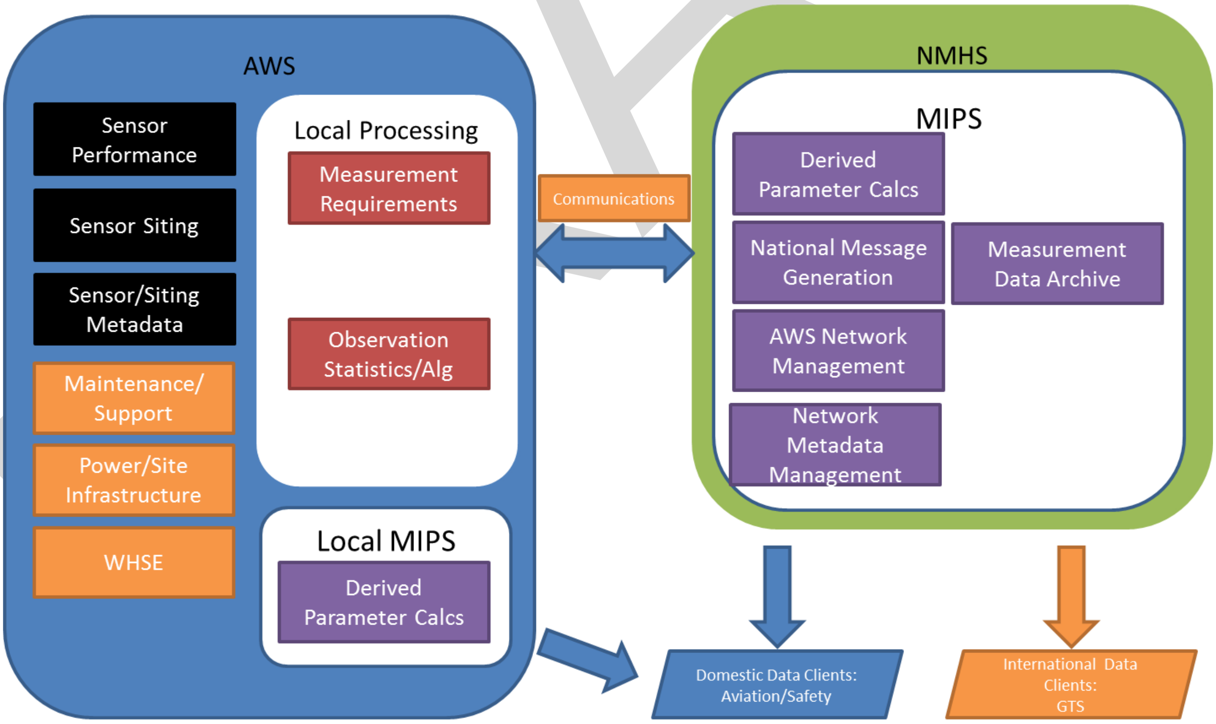


Figure 3: "Traditional" AWS configuration, with local data users.

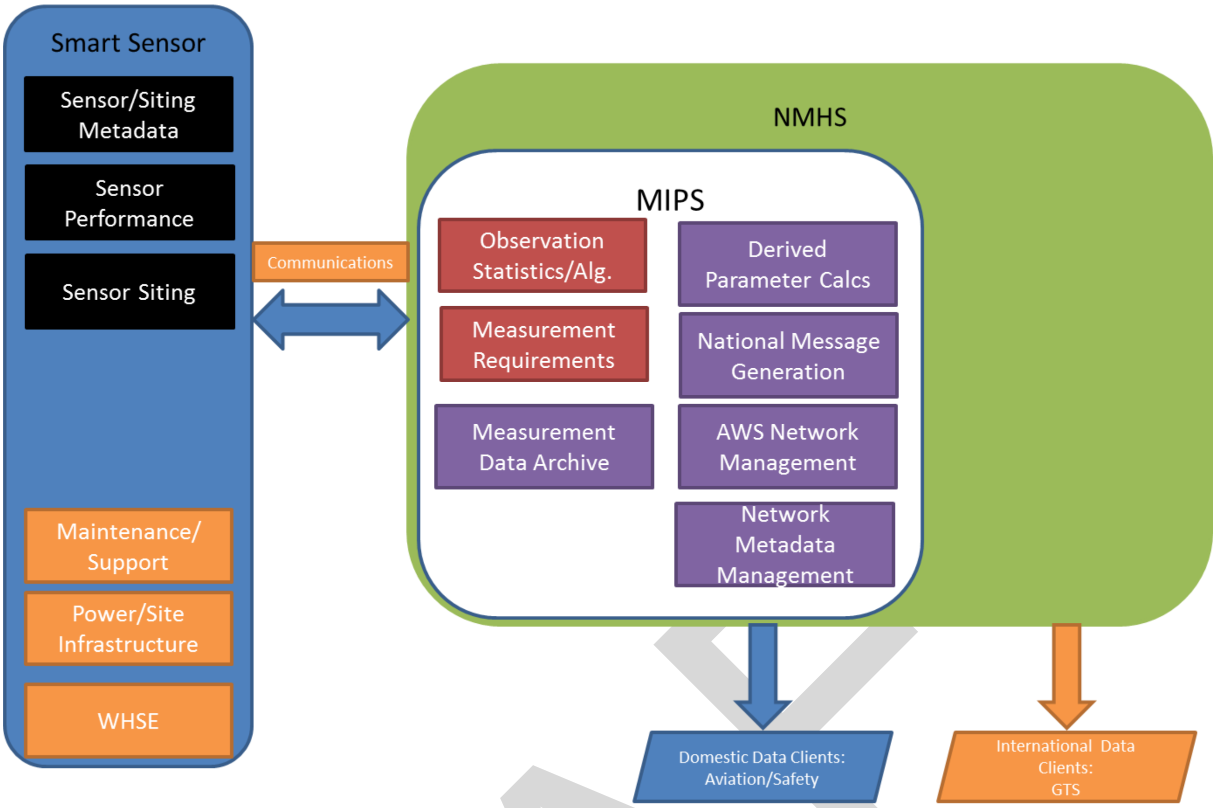


Figure 4: Partial IOT configuration

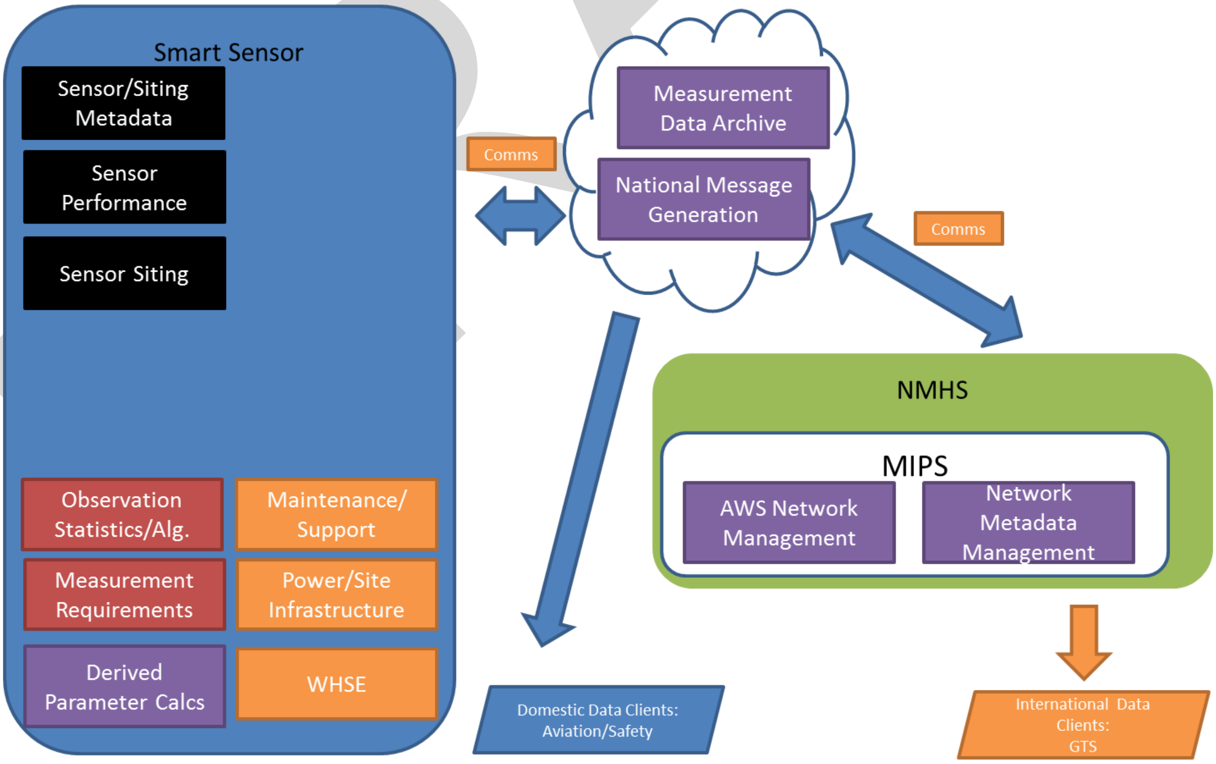


Figure 5: Full IOT Configuration

5 AWS NETWORK ASPECTS

In the following sections the key AWS Network Aspects (from Section 3 - Lifecycle Management, MIPS, AWS/Sensors) will examined in greater detail.

5.1 Lifecycle Management

5.1.1 Phases of an AWS Network Procurement

The procurement and installation of an observation network is usually a big project, which involves many other activities besides procurement of equipment.

The following phases can be identified:

1. **Preparation:** In this phase an analysis is made of what is needed to meet the identified User Requirements. This analysis may include:
    a. Equipment Siting: Is this a new network or are (some) existing sites being reused/upgraded?
    b. Network Architecture
    c. Data Communications
    d. Required Sensor Performance/Characteristics
    e. Budget
    f. Roles of Supplier/Tenderer and Customer/NMHS
    g. What is being procured: Is this just hardware, if so how will this equipment be supported into the future?

2. **Procurement Procedure:** This usually starts with preparing the requirement specifications for the systems to be procured. However, there are additional documents needed, for example, a statement of work, a concept agreement, and evaluation procedure, concept test plans, etc.

3. **Implementation:**
    a. After building the system by the Supplier, it has to be tested before installation,
    b. After acceptance it has to be installed, tested, users have to be trained, and
    c. After site acceptance and commissioning, the system can be declared operational. This phase may also include removing old equipment from station sites.

4. **Operational phase:** This is the period that the observation network is providing data for operational use. During this phase, the system owner has to
    a. maintain (preventive, corrective, calibration) the system,
    b. maintain the station and the installation sites,
    c. maintain the instrumentation, the electronics, the data processing systems, etc.

    This phase usually lasts between 10 to 15 years, much longer that the procurement and installation phases together. The owner of the system may handle the maintenance and support activities themselves, or support can be (partially) outsourced to third party (private) companies.

These phases will be considered in greater detail in the following sections.

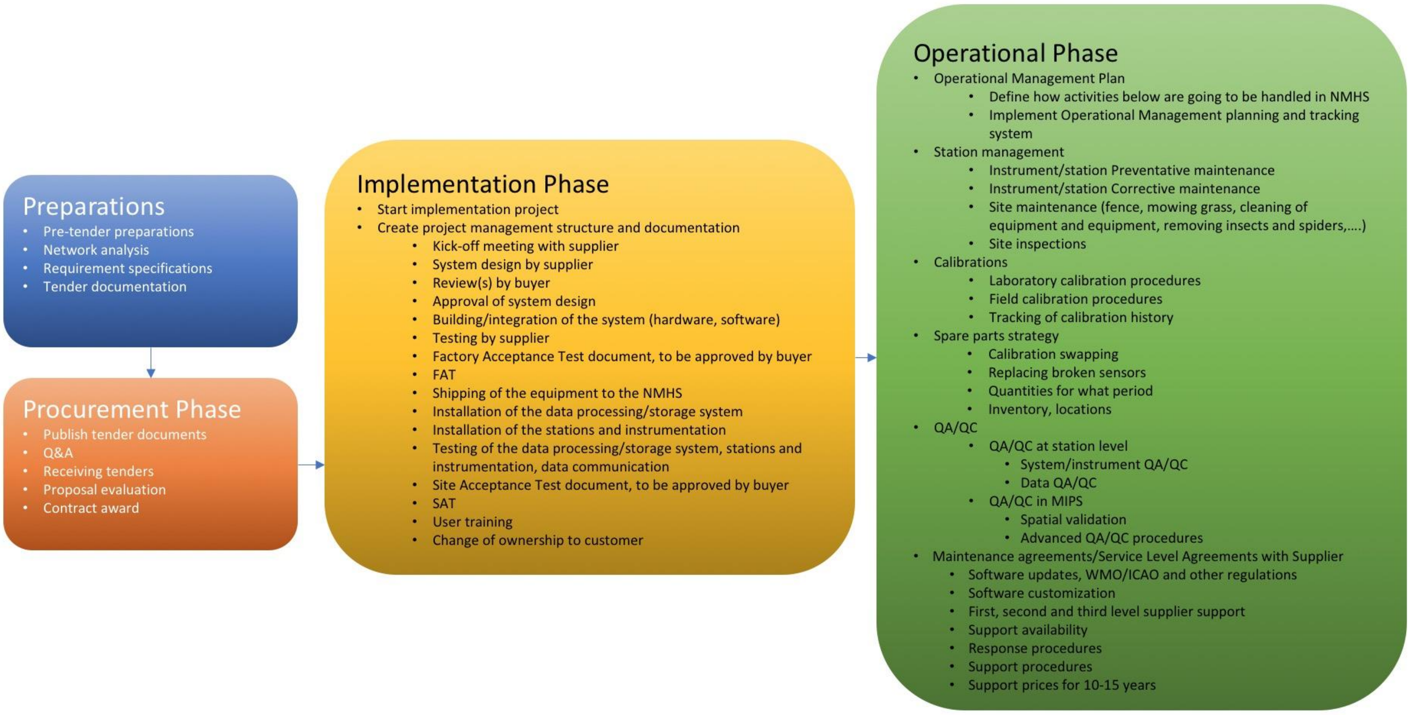


Figure 6: The different phases in purchasing, installing and operating an observation network. The activities are explained in the text.

5.1.1.1 Tender Management (Preparations and Procurement phase)

For the procurement the requirement specifications are needed, but also additional documents such as a statement of work, a concept agreement, spare part lists, acceptance protocols, factory and site acceptance procedures, etc.

5.1.1.2 Implementation Management

(Implementation Phase) The implementation of the new observation stations and data processing/storage equipment, is a project, and requires project management documentation. A typical implementation projects includes the following activities:

- Kick-off meeting with Supplier
- System design by Supplier
- Review(s) by Buyer/NMHS
- Approval of system design
  - System design should anticipate the Operational Management aspects, for example traceability of sensors, tools for maintenance.
- Building/integration of the system (hardware, software)
- Testing by Supplier
- Factory Acceptance Test (FAT) document, to be approved by Buyer/NMHS
- FAT
- Shipping of the equipment to the NMHS
- Installation of the data processing/storage system
- Installation of the stations and instrumentation
- Testing of the data processing/storage system, stations and instrumentation, data communication
- Site Acceptance Test (SAT) document, to be approved by Buyer/NMHS
- SAT
- User training
- Change of ownership to Customer

The NMHS may execute some of these activities (for example, station installation), but most of these activities require activities from the Supplier. All these activities are defined in a project plan, which is shared and agreed on with the Supplier. The Buyer/NMHS has to define this project plan, although

FAT and SAT test plans usually are provided by the Supplier, and they are only accepted by the Buyer/NMHS once the content describes testing that is satisfactory for the Buyer/NMHS. The Buyer/NMHS is strongly advised to include a Statement of Work with the tender documents that unambiguously describes what is expected from the Supplier and what are the responsibilities for the Buyer/NMHS.

5.1.1.3 Operational Management

During the operational period of the observation network, the most important things are the *availability of the data* and the *quality of the data*. To achieve the best results for both, a number of operational support activities are required. They are shown in Figure 6 and listed below.

These activities usually have to be executed by the NMHS, although some support activities are provided by the Supplier of the systems or by others.

Operational Management is the most important phase for an operational observation network. If this is not planned and arranged properly during the purchasing procedure, the NMHS may end up with an excellent quality observation network, but after a few years this network will not be capable of providing good quality observations anymore.

What	Who	Remarks
Operational Management Plan		
Define how activities below are going to be handled in NMHS	NMHS	NMHS to define how they intend to support their observation network for the next 10-15 years to guarantee the highest availability and the best data quality.
Implement Operational Management planning and tracking system	NMHS	
Station management The topics below are based on best practices from an NMHS itself and WMO provides some guidance on how to manage and maintain stations. Instrument manufactures usually provide guidance on calibration periods and procedures, but these also depend on local conditions NMHS experience).		
Instrument/station Preventative maintenance	NMHS	Guidance/instructions to be provided by the manufacturers of the instruments and equipment.
Instrument/station Corrective maintenance	NHMS	Guidance/instructions to be provided by the manufacturers of the instruments and equipment.
Site maintenance (fence, mowing grass, cleaning of equipment and equipment, removing insects and spiders,….)	NMHS	
Site inspections		
Calibrations		
Laboratory calibration procedures	NMHS/ Supplier	The calibration procedures must be provided by the manufacturers of the instruments. NMHS has to decide how the instruments are going to be calibrated. In house calibrations require skilled staff and calibration equipment.
Field calibration procedures	NMHS	If applicable
Tracking of calibration history	NMHS	
Spare parts strategy Spare parts can be purchased to be used for calibration swapping of instruments (preventative maintenance) and to quickly replace instruments when they break. The strategy on how to deal with this, has to be defined by the NMHS. The Supplier of instruments and equipment can provide a spares part list based on the spares strategy from the NMHS.		
Calibration swapping	NMHS	
Replacing broken sensors	NMHS	
Quantities for what period	NMHS/	

	Supplier	
Inventory, locations	NMHS	
QA/QC		
QA/QC at station level	NMHS/ Supplier	Basic QA/QC should be executed on the “raw” data in the stations. The NMHS must provide the algorithms/procedures, during the system configuration this has to be implemented.
System/instrument QA/QC	NMHS/ Supplier	Basic QA/QC should be executed on the system health in the stations. The NMHS must provide the algorithms/procedures, during the system configuration this has to be implemented.
Data QA/QC		
QA/QC in MIPS	NMHS	In MIPS, more sophisticated QA/QC procedures.
Spatial validation	NMHS	In MIPS, more sophisticated QA/QC procedures.
Advanced QA/QC procedures	NMHS	In MIPS, more sophisticated QA/QC procedures.
Maintenance agreements/Service Level Agreements with Supplier When an observation network system is purchased, it is good practice to ask the Supplier for a Service Level Agreement (SLA). In this SLA, the Supplier has to explain about the warranty procedures, and also additional support services they can provide during and after the warranty period. The SLA should list the services, the prices, hourly rates for support, inflation correction, etc.		
Software updates, WMO/ICAO and other regulations	NMHS/ Supplier	NMHS to sign SLA with Supplier.
Software customization	NMHS/ Supplier	NMHS to sign SLA with Supplier.
First, second and third level Supplier support	NMHS/ Supplier	NMHS to decide which levels of support they are able to provide itself. Sign SLA with Supplier if additional support is required.
Support availability	NMHS/ Supplier	NMHS to agree on in SLA with Supplier.
Response procedures	NMHS/ Supplier	NMHS to agree on in SLA with Supplier.
Support procedures	NMHS/ Supplier	NMHS to agree on in SLA with Supplier.
Support prices for 10-15 years	NMHS/ Supplier	NMHS to agree on in SLA with Supplier.

5.1.2 Example Documents

Life cycle management activities are not always easy to specify in requirement specifications for tender documents. However, it is possible to provide some example documents for life cycle management.

Table 3: Example documents for Life Cycle Management

Document	Function Description
Statement of Work	Describes activities and responsibilities for NMHS and Supplier
Training and Documentation	Describes how training and documentation can be requested in a tender.
Test Procedures	Describes how factory testing and site testing can be requested in a tender.
Maintenance Conditions	Describes how maintenance and support can be requested in a tender.
Recommended Spare Parts List	Describes what spares are required to guarantee the operations of the network for a period of time

The aim of the example documents is to provide guidance. Most NMHS have their own documents/templates/formats that should be used for this purpose. Their inclusion here allows NMHS to check their own documentation against the examples to ensure their Procurement considers the relevant aspects.

These documents have not been checked or approved by WMO legal. They are provided as examples only and should not be used without specific endorsement by the NMHS's own legal departments.

5.2 Meteorological Information Processing System (MIPS) Requirements

The main functionalities of a MIPS are:

- **Acquire meteorological data**
  Meteorological data shall be acquired from the AWS. Sometimes data from other sources also has to be ingested by the MIPS. The MIPS needs to have a "recovery mechanism" as well, i.e. a system that retrieves older data from the AWS that, for example, was missing due to failing data communication.
- **Process and store meteorological data and metadata**
  Much of the data has to be processed and stored in the MIPS, for example in a file system or in a database. The storage period should be limited to what is needed to fulfil operational requirements. The stored data is used to generate reports and real time weather monitoring and forecasting, the MIPS is not intended and designed for long term storage of data. For that purpose, and for giving access to other users of the data (climatology, scientists), the data should be copied to another database system. The MIPS also has to store metadata (station data, instrument data, calibration information, etc.).
- **Generation of meteorological reports**
  The MIPS may automatically generate meteorological reports, for examples SYNOPs, and if required, METARs for selected stations. If required, NMHS' may want to have additional types of internal or national reports.
- **Distributing meteorological data and reports**
  The MIPS shall be able to automatically distribute meteorological data and reports. SYNOP reports usually have to be sent to a message switch (MSS). The MIPS also must have the capability to interface to other external systems to send data to or to receive data from.
- **Observation network management and system configuration**
  The control, management and configuration of a meteorological observation network today can be done remotely using computers and data communication technology. The MIPS is the system for this management of the network. Moreover, the processing of data, the data files or database structure and contents, the report generation and distribution of data/reports has to be managed from the MIPS.

In addition to the user requirements, there may be additional requirements related to the system itself, such as

- System redundancy
- Data communication methodology (Ethernet, TCP/IP and other protocols, GPRS, satellite, land line,….), bi-directional between the MIPS and AWS
- Interfaces with external systems

5.2.1 Considerations

- WMO requests reports to be prepared and exchanged via the GTS via a message switch (MSS) through BUFR code. Depending on the observation network architecture that is chosen (see Figures 2 to 5), the MIPS has to prepare the reports in BUFR, or the AWS stations will have to do this (if the reports are directly forwarded from the AWS to the GTS).

- It is strongly preferred to use open data communication protocols between the AWS and the MIPS. If this is applied, then AWS stations can be replaced without being limited to a particular brand/type AWS due to proprietary communication protocols.

5.3 WMO Guidance material on AWS

5.3.1 AWS for an Application

The WMO Guide to the GOS (1), Appendix III.2 provides some basic guidance on the observations required for a range of applications [summarized in Table 5 below]. In the Table, five types of AWS are listed:-

SYNOP Land Station	Basic station to meet WMO Land Network Requirements[3].	Strong sensor quality and exposure performance requirements so that accurate forecasting can be performed. Supports aviation operations.
Principle Climatological Station	Provides significantly greater number of observations, c.f. SYNOP, in support of representing the climate characteristics of the location.	Very stringent sensor quality and exposure performance requirements so that accurate forecasting can be performed.
Aeronautical Meteorological Station	Includes all sensors required by ICAO (2)	Strong sensor quality and exposure performance requirements so that accurate forecasting can be performed in support of aviation operations.
Standard Station	Combines the principle sensors from the above Station Types.	Medium to strong sensor quality and exposure performance requirements to support forecasting and industry operations.
Other Station	Custom Station Types to provide network gap filling or to meet commercial requirements	Medium sensor quality and exposure performance requirements to support forecasting and industry operations.

Table 4: AWS Types

In the absence of User Requirements, these five common station configurations provide a useful starting point in determining the User Requirements for different applications.

It should be noted that, while the Table 4 above represents the minimum sensor suites to meet defined standard requirements, there are many reasons to deploy an AWS Network - an AWS may have only 1 or 2 sensors, or an entirely different configuration to those listed in Table 4/Table 5, yet still be Fit for Purpose for an NMHS.

[3] Note: (3) Part III 2.3.2.4 includes only Precipitation Yes/No. However, the installation of equipment to measure Precipitation Amount is recommended as it is not significantly more complex/expensive but provides information valuable for a range of Users.

	From Guide to the GOS, Appendix III.2			
	SYNOP Land Station	Principle Climatological Station	Aeronautical Meteorological Station	Standard Station
Reference	(3) Part III 2.3.2.4	(3) Part III 2.10.8	(3) Part III 2.8.5	
Atmospheric Pressure	Required	Required	Required	Required
Pressure Tendency				Optional
Air Temperature	Required	Required	Required	Required
Humidity	Required	Required	Required	Required
Surface Wind	Required	Required	Required	Required
Cloud Amount		Required	Required	Required
Extinction Profile/Cloud Base Height	Optional	Required	Required	Required
Present/Past Weather		Required	Required	Required
State of the Ground		Required		Optional
Visibility	Optional	Required	Required	Required
Precipitation Amount	Recommended	Required		Required
Precipitation Yes/No	Required	Required		Required
Intensity of Precipitation	Optional			
Soil Temperature		Required		Required
Sunshine/Solar Radiation		Required		Required

Table 5: AWS Sensor List based on Application.

Table 5 Key:

Required	(green)
Optional	(orange)
Recommended	(yellow)
Not Required	(white)

5.3.2 AWS Siting

The CIMO Guide (4) Part I, Chapter 1 Annex 1.B provides extensive guidance on the siting of individual sensors.

It should be noted that the siting requirements refer, not just to the surroundings of the Meteorological Equipment Enclosure, but to the other equipment in the enclosure. The following references provide some examples of the particular care must be taken to ensure correct measurement:-

Requirement		Relevant Guidance
Temperature/solar radiation equipment is not shaded		(4) Annex 1.B 2
The airflow around radiation shields/screens, precipitation gauges and wind measurement equipment is not significantly impacted	Temperature/ Humidity	(4) Annex 1.B 2
	Precipitation	(4) Annex 1.B 3
	Wind	(4) Annex 1.B 4 (4) Part I, 5.9.2
Temperature/solar radiation equipment is not located near heat sources		(4) Annex 1.B 2
Solar Radiation equipment is not placed so that reflected radiation from other equipment impacts the measurement	Global/Diffuse Radiation	(4) Annex 1.B 5
	Direct Radiation/ (5)Sunshine Duration	(4) Annex 1.B 6
Maintenance of equipment (particularly anemometer masts) can be done safely and without unduly impacting other observations		(5) 2.4.1.7

Many NMHS have developed their own layouts, which reflect local and historical priorities. In the absence of such guidance the layout in **Error! Reference source not found.** meets WMO Class 1 siting requirements for the instruments in the Southern Hemisphere – the mirror image [that is, with the anemometer at the top] would be suitable for the Northern Hemisphere.
Note: the layout meets Class 1 requirements of the instruments with respect to each other – Class 1 also requires clearances around the enclosure [See (4) *Annex 1.B]*. There is further discussion of this in Annex 1.

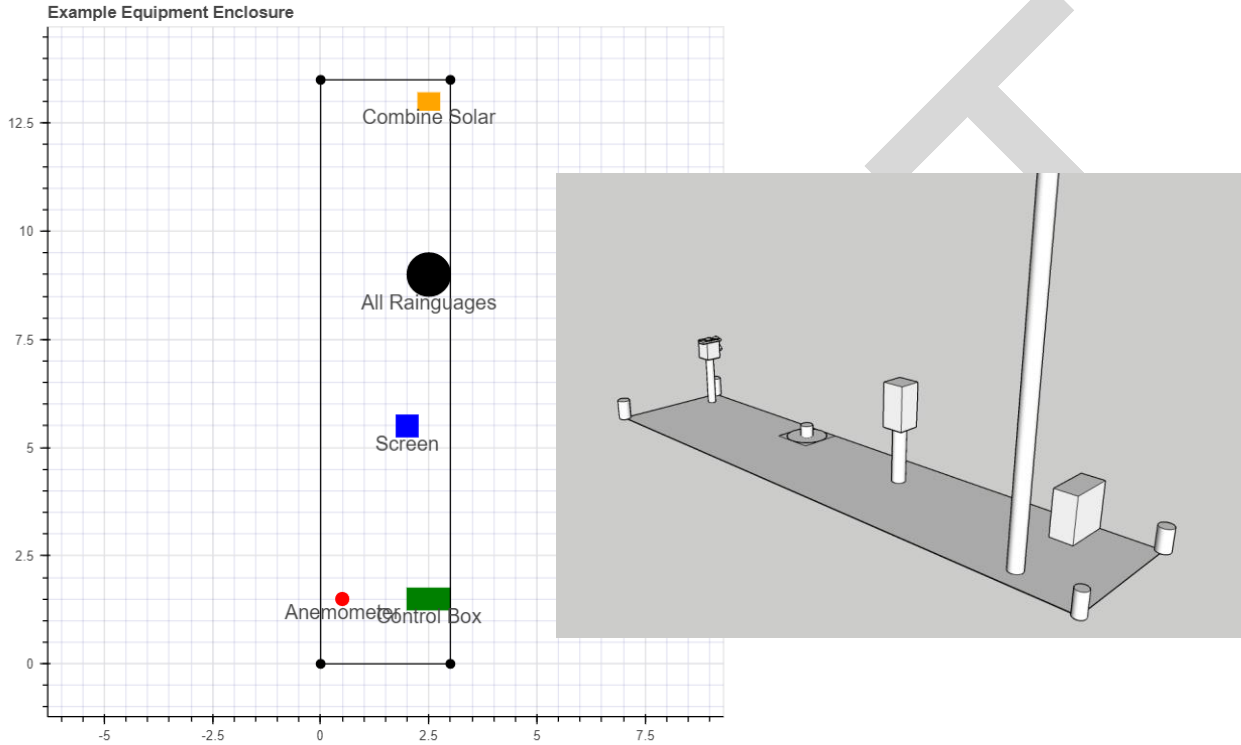


Figure 7: Example Met Enclosure Layout that meets CIMO Class 1 Guidance for equipment layout in the Southern Hemisphere

5.3.3 WMO Guidance on Observations

The WMO provides guidance specific to the measurement of individual variables, primarily in the CIMO Guide (4).

Observation	Exposure/Siting	Suitable Sensors	Specified Technologies	Available Technologies
Temperature	(4) Part I 2.1.4.1/ Part I 2.4.3	(4) Part I 2.4	Electrical Resistance or Thermocouple (3) Part III 3.3.3.1	Electrical Resistance/ Thermocouple/ Thermistor
Grass Temperature	(4) Part I 2.2.2.2	(4) Part I 2.4		Electrical Resistance/ Thermocouple/ Thermistor
Pressure	(4) Part I 3.8	(4) Part I 3.3		Variable Capacitive/ Piezo-resistive/ Resonance
Humidity	(4) Part I 4.1.4.2/4.6.5 [Psychrometer Siting 4.2.2.3]	(4) Part I 4.6	Psychrometer or other instrument of equal or better accuracy (3) 3.3.4.1	#Electrical Psychometric/ Capacative
Surface Wind	(4) Part I 5.9	(4) Part I 5.4-5.6		Speed:Cup/Propeller Direction:Vane Both: Ultrasonic
Precipitation Amount & Precipitation Intensity	(4) Part I 6.2, 6.4	(4) Part I 6.5		TBRG/Weighing Gauges
Soil Temperature	(4) Part I 2.2.2.3 [Depths: 5/10/20/50/100cm], 2.4.3(c) (3) Part III, 3.3.12.1 [Depths: 5/10/20/50cm] (3) Part III, 2.10.9 [At Principal Climatological Stations Depths: 5/10/20/50/100/150/300cm] (3) Part III, 2.13.5 [At Agricultural Meteorological Stations Depths: 5/10/20/50/100cm]	(4) Part I 2.4		Electrical Resistance/ Thermocouple/ Thermistor
Sunshine Duration&	(4) Part I 8.3	(4)Part I 8.1.4, 8.2		Pyroheliometers Pyranometers
Direct Solar^ radiation	(4) Part I 7.2.2	(4)Part I 7.2	Pyrheliometers (4)Part I 7.2	Pyrheliometers
Global and Diffuse Sky Radiation^&	(4) Part I 7.3.2.1, 7.3.3	(4)Part I 7.3	Pyranometer (4)Part I 7.3	Pyranometers
Long Wave Radiation^	(4) Part I 7.4	(4)Part I 7.4	Pyrgeometers Pyranometers	Pyrgeometers
Snowfall/Snow Cover	(4) Part I 6.7	(4)Part I 6.7.2		Ultrasonic laser

The use of electrical psychometric methods [that is, wet/dry electrical thermometers] requires regular filling of water reservoirs/maintenance of wick. For this reason, it is not recommended for sites which will require unattended operation.
^ See Note below
& Depending on hardware used, this observation may require a solar tracker.

Note: Most WMO Guidance on observation performance is hardware agnostic – that is, the requirements specify the performance of the *measurement* not the specific hardware. In contrast, solar radiation observations are very closely linked to specialised hardware used to perform the measurement and the requirements are derived from ISO (6) and WMO (4) guidance on this hardware.

5.3.3.1 Sensor/Siting Performance

Observation	Installation Height	Measurement Range	Operational Conditions	Reporting Resolution	Sensor Performance Constant	Sensor Uncertainty
Air Temperature	1.25 - 2.0m[4]Part I, 2.1.4.1	-80C - 60C[4]Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1 Environmental	0.1C[4]Annex 1.E	Time Constant: 20s[4]Annex 1.E	0.2C[4]Part I, Annex 1.E
Direct Solar Radiation	1.5m [or non obstructed height][ ]	0 – 2,000 W/m^2[ ]	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1 Environmental	1 W/m^2.[4]Part I, Annex 1.E	Response Time [95%]: < 30s[4]Part I, Table 7.2 [Good Quality Pyrheliometers]	1 min totals [0.9%]/1 hour totals [0.7%]/daily totals [0.5%][4]part I, Table 7.2
Global/Diffuse Sky/Reflected Radiation	1.5m [or other unobstructed height][4]Part I, 7.3.3.4 [1-2m]	0 – 2,000 W/m^2[ ]	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1 Environmental	1 W/m^2[4]Part I, Annex 1.E		1 hour totals:3%/daily totals: 2%[4]Part I, Table 7.4 [High Quality]
Long Wave Radiation	1.5m [or other unobstructed height][ ]	-250 – +250 W/m^2[ ]	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1 Environmental	1 W/m^2[4]Part I, Annex 1.E		daily totals: 10%[4]Part I, Annex 1.E
Precipitation Amount	Local Requirements[4]Part I, 6.1.4.1	0-500mm/day[4]Part I, Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	0.1mm[4]Part I, Annex 1.E		5% or 0.1 mm[4]Part I, Annex 1.E
Precipitation Intensity	Local Requirements[4]Part I, 6.1.4.1	0.02 – 2,000 mm/hour[4]Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	0.1mm/hr[4]Part 1, Annex 1.E		Under constant flow conditions in laboratory: o 5% for > 2 mm/h, o 2% for > 10 mm/h. • In the field: o 5 mm/h, o 5% above 100 mm/h.[4]Part I, Annex 1.E
Pressure	No Requirement[ ]	500-1080HPa[4]Part I, Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	0.1hPa[4]Part I, Annex 1.E	2s[4]Part I, Annex 1.E	0.15 hPa [Tendency 0.2hPa][4]Part I, Annex 1.E
Relative Humidity	1.25 - 2.0m[4]Part I, 4.2.2.3	0-100% [DP: -80-35C][4]Part I, Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	1% [DP: 0.1C][4]Part I, Annex 1.E	Time Constant:40s/ [DP: 20s][4]Annex 1.E	+/- 3 %RH [DP: 0.25C][4]Part I, Annex 1.E
Snowfall/Snow Cover	Local Snowfall conditions determine height[ ]	0-25m[4]Annex 1.E [Note difference to G2G Annex III.1 [0-10m]	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1 Environmental	1 cm[4]Annex 1.E	Time Constant: 10s[4]Annex 1.E	1cm[4]Part I, Annex 1.E
Soil Temperature	5/10/20/50/100(opt)/150(opt)/300(opt) cm[2]Part III, 2.10.9 and 2.13.5	-50 °C to +50 °C[4]Annex 1.E	-40/55C, 0/100%RH, [50m/s][8]Appendix B, 3.1 Environmental	0.1 °C[4]Annex 1.E	20s[4]Annex 1.E	0.2C[4]Part I, Annex 1.E
Sunshine Duration	1.5m [or other unobstructed height][ ]	0-24h[4]Part I Annex 1.E 7.1	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	60s[4]	Time Constant: 20s[4]Part I, Annex 1.E 7.1	0.1h or 2%[4]Part I, Annex 1.E
Wind Direction	10m[4]Part I, 5.9.2	0-500mm/day[4]Part I, Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	1 degree[4]Part I, Annex 1.E	Damping Ratio:>0.3[4]Annex 1.E, Part I, 5.1.1	5 degrees[4]Part I, Annex 1.E
Wind Speed	10m[4]Part I, 5.9.2	0-75m/s[4]Part I, Annex 1.E	-40/55C, 0/100%RH, 50m/s[8]Appendix B, 3.1	0.5m/s[4]Part I, Annex 1.E	Distance Constant:2-5m[1]Part I, Annex 1.E; Part IV Chapter 2 2.2.3	• 0.5 m/s for WS ≤ 5 m/s, • 10% for WS > 5 m/s[4]Part 1, Annex 1.E

5.3.3.2 Processing Performance

Observation	Calculated Parameters	Minimum Data	Sampling Frequency	Stuck Sensor	Units
Air Temperature	Instantaneous Value = 1 Minute Average[4]Part II, 1.3.2.4	66%[1]Appendix VI.2 2. Basic Quality Control Procedures(ii)	4 times in sensor time constant[4]Part IV, Chapter 2, 2.4.2	0.1C[1]Appendix VI.2 2.b.ii	degrees Celsius[4]1.5.3.1 Symbols and Units
Direct Solar Radiation	[4]Deduced from Part I, Table 7.2 Uncertainties	66%[1]Appendix VI.2 2. Basic Quality Control Procedures(ii)	2x in Sensor Time Constant[4]Part IV, Chapter 2, 2.4.2		W/m^2[4]Part I, 1.5.3 (k)
Global/Diffuse Sky/Reflected Radiation	[ ]Deduced in part from Part I, Table 7.4 Origin of 10 min, net shortwave and stats?	66%[1]Appendix VI.2 2. Basic Quality Control Procedures(ii)	2 tims in sensor time constant[4]Part IV, 2.4.2		W/m^2[4]Part I, 1.5.3.1 (k)
Long Wave Radiation	[ ]	66%[1]Appendix VI.2 2. Basic Quality Control Procedures(ii)	[4]Part IV, 2.4.2		W/m^2[4]Part I, 1.5.3 (k)
Precipitation Amount	[ ]				mm[4]1.5.3.1 Symbols and Units
Precipitation Intensity	[ ]				mm/hr[4]Part I, 1.5.3 (g)
Pressure	[4]Part II, 1.3.2.4	66%[1]Appendix VI.2 Part 2.II	2Hz[4]Part IV, Chapter 2, 2.4.2	0.1hPa[1]Appendix VI.2 2.b.ii	hPa[4]1.5.3.1 Symbols and Units
Relative Humidity	[4]Part II, 1.3.2.4	66%[1]Appendix VI.2 2.b.ii	4 times in sensor time constant[4]Part IV, Chapter 2, 2.4.2	1% RH [RH	% [DP: degrees C][4]1.5.3.1 Symbols and Units
Snowfall/Snow Cover	[ ]				0.1cm[1]Appendix III.1 [not consistent with 1cm resolution in CIMO Guide Annex 1.E]
Soil Temperature	[4]Part II, 1.3.2.4	66%[1]Appendix VI.2.2	Every 10 seconds or better[4]Part IV, Chapter 2, 2.4.2		degrees C[4]1.5.3.1b
Sunshine Duration	[ ]		[4]Part IV, 2.4.2		hours (h)[4]1.5.3.1 (l)
Wind Direction		75%[1]Appendix IV.2 a.ii	1Hz or greater [4Hz Preferred][4]Part II, 1.3.2.4	10 degrees[1]Appendix VI.2. 2.b.ii	degrees[4]1.5.3.1 Symbols and Units
Wind Speed	[4]Part I, 5.1.1;5.8.3; Part II, 2.2.1	75%[1]Appendix IV.2 a.ii	1Hz or greater [4Hz Preferred][4]Part II, 1.3.2.4	0.5m/s[1]Appendix VI.2. 2.b.ii	m/s[4]1.5.3.1 Symbols and Units

5.3.4 Total Measurement Uncertainty

The Total Measurement Uncertainty specified in User Requirements are typically for "all the Uncertainty" in the Measurement – the Uncertainty Budget. For a typical meteorological measurement, the Budget can be broken down into:-

- **Siting Uncertainty:** How well does the location of the Meteorological Equipment represent the surrounding area?
- **Total Measuring System Uncertainty:** This encompasses-
    - **Exposure Uncertainty:** What is the impact of the exposure on the measurement?
    - **Instrument Uncertainty:** What is the uncertainty due to the sensor and the electronic measurement process at the AWS?
    - **Calibration and Adjustment Uncertainty:** What is the uncertainty in the Calibration and Adjustment processes?
    - **Field Verification Uncertainty:** What is the uncertainty in the Field Verification processes?

5.3.4.1 Siting Uncertainty

To date, Siting Uncertainty has been described, but not quantified, by tools such as the CIMO Siting Classifications ((4) Part I, Annex 1.B).
The WMO is currently undertaking a number of projects to quantify these effects.

5.3.4.2 Total Measuring System Uncertainty

WMO has developed a Sustained Performance Classification (7) that recommends Measurement System Uncertainties based on the User Requirements for the AWS. These Classifications are:-

- Class A: Measurement meets the WMO/CIMO required or achievable uncertainty. Maintenance and calibration are organized to sustain this measurement uncertainty in the field and over time. For example, the measurements at reference climatological or research stations.
- Class B: Measurement has a wider uncertainty interval than class A. Maintenance and calibration are organized to sustain this measurement uncertainty in the field and over time. For example, the measurements at synoptic or controlled aeronautical stations.
- Class C: Specifications and/or ongoing maintenance and calibration are more relaxed than class B. For example, the measurements at well-maintained public weather stations.
- Class D: Initial specifications wider than class C or no information available, and unknown quality of the data over time. For example, the measurements at crowdsourced weather stations.

In the absence of User Requirements, it is recommended that AWS equipment meet Class B.

The Exposure Uncertainty, Instrument Uncertainty, Calibration/Adjustment Uncertainty and Field Verification Uncertainty all contribute to the Total Measuring System Uncertainty, and hence the classification.

5.3.4.2.1 Exposure Uncertainty

The exposure includes all the hardware and engineering required to place the sensor in the environment – for example, instrument screens/radiation shields, masts and posts, mounting arms, cabinets, etc.

To date, some information is available from WMO intercomparisons (for example, (8)).

In the interim, this AWS Tender specification recommends clauses, where Tenderers are supplying the exposure hardware (for example, instruments in a screen), that require Tenderers to provide details/estimates of the uncertainty introduced by their exposure hardware. This can include the conditions under which the details/estimates are valid. This will enable Customers/NMHS to compare the offerings from different Tenderers.

5.3.4.2.2 Instrument Uncertainty

This includes everything involved in producing the "number" at the AWS. i.e. the uncertainty of the "just calibrated" sensor, the uncertainty of the electronics used to convert the measured parameter [e.g. resistance] into the meteorological variable [e.g. temperature], the drift of the sensor and electronics over time, and the effect of ageing/maintenance/cleaning on the sensor performance.

The WMO provides guidance ((4) Part I, Annex 1.E) on Required and Achievable Measurement Uncertainties for the *uncertainty of the reported value with respect to the true value* i.e. the Total Measurement Uncertainty. However, these have commonly been somewhat incorrectly used to define the uncertainty of only the Measurement System Uncertainty.

This AWS Tender specification recommends 2 clauses in this area:-

- A clause which uses the Achievable Measurement Uncertainty values ((4) Part I, Annex 1.E) for the Measurement System Uncertainty (sensor and measurement electronics) as delivered; and
- A clause, seeking details/documentation from the Tenderer on the expected performance of the Measurement System (the sensor/electronics supplied by the Tenderer) including at least a year under Field/Operational conditions. In their response, the Tenderer may need to describe the calibration and maintenance regime required to achieve their stated measurement system performance.

This will enabled Customers to compare the offerings of different Tenders.

5.3.4.2.3 Calibration and Adjustment Uncertainty

This includes the uncertainty in the Calibration references, and the processes/algorithms/equipment [e.g. thermal baths] that are used to perform the comparisons, and adjustments.

It is anticipated that aspect of the Uncertainty Budget has already be undertaken by the calibration laboratories of many member NMHS.

5.3.4.2.4 Field Verification Uncertainty

This includes the uncertainty in the Field transfer standards, and the processes/algorithms/equipment that are used to perform the verifications.

It is anticipated that tools for this will be produced by WMO in the future to quantify the uncertainties introduced using this process.