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CHAPTER 5. TRAINING OF INSTRUMENT SPECIALISTS

5.1 INTRODUCTION

5.1.1 General

Given that the science and application of meteorology ~~are based~~rely increasingly on continuous series of measurements using instruments and systems of increasing sophistication, this chapter is ~~concerned with~~focused on the training of those specialists who deal with all aspects of these systems: the planning, specification, design, installation, calibration, maintenance and ~~application~~operation of the meteorological measuring instruments and remote-sensing systems~~.~~, and the management of observations programmes and networks. Although to a lesser extent, the chapter also deals with the training requirements for those performing manual observations[1]. Competency frameworks for all these specialists are provided in Annexes 5.A to 5.D and are addressed more fully in 5.2.4. This chapter is aimed at technical managers and trainers and not least at the observations and instrument specialists themselves who want to advance in their profession.

Training skilled personnel is critical to the availability of necessary and appropriate technologies in all countries so that the WMO Integrated Global Observing System (WIGOS) can produce cost-effective data of uniform good quality and timeliness. However, more than just technical ability with instruments is required. Modern meteorology requires technologists who are also capable as planners and project managers, knowledgeable about telecommunications and data processing, good advocates for effective technical solutions, and skilled in the areas of financial budgets and people management. Thus, for the most able instrument specialists or meteorological instrument systems engineers, training programmes should be broad-based and include personal development and management skills as well as expertise in modern technology.

Regional Training Centres (RTCs)[2] have been established in many countries under the auspices of WMO, and many of them offer training in various aspects of the operation and management of instruments and instrument systems. ~~Regional Training Centres are listed in the annex.~~ Similarly, Regional Instrument Centres (RICs)[3] and Regional Marine Instrument Centres (RMICs)[4] have been set up in many places, and some of them can provide training. ~~Their locations and functions are listed in Part I, Chapter 1, Annex 1.A, and Part II, Chapter 4, Annex 4.A and are discussed briefly in sections 5.5.1.2, and 5.5.1.3, respectively.~~

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[1] For example: cloud, visibility, present weather or sea state observations, at locations where advanced instrumentation for these purposes are unavailable.

[2] For the most recent information on RTCs and their components, please visit: https://www.wmo.int/pages/prog/dra/etrp/rtcs.php

[3] Information on RICs capabilities and activities is available in Volume I, Chapter 1, Annex 1.C of this Guide and at: https://www.wmo.int/pages/prog/www/IMOP/instrument-reg-centres.html

[4] For RMICs please see Volume II, Chapter 4, Annex 4.A of this Guide, or visit: http://www.jcomm.info/index.php?option=com_content&view=article&id=335:rmics&catid=34:capacity-building

5.1.2 Technology transfer

Training is a vital part of the process of technology transfer, which is the developmental process of introducing new technical resources into service to improve quality and reduce operating costs. New resources demand new skills for the introductory process and for ongoing operation and maintenance. This human dimension is more important in capacity ~~building~~development than the technical material.

As meteorology is a global discipline, the technology gap between developed and developing nations is a particular issue for technology transfer. Providing for effective training strategies, programmes and resources which foster self-sustaining technical infrastructures and build human capacity in developing countries is a goal that must be kept constantly in view.

5.1.3 Application to all users of meteorological instruments

This chapter deals with training mainly as an issue for National ~~Hydrometeorological~~Meteorological and Hydrological Services~~.~~ (NMHSs). However, the same principles apply to any organizations that take meteorological measurements, whether they train their own staff or expect to recruit suitably qualified personnel. In common with all the observational sciences, the benefits of training are self-evident, to ensure standardized measurement procedures and the most effective use and care of equipment~~, are self-evident~~.

5.2 APPROPRIATE TRAINING FOR OPERATIONAL REQUIREMENTS

5.2.1 Theory and practice

Taking measurements using instrument systems depends on physical principles (for example, the ~~thermal expansion of mercury~~change in resistance) to sense the atmospheric variables and transduce them into a standardized form that is convenient for the user~~,~~ (for example, ~~a recorded trace on a chart or~~ an electrical signal to input into an automatic weather station~~.~~). The theoretical basis for understanding the measurement process must also take into account the coupling of the instrument to the quantity being measured (the representation or ~~"~~exposure~~"~~) as well as the instrumental and observational errors with which every measurement is fraught. The basic measurement data is then often further processed and coded in more or less complex ways, thus requiring further theoretical understanding~~,~~ (for example, the reduction of atmospheric pressure to mean sea level~~ and~~, or upper-air messages derived from a radiosonde flight~~.~~).

Taking the measurement also depends on practical knowledge and skill in terms of how to install and set up the instrument to take a standardized measurement, how to operate it safely and accurately, and how to carry out any subsequent calculations or coding processes with minimal error.

Thus, theoretical and practical matters are closely related in achieving measurement data of known quality, and the personnel concerned in the operation and management of the instrument systems need theoretical understanding and practical skills which are appropriate to the complexity and significance of their work. The engineers who design or maintain complex instrumentation systems require a particularly high order of theoretical and practical training.

5.2.2 Matching skills to the tasks

Organizations need to ensure that the qualifications, skills and numbers of their personnel or other contractors (and thus training) are well matched to the range of tasks to be performed. For example, the training needed to read air temperature in a Stevenson screen is at the lower end of the range of necessary skills, while theoretical and practical training at a much higher level is plainly necessary in order to specify, install, operate and maintain automatic weather stations, meteorological satellite receivers and radars.

Therefore, it is useful to apply a classification scheme for the levels of qualification for operational requirements, employment, and training purposes. The national grades of qualification in technical education applicable in a particular country will be important benchmarks. To help the international community achieve uniform quality in their meteorological data acquisition and processing, WMO recommends the use of its own classification of personnel with the accompanying duties that they should be expected to carry out competently.

5.2.3 WMO classification of personnel

The WMO classification scheme[5] identifies two broad categories of personnel: ~~graduate~~ professionals and technicians (WMO, ~~2001~~2015a). For meteorological and hydrological personnel, these categories are designated as follows: meteorologist and meteorological technician, and hydrologist and hydrological technician, respectively. The recommended ~~syllabus~~learning outcomes for each ~~class~~classification includes a substantial component on instruments and methods of observation related to the education, training and duties expected at that level. The WMO classification of personnel also sets guidelines for the ~~work content,~~ qualifications ~~and skill levels required~~ for instrument specialists~~. Section 7.3 of WMO (2001) includes an example of competency requirements, while WMO (2002) offers~~, including detailed ~~syllabus examples~~learning outcomes for the initial training and specialization of meteorological personnel. These guidelines enable syllabi and training courses to be properly designed and interpreted; they also assist in the definition of skill deficits and aid the development of balanced national technical skill resources.

5.2.4. WMO Competencies for Meteorological Observations, Instrumentation, Calibration and Observing Programme and Network Management

The WMO competency frameworks for Meteorological observations (Annex 5.A), Instrumentation (Annex 5.B), Calibration (Annex 5.C) and Observing Programme and Network Management (Annex 5.D) provide a more detailed description of the job responsibilities, job tasks, knowledge and skills of instruments practicing professionals, as opposed to required entry qualifications described in the Guide to the Implementation of Education and Training Standards in Meteorology and Operational Hydrology (WMO, 2015a). The role of these frameworks is to aid in identifying training needs as well as in defining the appropriate learning outcomes of training. These replace the competencies previously found in the Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology, 7.3, (WMO, 2001). These standards can be used to assess staff members, identify training needs, and help to scope the desired learning outcomes of training initiatives. The Guide to Competency (WMO, 2018) provides further guidance on competency assessment and management, as well as competency-based training.

5.3 SOME GENERAL PRINCIPLES FOR TRAINING

5.3.1 Management policy issues

5.3.1.1 A personnel plan

It is important that ~~National Meteorological Services~~NMHSs have a personnel plan that includes instrument specialists, recognizing their value in the planning, development and maintenance of adequate and cost-effective weather observing programmes. The personnel plan would show all specialist instrument personnel at graded levels ~~(WMO, 2001)~~ of qualification~~.~~ (WMO, 2015a). Skill deficits should be identified and provision made for recruitment and training. The WMO competency frameworks (Annexes 5.A to 5.D) will help in refining personnel plans. Quality

[5] Classification scheme approved by the WMO Executive Council at its fiftieth session (1998), and endorsed by the World Meteorological Congress at its thirteenth session (1999).

management systems are also now recommended for all services, and quality systems are required under WMO technical regulations for Aeronautical meteorological services (WMO, 2016).

5.3.1.2 Staff retention

Every effort should be made to retain scarce instrumentation technical skills by providing a work environment that is technically challenging, has opportunities for career advancement, and has salaries comparable with those of other technical skills, both within and outside the ~~Meteorological Service~~NMHS.

5.3.1.3 Personnel development

Training should be an integral part of the personnel plan. The introduction of new technology and re-equipment imply new skill requirements. New recruits will need training appropriate to their previous experience, and skill deficits can also be made up by enhancing the skills of other staff. This training also provides the path for career progression. It is helpful if each staff member has a career profile showing training, qualifications and career progression, maintained by the training department, in order to plan personnel development in an orderly manner.

5.3.1.4 Balanced training

National training programmes should aim at a balance of skills over all specialist classes and job responsibilities (as described in the competency frameworks, Annexes 5.A to 5.D), giving due attention to the ~~training, supplementation~~initial, supplemental and refresher phases of training, and which result in a self-sustaining technical infrastructure.

5.3.2 Aims and objectives for training programmes

In order to achieve maximum benefits from training it is essential to have clear aims and specific objectives on which to base training plans, syllabi and expenditure. The following strategic aims and objectives for the training of instrument specialists may be considered.

5.3.2.1 For managers

Management aims in training instrument specialists should be, among others:

(a) To improve and maintain the quality of information in all meteorological observing programmes;

(b) To enable ~~National Meteorological and Hydrological Services (NMHSs)~~NMHSs to become self-reliant in the knowledge and skills required for the effective planning, implementation and operation of meteorological data-acquisition programmes, and to enable them to develop maintenance services ensuring maximum reliability, accuracy and economy from instrumentation systems;

(c) To realize fully the value of capital invested in instrumentation systems over their optimum economic life.

WMO is developing a Compendium of Topics for Management Development for NMHSs (in preparation), which includes topics related to managing people (coaching and mentoring; influencing, negotiating and managing conflict; leading teams; motivating teams; managing time; communicating effectively; managing human resources) and topics related to organizational development (managing finance, managing projects; managing change; planning strategically), which are required more by middle and senior managers. Instrument specialists with leadership aptitude should be identified for management training at an appropriate time in their careers, and provided opportunities for development.

5.3.2.2 For trainers

~~The design of training courses should aim:~~

~~(a) To~~WMO has developed a set of Competency Requirements for Education and Training Providers for Meteorological, Hydrological, and Climate Services (WMO, 2013). This framework describes the following job responsibilities as competency units:

1. Analyse the organizational context and manage the training processes;
2. Identify learning needs and specify learning outcomes;
3. Determine a learning solution (or mechanism for training);
4. Design and develop learning activities and resources;
5. Deliver training and manage the learning process.

Fulfilment of each of these competencies will help to provide balanced programmes of training which meet the defined needs of the countries within each region for skills at ~~graded~~all levels;

~~(b) To provide~~ ensure effective knowledge ~~transfer~~ and skill ~~enhancement~~development in ~~National Meteorological Services~~NMHSs by using appropriately qualified tutors, good ~~training aids~~learning resources and facilities, and effective learning methods;

~~(c) To~~ provide for monitoring the effectiveness of training by appropriate assessment and reporting procedures; and help to provide effective training within given constraints. See 5.4 for a more detailed description of these competency areas.

~~(d) To provide training at a minimum necessary cost.~~

5.3.2.3 For ~~trainers and~~ instrument specialists

The general ~~objective~~goal of training ~~is to equip~~ instrument specialists ~~and engineers (at graded levels of training and experience):~~

~~(a) To appreciate~~is to develop the ~~use, value and desirable accuracy of all instrumental measurements;~~

~~(b) To understand and apply the principles of siting instrument enclosures and instruments so that representative, homogeneous and compatible datasets are produced;~~

~~(c) To acquire the~~competencies (skills, knowledge~~ and skill to carry out installations, adjustments and repairs and to provide a maintenance~~, and behaviours) required for successful service ~~ensuring maximum reliability, accuracy and economy from meteorological instruments and systems;~~delivery. For this reason, the WMO competency frameworks for Meteorological Observations, Instrumentation, Calibration, and Observing Programme and Network Management were developed. For detailed descriptions of each of these frameworks, see Annexes 5.A to 5.D.

~~(d) To be able to diagnose faults logically and quickly from observed symptoms and trace and rectify systematically their causes;~~

~~(e) To understand the sources of error in measurements and be competent in the handling of instrument standards and calibration procedures in order to minimize systematic errors;~~

~~(f) To keep abreast of new technologies and their appropriate application and acquire new knowledge and skills by means of special and refresher courses;~~

~~(g) To plan and design data-acquisition networks, and manage budgets and technical staff;~~

~~(h) To manage projects involving significant financial, equipment and staff resources and technical complexity;~~

~~(i) To modify, improve, design and make instruments for specific purposes;~~

~~(j) To design and apply computer and telecommunications systems and software, control measurements and process raw instrumental data into derived forms and transmit coded messages.~~

5.3.3 Training ~~for~~and quality management

Meteorological data acquisition is a complex and costly activity involving human and material resources, communication and computation. It is necessary to maximize the benefit of the information derived while minimizing the financial and human resources required in this endeavour.

The aim of quality data acquisition is to maintain the flow of representative, accurate and timely instrumental data into the national meteorological processing centres at the least cost. Through every stage of technical training, a broad appreciation of how all staff can affect the quality of the end product should be encouraged. The discipline of total quality management (~~Walton, 1986, and Imai, 1986~~see WMO, 2017a) considers the whole measurement environment (applications, procedures, instruments and personnel) in so far as each of its elements may affect quality. In total quality management, the data-acquisition activity is studied as a system or series of processes. Critical elements of each process, for example, time delay, are measured and the variation in the process is defined statistically. Problem-solving tools are used by a small team of people who understand the process, to reduce process variation and thereby improve quality. Processes are continuously refined by incremental improvement.

~~WMO (1990) provides a~~A checklist of factors ~~under~~might be used with the following headings:

(a) Personnel recruitment and training;

(b) Specification, design and development;

(c) Instrument installation;

(d) Equipment maintenance;

(e) Instrument calibration.

All of the above influence data quality from the instrument expert's point of view. The checklist can be used by managers to examine areas over which they have control to identify points of weakness, by training staff within courses on total quality management concepts, and by individuals to help them be aware of areas where their knowledge and skill should make a valuable contribution to overall data quality.

The International Organization for Standardization provides for formal quality systems, defined by the ISO 9000 ~~group of specifications (ISO, 2005, 2008, 2009, 2011),~~family of standards, under which organizations may be certified by external auditors for the quality of their production processes and services to clients. These quality systems depend heavily on training in quality management techniques.

Trainers will want to review guidance on quality management of competency assessment and training, discussed in the Guide to Competency, Part III (WMO, 2018).

5.3.4 How people learn

5.3.4.1 The learning environment

Learning is a process that is very personal to the individual, depending on a person's needs and interests. People are motivated to learn when there is the prospect of some reward, for example, a salary increase. ~~Nonetheless,~~However, research shows that other rewards, such as job satisfaction, involvement, personal fulfilment, having some sense of power or influence, and the affirmation of peers and superiors are ~~also~~at least equally strong, if not stronger, motivators. These rewards come through enhanced work performance and relationships with others on the job.

Learning is an active process in which the student reacts to the training environment and activity. A change of behaviour occurs as the student is involved mentally, physically and emotionally. ~~Too much mental or emotional stress during learning time will be counterproductive.~~

Trainers and managers should attempt to stimulate and encourage learning by creating a conducive physical and psychological climate and by providing appropriate experiences and methods that promote learning. Students should feel at ease and be comfortable in the learning environment, which should not provide distractions. The "psychological climate" can be affected by the student's motivation, the ~~manner and vocabulary~~presentation style of the ~~tutor~~trainer and learning resources, the affirmation of previously-acquired knowledge, avoiding embarrassment and ridicule, establishing an atmosphere of trust, and the selection of ~~teaching methods~~learning activities.

5.3.4.2 Important principles

Important principles for training include the following:

(a) *Readiness*: Learning will take place more quickly and be more effective if the student is ready, interested and wants to learn~~;~~.

(b) *Objectives*: The learning objectives ~~of the training~~ (including ~~performance~~those related to competency standards) should be clear to ~~those responsible~~trainers and ~~those involved;~~learners, and assessable to ensure they have been achieved.

(c) *~~Involvement~~Active engagement*: Learning is more effective if students actively work out solutions and do things for themselves, rather than being passively supplied with answers or merely ~~shown~~demonstrated a skill~~;~~.

(d) *Association or Relevance*: Learning should be related to ~~past~~current job experiences, noting similarities and differences~~;~~ to current practices.

(e) *Formative evaluation*: Learning ~~*rate*: The rate of training~~ should ~~equal the rate at which an individual can learn (~~be confirmed by periodic practice or testing~~), with learning~~ and feedback. Learning that is distributed over several short sessions~~ rather~~, each ending in evaluation or practice, will be more effective than one long session~~ being more likely to be retained;~~.

(f) Practice or *Reinforcement*: ~~Useful~~Practical exercises and repetition will help instil ~~new~~ learning~~;~~.

(g) *~~Intensity~~: ~~Intense~~Immediacy*: Telling of intense, vivid or ~~dramatic~~personal experiences capture the imagination and ~~make more~~ may increase attention, relevance, and impact;

(h) *~~Effectiveness~~: ~~Experiences which~~Efficacy*: Learning experiences that challenging but allow for success are more satisfying ~~are~~and better for learning than those which ~~are embarrassing or~~

~~annoying. Approval~~might too easily lead to failure and create embarrassment. Receiving approval encourages learning~~;~~.

(i) Ongoing *Support*: The trainee's supervisor must be fully supportive of the training and must be able to maintain and reinforce it~~;~~.

(j) *Planning and evaluation*: Training should be planned, carried out and evaluated systematically, in the context of organizational needs.

Refer to the Guidelines for Trainers in Meteorological, Hydrological and Climate Services (WMO, 2013) for additional principles and to the WMO Trainer Resources Portal (http://etrp.wmo.int/moodle/course/view.php?id=30) for additional guidance on many training topics.

5.3.4.3 Varying the methods

People in a group will learn at different speeds. Some training methods (see ~~section~~ 5.4) will suit some individuals better than others and will be more effective under different circumstances. Variety will likely increase attention as well. Using a variety of training methods and resources will more likely help ~~the~~a diverse group learn ~~more rapidly~~well.

~~Research (Moss, 1987) shows that, through the senses, our retention of learning occurs from the following:~~

~~(a) Sight (83%);~~

~~(b) Hearing (11%);~~

~~(c) Other senses (6%).~~

~~However, we learn best by actually performing the task. Methods or training media in general order of decreasing effectiveness are:~~

~~(a) Real experience;~~

~~(b) Simulated practical experience;~~

~~(c) Demonstrations and discussions;~~

~~(d) Physical models and text;~~

~~(e) Film, video and computer animation;~~

~~(f) Graphs, diagrams and photographs;~~

~~(g) Written text;~~

~~(h) Lectures.~~

~~These methods may, of course, be used in combination. A good lecture may include some of the other methods.~~

~~Traditional educational methods rely heavily on the spoken and written word, whereas evidence shows that visual and hands-on experience are far more powerful.~~

Training for instrument specialists can take advantage of ~~the widest~~a wide range of methods and media~~.~~ (see 5.4.5). The theoretical aspects of measurement and instrument design ~~are~~may be taught ~~by~~via lectures ~~based on text and formulae~~or video and supported by graphs and diagrams. A working knowledge of the instrument system for operation, maintenance and calibration can be gained by the use of ~~photographs with~~illustrated text~~,~~; films~~ or~~, videos ~~showing manual adjustments,~~or in-person demonstrations; physical models ~~which may~~that can be disassembled~~, demonstrations,~~ and assembled for practice; and ultimately practical ~~experience~~experiences in operating systems and making observations. Unsafe practices or modes of use may be simulated.

5.3.5 ~~Personal skills~~Core competencies development

A meteorological instrument systems engineering group needs people who are not only technically capable, but who are broadly educated ~~and are able to speak and write well. Good personal communication skills are necessary to support and justify technical programmes and particularly in management positions.~~to support the development of a wide range of core competencies shared by other professionals. This includes being able to speak and write well, to work collaboratively in teams, to manage tasks and projects efficiently, to use computer technologies effectively, and to use good decision-making processes. Skilled technologists should receive training so that they can play a wider role in the decisions that affect the development of their ~~Meteorological Service~~NMHS.

~~There is a tendency for~~Good personal communication skills are necessary to work collaboratively and to support and justify technical programmes, particularly in management positions. Some staff who are numerate and have good practical~~,~~ and manual ~~ability to~~ abilities may be less able with ~~verbal and written linguistic skills. In the annual personal performance review of their staff, managers should identify any opportunities for staff to enhance their personal~~communication skills ~~by taking special~~, and may benefit from courses~~, for example,~~ in public speaking, negotiation, letter and report writing or assertiveness training. Some staff may need assistance in learning a second language in order to further their training.

~~5.3.6 Management training~~

~~Good management skills are an important component of engineering activity. These skills involve time management; staff motivation, supervision and performance assessment (including a training dimension); project management (estimation of resources, budgets, time, staff and materials, and scheduling); problem solving; quality management; and good verbal and written communication skills. Instrument specialists with leadership aptitude should be identified for management training at an appropriate time in their careers.~~

~~Today's manager may have access to a personal computer and be adept in the use of office and engineering software packages to be used, for example, for word processing, spreadsheets, databases, statistical analysis with graphics, engineering drawing, flow charting, and project management. Training in the use of these tools can add greatly to personal productivity.~~

5.3.7 A lifelong occupation

5.3.7.1 Three training phases

Throughout their working lives, instrument specialists should expect to be engaged in repeated cycles of personal training, both through structured study and informal on-the-job training or self-study. Three phases of training can be recognized as follows:

(a) A developmental, initial training phase when the trainee acquires general theory and practice ~~at graded~~as qualifications at various levels~~;~~ (see WMO, 2015a);

(b) A supplementation phase, or specialist training, where the training is enhanced by learning about specific techniques and equipment~~;~~ (see Annexes 5.A to 5.D);

(c) A refresher training phase~~,~~ where some years after formal training the specialist needs refresher training and updates on ~~current~~new techniques and equipment.

5.3.7.2 ~~Training~~Initial training

For instrument specialists, the initial training phase of technical education and training usually occurs partly in an external technical institute and partly in the training establishment of the NMHS where a basic course in meteorological instruments is taken. Note that technical or engineering education may extend over ~~both~~all WMO ~~class~~classification levels.

5.3.7.3 Specialist training

The supplementation phase will occur over ~~a few~~several years as the specialist takes courses on special systems, for example, automatic weather stations~~,~~ or radar, or ~~on~~in disciplines like computer software applications or management skills. ~~Increasing~~For specialist training, increasing use will be made of external training resources, including WMO-sponsored training opportunities.

5.3.7.4 Refresher training

As the instrument specialist’s career progresses there will be a need for periodic refresher courses to cover advances in instrumentation and technology, as well as for other supplementary courses, in core competency areas, for example.

There is an implied progression in these phases. Each training course will assume that students have some prerequisite ~~training on~~knowledge upon which to build.

5.4 THE TRAINING PROCESS

5.4.1 The role of the trainer

Most instrument specialists find themselves in the important and satisfying role of trainer from time to time and for some it will become their full-time work, with its own field of expertise. All trainers need ~~an appreciation of the attributes of~~to develop competencies to become a good trainer.

A good trainer is concerned with quality results, is highly knowledgeable in specified fields, and has good communication skills. He or she will have empathy with students, and will be patient and tolerant, ready to give encouragement and praise, flexible and imaginative, and practised in a variety of training techniques.

Good trainers will set clear objectives and plan and prepare training sessions well. They will maintain good records of training prescriptions, syllabi, course notes, courses held and the results, and of budgets and expenditures. They will seek honest feedback on their performance and be ready to modify their approach. They will also expect to be ~~always~~ learning themselves throughout their careers.

The WMO Guidelines for Trainers in Meteorological, Hydrological and Climate Services (WMO, 2013) provide a more detailed treatment of the required competencies of trainers. These competencies describe the training process and are outlined more succinctly below.

5.4.2 ~~Task~~Analyse the organizational context and manage the training processes

To ensure that training is implemented in ways that will lead to the success of the instruments specialists in the organization, the organizational context must be continually analysed, and training plans, policies and processes must be developed and monitored for effectiveness.

This competency will primarily be the responsibility of senior staff members who have overall responsibility for training, training managers, people who make decisions about overall human resource development strategies, and all trainers who would benefit from having increased awareness of the context in which they are operating.

Training should be conducted in fully awareness of the current and evolving organizational and learning contexts, taking into account organizational requirements, how human resources are made available and applied, how strategic training plans are developed, and how training procedures are implemented to comply with organizational and training plans, policies and processes. It can be beneficial to develop and implement both a strategic training plan and an operational training plan. When implemented, training plans, policies, and processes should be monitored and updated to address evolving needs and technological advances.

In order to carry out these responsibilities, one must understand factors that can cause change within an organization, including political, economic, social, and technological factors. One must also be able to develop and implement plans, policies and processes, know which technologies are required to support training, and be able to apply quality assurance methods, financial management, and marketing principles to promote training. Finally, one should recognize and respond to organizational, technological and research trends regarding training practices.

5.4.3 Identify learning needs and specify learning outcomes

Training professionals should use systematic methods for identifying organizational and individual learning needs, and to specify these as the learning outcomes required of training—and what needs to be assessed after training.

Training Needs Assessment is the process of determining when and what training is required. Needs assessment should be a first step before making any training decision. Without it, training might be used to address problems that it cannot solve, or might not address the highest priority needs. In other words, significant effort might be expended in conducting training that will not have the desired impact. For example, if the staff member already has sufficient skills, processes and procedures are not effective, or if the necessary technology is not available or in good condition, training with not improve the situation.

Learning needs assessment often begins with task analysis

. The instrument specialist must be trained to carry out many repetitive or complex tasks for the installation, maintenance and calibration of instruments, and sometimes for their manufacture. A task analysis ~~form~~checklist may be used to define the way in which the job is to be done, and could be used by the tutor in training and then as a checklist by the trainee. First, the objective of the job and the required standard of performance ~~is~~are written down. The job is broken down into logical steps or stages of a convenient size. The form might consist of a table whose columns are headed, for example with: steps, methods, measures, and reasons:

(a) Steps (what must be done): These are numbered and consist of a brief description of each step of the task, beginning with an active verb;

(b) Methods (how it is to be done): An indication of the method and equipment to be used or the skill required;

(c) Measures (the standard required): Includes a qualitative statement, reference to a specification clause, test, or actual measure;

(d) Reasons (why it must be done): A brief explanation of the purpose of each step.

A flow chart would be a good visual means of relating the steps to the whole task, particularly when the order of the steps is important or if there are branches in the procedure.

~~5.4.3 Planning the training session~~

~~The training process consists of four stages, as shown in the figure:~~

~~**ELEMENT 1: Floating object (Automatic)**~~
~~**ELEMENT 2: Picture inline fix size**~~
~~Element Image: 8_IV_5_en.eps~~
~~**END ELEMENT**~~

~~**Stages in the training process**~~

~~**END ELEMENT**~~

~~(a) Planning:~~

~~(i) Review the training objectives, established by the employing organization or standards-setting body (for example, WMO);~~

~~(ii) Analyse the features of the body of knowledge, task or skill that is the subject of the session;~~

~~(iii) Review the characteristics of the students: qualifications, work experience, language ability, specific problems;~~

~~(iv) Assess the required level of training (Which students may need special attention?);~~

~~(v) Determine the objectives for the session (What results are required? How can they be measured?);~~

~~(b) Preparation:~~

~~(i) Select course content: Assemble information, organize it in a logical sequence;~~

~~(ii) Determine training methods and media: appropriate to the topic, so as to create and maintain interest (see section 5.4.5);~~

~~(iii) Prepare a session plan: Set out the detailed plan with the time of each activity;~~

~~(iv) Plan evaluation: What information is required and how is it to be collected? Select a method and prepare the questions or assignment;~~

~~(c) Presentation:~~

~~(i) Carry out training, using the session plan;~~

~~(ii) Encourage active learning and participation;~~

~~(iii) Use a variety of methods;~~

~~(iv) Use demonstrations and visual aids;~~

~~(d) Evaluation:~~

~~(i) Carry out the planned evaluation with respect to the objectives;~~

~~(ii) Summarize results;~~

~~(iii) Review the training session for effectiveness in light of the evaluation;~~

~~(iv) Consider improvements in content and presentation;~~

~~(v) Write conclusions;~~

~~(vi) Apply feedback to the next planning session.~~

~~All training will be more effective if these stages are worked through carefully and systematically.~~

~~5.4.4 Effectiveness of training~~

Learning needs finally need to be expressed in terms of learning outcomes, which in turn describe what needs to be assessed when training completed (see 5.4.6). Well-written learning outcomes for professional training (Specialist and Refresher training) should describe learning in terms of what a learner should be able to do following the learning experience, not just what they should know or understand. This helps to ensure a direct connection to required job competencies and job tasks, which provides the justification for training. However, even for Initial training, which may include as much theory as practice, learning outcomes that use action verbs ("apply", "perform", "demonstrate", "analyse", "solve", etc., rather than "know" or "understand") will help in deciding what to teach and how to assess learning.

5.4.4 Determining a learning solution

Professionals learn their skills in a wide variety of ways, both formally and informally. Learning solutions is a term we use to describe the modes of learning used (for example, classroom or online learning) and the structures in which learning takes place (for example, a course, self-directed study, on-the-job mentoring or coaching). Once you know what learning outcomes are required, the next step in planning is to decide which learning solutions should be used. Trainers should resist the temptation to jump to a quick solution, and instead examine the needs and constrains to come up with the best solution or solutions possible.

Each of the following represents an effective learning solution if chosen for the proper learning outcomes and organizational abilities and constraints.

Formal solutions:

(a) Short classroom courses, workshops, or seminars;

(b) Long classroom courses, such as university courses;

(c) Online distance learning courses made up of mostly live presentations or webinars;

(d) Online distance learning courses that are guided by a remote trainer or partially self-directed, and may utilize offline materials as well.

Informal and Semi-Formal solutions:

(a) On-the-job training, job practice under the guidance of an experienced person. This form can be highly effective for instrument specialists, who may need extensive hands-on practice with authentic equipment. However, on-the-job training may not teach or assess theoretical background knowledge sufficiently.

(b) Coaching and mentoring, in which a more experienced person provides either intensive guidance for a brief period or periodic guidance over an extended period of time.

(c) Short online seminars or webinars, from less than an hour to one-day.

(d) Conferences or seminars, in person interaction with other professionals.

(e) Self-directed learning, in which the learner accesses information and learning resources, such as online or computer-based tutorials or videos, as assigned or under their own initiative.

(f) Job rotation or secondment, skill expansion through brief assignments in different jobs, or a longer but fixed-term assignment to gain additional work experience.

(g) A job manual or documented instructions (using printed or online resources for self-help on the job).

(h) Learning from colleagues (in office or off-the-job discussions, or via an online community, sometimes through formal or informal communities of practice, including online discussion forums or blogs).

(i) Working in teams, for example with peers or more experienced colleagues.

(j) Working independently, but under close supervision (as a trained, but still new employee).

Often the best choices for learning are blended solutions, combinations of the above solutions or variations on them.

5.4.5 Design and develop learning activities and resources

Once the learning objectives are specified and the learning solution or solutions are chosen, trainers must plan the training and design the learning activities and resources that will be included. This must be done based on established learning theory and a firm understanding of the learners. Learners in universities and technical schools may have different needs and preferences than professions requiring refresher training. For example, workplace learners will likely want to understand the immediate benefits of the training for their work and want to reach the learning outcomes more quickly. Trainers must also assess the current skill level of the learners, and especially which students may need special attention.

Designing a training event or other learning solution begins with knowing what learning outcomes are required, and how to help learners achieve them. Trainers will want to consider the strengths and limitations of the learning activities that might be used. In general, trainers will need to know how to create learning activities that include authentic tasks, and provide opportunities for practising the required skills. But they will also need to be able to prepare presentations and learning resources and choose the tools, technology and software required for learning.

Learning activities should be offered in a logical sequence, and provide variety and practice. The sequence must also be efficient. Active learning approaches not only provide opportunities for practice, but for assessment and feedback, which is just as critical during training as at the end.

The following list of learning activities is a sample of the range available. They can be mixed and merged to create many variations of training events.

(a) Lectures: When thorough theoretical coverage is needed, a lecture can be the most direct method. However, lectures are most effective when short, well-structured and followed by more active approaches. Lectures can be kept active also by interspersing questions and discussions.

(b) Demonstrations: Rather than simply describing via a lecture, it is much more effective to demonstrate complex technical skills, whether in the classroom, a laboratory, or work situation. Demonstrations are critical for the initial teaching of manual maintenance and calibration procedures, for example. Demonstrations are best if followed by opportunities to practice and ask questions.

(c) Field studies: The opportunity to observe practices or new instruments in the field environment is useful for teaching installation, maintenance or calibration.

(d) Questions and Issues: Rather than lecture, instruction can be done around questions or issues that encourage students to think critically and solve problems.

(e) Learner-centred discussions: Instead of only teacher-led question and answer sessions that might follow a lecture, letting students answer each other's questions and guide the direction of discussion can make learners more animated and feel more responsible.

(f) Small group discussions: Break students into small discussion groups to encourage more contributions by each person and to bring out more diversity of opinion.

(g) Problem-driven or case-driven learning: Start by posing questions, problems, situations/cases, or stories that require learners to critically think about and discuss answers or solutions.

(h) Practice exercises: Create sets of practice exercises, such as lab exercises, that require the application of skills to be learned.

(i) Projects: Engage learners in real-world tasks and challenges. For informal learning situations, these might include actual job tasks, internships, apprenticeships, or some other work. In formal situations, projects might include research, report writing, data gathering and statistical analysis, making a presentation, or creating a local application or case study.

(j) Collaborative Learning or Decision Making: Learners collaborate in exploring complex problems by analysing information, drawing conclusions, generating solutions and making decisions. Learning in groups can help both capable and less capable learners.

5.4.6 Deliver training and manage the learning event

A well designed training event still requires smooth delivery to become successful. This means offering training in an environment that fosters and sustains learning through involvement, effective communication, and paying careful attention to the learners.

Good training delivery begins by ensuring that learning activities are engaging and well facilitated so they proceed smoothly. Trainers should clearly communicate the purpose and expected outcomes of learning activities, and create a supportive environment that is open to the input of learners, and encourages them to freely ask questions and share concerns. Trainers must develop mutual trust and respect between the trainer and learners, as well as between learners. They need to know how to be good listeners, and also know how to ask probing questions and provide effective feedback. At times they may need to mitigate disruptions and conflict.

Finally, they need to have the technical skills to apply technologies that will be used during training, both the instruments to be understood and the training tools, such as computers and presentation technologies.

5.4.7 Assess learning and evaluate the learning process

5.4.~~4~~7.1 ~~Targeted~~Optimizing training

With the limited resources available for training, real effort should be devoted to maximizing the effectiveness of training. Training courses and resources should be dedicated to optimizing the benefits of training the right personnel at the most useful time. For example, too little training may be a waste of resources, sending management staff to a course for maintenance technicians would be inappropriate, and it is pointless to train people 12 months before they have access to new technology.

Training opportunities and methods should be selected to best suit knowledge and skills requirements and trainees, bearing in mind their educational and national backgrounds. To ensure maximum effectiveness, training should be evaluated.

5.4.7.2 Assessing learning

Many trainers would say that assessment is the part of training about which they are least confident. Assessment is stressful for both trainers and for learners. However, it is an essential part of learning. Without it, learners do not know how well they are learning, and trainers do not know if their training is successful.

In some ways, learning assessment is simple. What we need to assess is actually decided right from the beginning, when we determine the required learning outcomes. If you have defined learning outcomes well, then you know what you have to assess.

What is difficult is finding effective and practical ways to assess job tasks in a training environment. It is hard to recreate realistic conditions outside the job environment. However, this can be approximated through exercises that use standard work equipment and real data.

Job competencies are best assessed on the job, particularly if the assessment has implications for the certification of the person to perform that job. However, job tasks are composed of many smaller actions and based on a large amount of background knowledge, and simpler assessment methods can assess these smaller tasks and background knowledge to make a contribution to a more complete assessment of how someone will be able to perform on the job.

A variety of learning assessment methods might be used: quizzes, projects or reports, problems and exercises, observations of tasks, peer- and self-assessment, etc. Nearly any active learning approach, if well observed, can also become an effective assessment method. Skills are best tested by observation during performance of the learned task in a realistic environment. A checklist of required actions and skills (an observation form) for the task may be used by the assessor.

5.4.~~2~~7.3 Evaluating the training

~~Evaluation~~Training evaluation is a process of obtaining ~~certain~~ information on the effectiveness of training and providing it to those who can influence future training performance. Several approaches to evaluating training may be applied, depending on who needs the information, among the following:

(a) WMO, which is concerned with improving the quality of data ~~collected in~~obtained from the Global Observing System. It generates training programmes, establishes funds and uses the services of experts primarily to improve the skill base in developing countries;

(b) The ~~National Meteorological Service~~NMHS, which needs quality weather data and is concerned with the overall capability of the division that performs data acquisition and particular instrumentation tasks within certain staff number constraints. It is interested in the budget and cost-benefit of training programmes;

(c) The training department or Regional Training Centre, which is concerned with establishing training programmes to meet specified objectives within an agreed budget. Its trainers need to know how effective their methods are in meeting these objectives and how they can be improved;

(d) Engineering managers, who are concerned with having the work skills to accomplish their area of responsibility to the required standard and without wasting time or materials;

(e) Trainees, who are concerned with the rewards and job satisfaction that come with increased competence. They will want a training course to meet their needs and expectations.

Thus, the effectiveness of training should be evaluated at several levels. National and Regional Training Centres might evaluate their programmes annually and triennially, comparing the number of trainees in different courses and pass levels against budgets and the objectives which have been set at the start of each period. Trainers will need to evaluate the relevance and effectiveness of the content and presentation of their courses.

5.4.7.4~~.3~~ Types of evaluation

Types of evaluation include the following:

(a) A training report, which does not attempt to measure effectiveness. Instead, it is a factual statement of, for example, the type and the number of courses offered, dates and durations, the number of trainees trained and qualifying, and the total cost of training. In some situations, a report is required on the assessed capability of the student;

(b) Reaction evaluation, which measures the reaction of the trainees to the training programme. It may take the form of a written questionnaire through which trainees ~~score~~share, at the end of the course, their opinions about relevance, content, methods, training aids, presentation and administration. As such, this method cannot immediately improve the training that they ~~receive.~~are receiving. Therefore, every training course should also have regular opportunities for review and student feedback through group discussion. This enables the trainer to detect any problems with the training or any individual's needs and to take appropriate action;

(c) Learning ~~evaluation~~assessment, which measures the trainee's new knowledge and skills, ~~which are best~~is obviously a measure of the training effectiveness and helpful for the trainee as well (see also 5.4.7.2). Assessment provides more information when compared against a pre-training test. Various forms of written test (essay, short answer questions, true or false questions, multiple-choice questions, drawing a diagram or flow chart) can be devised to test a trainee's knowledge. Trainees may usefully test and score their own knowledge~~. Skills are best tested by a set practical assignment or by observation during on-the-job training (WMO, 1990). A checklist of required actions and skills (an observation form) for the task may be used by the assessor~~;

(d) Performance evaluation, which measures how the trainee's performance on the job has changed after some time, in response to training, which is best compared with a pre-training test. This evaluation may be carried out by the employer at least six weeks after training, using an observation form, for example. The training institution may also make an assessment by sending questionnaires to both the employer and the trainee;

(e) ~~Impact~~Impacts evaluation, which measures the effectiveness of training by determining the change in an organization or work group. This evaluation may require planning and the collection of baseline data before and after the specific training. Some measures might be: bad data and the number of data elements missing in meteorological reports, the time taken to perform installations, and the cost of installations.

5.4.~~4.4~~7.5 Training for trainers

Trainers also require training to keep abreast of technological advances, to learn about new teaching techniques and media, and to catch a fresh vision of their work. There should be provision in their NMHS's annual budget to allow the NMHS's training staff to take training opportunities, probably in rotation.

Some options are: personal study; short courses (including teaching skills) run by technical institutes; time out for study for higher qualifications; visits to the factories of meteorological equipment manufacturers; visits and secondments to other ~~NMHS~~NMHSs and RICs; and attendance at WMO and other training and technical conferences.

~~5.4.5 Training methods and media~~

~~The following list, arranged in alphabetical order, contains only brief notes to serve as a reminder or to suggest possibilities for training methods (more details may be found in many other sources, such as Moss (1987) and Craig (1987)):~~

~~(a) Case study:~~

- ~~(i) A particular real-life problem or development project is set up for study by individuals, or often a team;~~
- ~~(ii) The presentation of the results could involve formal documentation as would be expected in a real situation;~~

~~(b) Classroom lecture:~~

- ~~(i) This is most suitable for developing an understanding of information which is best mediated in spoken and written form: basic knowledge, theoretical ideas, calculations, procedures;~~
- ~~(ii) Visual media and selected printed handout material are very useful additions;~~
- ~~(iii) There should be adequate time for questions and discussion;~~
- ~~(iv) Lectures tend to be excessively passive;~~

~~(c) Computer-assisted instruction:~~

- ~~(i) This uses the capability of the personal computer to store large amounts of text and images, organized by the computer program into learning sequences, often with some element of interactive choice by the student through menu lists and screen selection buttons;~~
- ~~(ii) The logical conditions and branching and looping structures of the program simulate the learning processes of selecting a topic for study based on the student's needs, presenting information, testing for understanding with optional answers and then directing revision until the correct answer is obtained;~~
- ~~(iii) Some computer languages, for example, ToolBook for the IBM personal computer and HyperCard for the Macintosh, are designed specifically for authoring and presenting interactive training courses in what are known as "hypermedia";~~
- ~~(iv) Modern systems use colour graphic screens and may include diagrams, still pictures and short moving sequences, while a graphical user interface is used to improve the interactive communication between the student and the program;~~
- ~~(v) Entire meteorological instrument systems, for example, for upper-air sounding, may be simulated on the computer;~~
- ~~(vi) Elaborate systems may include a laser video disc or DVD player or CD-ROM cartridge on which large amounts of text and moving image sequences are permanently stored;~~

~~(vii) The software development and capital cost of computer-assisted instruction systems range from modest to very great; they are beginning to replace multimedia and video tape training aids;~~

~~(d) Correspondence courses:~~

~~(i) The conventional course consists of lessons with exercises or assignments which are mailed to the student at intervals;~~

~~(ii) The tutor marks the assignments and returns them to the student with the next lesson;~~

~~(iii) Sometimes it is possible for students to discuss difficulties with their tutor by telephone;~~

~~(iv) Some courses may include audio or video tapes, or computer disks, provided that the student has access to the necessary equipment;~~

~~(v) At the end of the course an examination may be held at the training centre;~~

~~(e) Demonstrations:~~

~~(i) The tutor demonstrates techniques in a laboratory or working situation;~~

~~(ii) This is necessary for the initial teaching of manual maintenance and calibration procedures;~~

~~(iii) Students must have an opportunity to try the procedures themselves and ask questions;~~

~~(f) Distance learning:~~

~~(i) Students follow a training course, which is usually part-time, in their own locality and at times that suit their work commitments, remote from the training centre and their tutor;~~

~~(ii) Study may be on an individual or group basis;~~

~~(iii) Some institutions specialize in distance-learning capability;~~

~~(iv) Distance learning is represented in this section by correspondence courses, television lectures and distance learning with telecommunications;~~

~~(g) Distance learning with telecommunications:~~

~~(i) A class of students is linked by special telephone equipment to a remote tutor. They study from a printed text. Students each have a microphone which enables them to enter into discussions and engage in question and answer dialogue. Any reliable communications medium could be used, including satellite, but obviously communications costs will be an issue;~~

~~(ii) In more elaborate and costly systems, all students have computers that are linked to each other and to the remote tutor's computer via a network; or the tutor teaches from a special kind of television studio and appears on a television monitor in the remote classroom, which also has a camera and microphones so that the tutor can see and hear the students;~~

~~(h) Exercises and assignments:~~

~~(i) These often follow a lecture or demonstration;~~

~~(ii) They are necessary so that students actively assimilate and use their new knowledge;~~

~~(iii) An assignment may involve research or be a practical task;~~

~~(i) Exhibits:~~

~~(i) These are prepared display material and models which students can examine;~~

~~(ii) They provide a useful overview when the real situation is complex or remote;~~

~~(j) Field studies and visits:~~

~~(i) Trainees carry out observing practices and study instrument systems in the field environment, most usefully during installation, maintenance or calibration;~~

~~(ii) Visits to meteorological equipment manufacturers and other Meteorological Services will expand the technical awareness of specialists;~~

~~(k) Group discussion/problem solving:~~

~~(i) The class is divided into small groups of four to six persons;~~

~~(ii) The group leader should ensure that all students are encouraged to contribute;~~

~~(iii) A scribe or recorder notes ideas on a board in full view of the group;~~

~~(iv) In a brainstorming session, all ideas are accepted in the first round without criticism, then the group explores each idea in detail and ranks its usefulness;~~

~~(l) Job rotation/secondment:~~

~~(i) According to a timetable, the student is assigned to a variety of tasks with different responsibilities often under different supervisors or trainers in order to develop comprehensive work experience;~~

~~(ii) Students may be seconded for a fixed term to another department, manufacturing company or another Meteorological Service in order to gain work experience that cannot be obtained in their own department or Service;~~

~~(iii) Students seconded internationally should be very capable and are usually supported by bilateral agreements or scholarships;~~

~~(m) Multimedia programmes:~~

~~(i) These include projection transparencies, video tapes and computer DVDs and CD-ROMs;~~

~~(ii) They require access to costly equipment which must be compatible with the media;~~

~~(iii) They may be used for class or individual study;~~

~~(iv) The programmes should include exercises, questions and discussion topics;~~

~~(v) Limited material is available for meteorological instrumentation;~~

~~(n) One-to-one coaching:~~

~~(i) The tutor works alongside one student who needs training in a specific skill;~~

~~(ii) This method may be useful for both remedial and advanced training;~~

~~(o) On-the-job training:~~

~~(i) This is an essential component of the training process and is when the trainee learns to apply the formally acquired skills in the wide variety of tasks and problems which confront the specialist. All skills are learnt best by exercising them;~~

~~(ii) Certain training activities may be best conducted in the on-the-job mode, following necessary explanations and cautions. These include all skills requiring a high level of manipulative ability and for which it is difficult or costly to reproduce the equipment or conditions in the laboratory or workshop. Examples of this are the installation of equipment, certain maintenance operations and complex calibrations;~~

~~(iii) This type of training uses available personnel and equipment resources and does not require travel, special training staff or accommodation, and is specific to local needs. It is particularly relevant where practical training far outweighs theoretical study, such as for training technicians;~~

~~(iv) The dangers are that on-the-job training may be used by default as the "natural" training method in cases where more structured training with a sound theoretical component is required to produce fully rounded specialists; that supervisors with indifferent abilities may be used; that training may be too narrow in scope and have significant gaps in skills or knowledge; and that the effectiveness of training may not be objectively measured;~~

~~(v) The elements necessary for successful on-the-job training are as follows:~~

~~a. A training plan that defines the skills to be acquired;~~

~~b. Work content covering the required field;~~

~~c. A work supervisor who is a good trainer skilled in the topic, has a good teaching style and is patient and encouraging;~~

~~d. Adequate theoretical understanding to support the practical training;~~

~~e. A work diary for the trainee to record the knowledge acquired and skills mastered;~~

~~f. Progress reviews conducted at intervals by the training supervisor;~~

~~g. An objective measure of successfully acquired skills (by observation or tests);~~

~~(p) Participative training:~~

~~(i) This gives students active ownership of the learning process and enables knowledge and experience to be shared;~~

~~(ii) Students are grouped in teams or syndicates and elect their own leaders;~~

~~(iii) This is used for generating ideas, solving problems, making plans, developing projects, and providing leadership training;~~

~~(q) Peer-assisted learning:~~

~~(i) This depends on prior common study and preparation;~~

- ~~(ii) In small groups, students take it in turns to be the teacher, while the other students learn and ask questions;~~

~~(r) Programmed learning:~~

- ~~(i) This is useful for students who are not close to tutors or training institutions;~~
- ~~(ii) Students work individually at their own pace using structured prepared text, multimedia or computer-based courses;~~
- ~~(iii) Each stage of the course provides self-testing and revision before moving on to the next topic;~~
- ~~(iv) Training materials are expensive to produce and course options may be limited.~~

~~Good teaching is of greater value than expensive training aids.~~

~~5.4.6 Television lectures~~

~~Some teaching institutions which provide predominantly extramural courses broadcast lectures to their correspondence students over a special television channel or at certain times on a commercial channel.~~

~~5.4.7 Video programmes~~

~~Video programmes offer a good training tool because of the following:~~

~~(a) They provide a good medium for recording and repeatedly demonstrating procedures when access to the instrument system and a skilled tutor is limited;~~

~~(b) The programme may include pauses for questions to be discussed;~~

~~(c) A video programme can be optimized by combining it with supplementary written texts and group discussions;~~

~~(d) Although professionally made videos are expensive and there is limited material available on meteorological instruments, amateurs can make useful technical videos for local use with modest equipment costs, particularly with careful planning and if a sound track is added subsequently.~~

5.5 RESOURCES FOR TRAINING

Other than the media resources suggested in the previous section, trainers and managers should be aware of the sources of information and guidance available to them; the external training opportunities which are available; the training institutions which can complement their own work; and, not least, the financial resources which support all training activities.

5.5.1 Training institutions

5.5.1.1 National education and training institutions

In general, NMHSs will be unable to provide the full range of technical education and training required by their instrument specialists, and so will have varying degrees of dependence on external educational institutions for training, supplementary and refresher training in advanced technology. Meteorological engineering managers will need to be conversant with the curricula offered by their national institutions so that they can advise their staff on suitable education and training courses. WMO (2001, 2002) give guidance on the syllabi necessary for the different classes of instrument specialists.

When instrument specialists are recruited from outside the NMHS to take advantage of well-developed engineering skills, it is desirable that they have qualifications from a recognized national institution. They will then require further training in meteorology and its specific measurement techniques and instrumentation.

5.5.1.2 The role of WMO Regional Instrument Centres in training

On the recommendation of CIMO~~,~~[6] ~~several,~~ WMO regional associations set up RICs[7] to maintain standards and provide advice. ~~Their terms of reference and locations are given in Part I, Chapter 1, Annex 1.A.~~

RICs are intended to be centres of expertise on instrument types, characteristics, performance, application and calibration. They ~~will~~should have a technical library on instrument science and practice; laboratory space and demonstration equipment; and ~~will~~should maintain a set of standard instruments with calibrations traceable to international standards. They should be able to offer information, advice and assistance to Members in their Region, and beyond.

Where possible, these centres ~~will~~should combine with a Regional Radiation Centre and should be located within or near an RTC in order to share expertise and resources.

A particular role of RICs is to assist in organizing regional training seminars or workshops on the maintenance, comparison and calibration of meteorological instruments and to provide facilities and expert advisors.

RICs should aim to sponsor the best teaching methods and provide access to training resources and media which may be beyond the resources of NMHSs. The centres ~~will need to~~should provide refresher training for their own experts in the latest technology available and training methods in order to maintain their capability.

Manufacturers of meteorological instrumentation systems could be encouraged to sponsor training sessions held at RICs.

5.5.1.3 The role of WMO-IOC Regional Marine Instrument Centres in training

On the recommendation of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology~~,~~[8], a network of RMICs[9] has been set up to maintain standards and provide advice regarding marine meteorology and other related oceanographic measurements. ~~Their terms of reference and locations are given in Part II, Chapter 4, Annex 4.A, respectively.~~

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[6] Recommended by the Commission for Instruments and Methods of Observation at its ninth session (1985) through Recommendation 19 (CIMO-IX).

[7] Information on RICs capabilities and activities is available in Volume I, Chapter 1, Annex 1.C of this Guide and at: https://www.wmo.int/pages/prog/www/IMOP/instrument-reg-centres.html

[8] Recommended by the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology at its third session (2009) through Recommendation 1 (JCOMM-III).

[9] For RMICs please see Volume II, Chapter 4, Annex 4.A, or visit: http://www.jcomm.info/index.php?option=com_content&view=article&id=335:rmics&catid=34:capacity-building

RMICs are intended to be centres of expertise on instrument types, characteristics, performance, application and calibration. They ~~will~~should have a technical library on instrument science and practice, laboratory space and demonstration equipment, and ~~will~~should maintain a set of standard instruments with calibrations traceable to international standards. They should be able to offer information, advice and assistance to Members in their Region.

RMICs ~~will~~should assist in organizing regional training seminars or workshops on the maintenance, comparison and calibration of marine meteorological and oceanographic instruments and ~~will~~ provide facilities and expert advisors.

RMICs should aim to sponsor the best teaching methods and provide access to training resources and media. In order to maintain their capability the centres ~~will~~should arrange refresher training for their own experts in training methods and the latest technology available.

Manufacturers of marine meteorological and oceanographic instrumentation systems could be encouraged to sponsor training sessions held at RMICs.

5.5.2 WMO training resources

5.5.2.1 WMO education and training syllabi

WMO (2001, 2002) include syllabi for specialization in meteorological instruments and in meteorological telecommunications. The education and training syllabi are guidelines that need to be interpreted in the light of national needs and technical education standards.

5.5.2.2 WMO survey of training needs

WMO conducts a periodic survey of training needs by Regions, classes and meteorological specialization. This guides the distribution and kind of training events sponsored by WMO over a four-year period. It is important that Member countries include a comprehensive assessment of their need for instrument specialists in order that WMO training can reflect true needs.

5.5.2.3 WMO education and training publications

These publications include useful information for instrument specialists and their managers. WMO (1986*b*) is a compendium in two volumes of lecture notes on training in meteorological instruments at technician level which may be used in the classroom or for individual study.

5.5.2.4 WMO ~~training library~~Education and Training Office resource links

~~The library produces a catalogue (WMO, 1986*a*) of training publications, audiovisual aids and computer diskettes, some of which may be borrowed, or otherwise purchased, through WMO.~~

The WMO Education and Training Office maintains the WMO Learn web portal (http://learn.wmo.int), which offers links to tools that provide access to information on events and learning resources in all areas of interest to WMO Members.

5.5.2.5 WMO instruments and observing methods publications

These publications~~,~~ (https://www.wmo.int/pages/prog/www/IMOP/publications-IOM-series.html), including reports of CIMO working groups~~ and rapporteurs~~ and instrument intercomparisons, and so forth, provide instrument specialists with a valuable technical resource for training and reference.

5.5.2.6 Special WMO-sponsored training opportunities

The ~~Managers~~managers of engineering groups should ensure that they are aware of technical training opportunities announced by WMO by maintaining contact with their training department and with the person in their organization who receives correspondence concerning the following:

(a) Travelling experts/roving seminars/workshops: From time to time, CIMO arranges for an expert to conduct a specified training course, seminar or workshop in several Member countries, usually in the same Region. Alternatively, the expert may conduct the training event at a RIC or RTC and students in the region travel to the centre. The objective is to make the best expertise available at the lowest overall cost, bearing in mind the local situation;

(b) Fellowships: WMO provides training fellowships under its Technical Cooperation Programme. Funding comes from several sources, including the United Nations Development Programme, the Voluntary Cooperation Programme, WMO trust funds, the regular budget of WMO and other bilateral assistance programmes. Short-term (less than 12 months) or long-term (several years) fellowships are for studies or training at universities, training institutes, or especially at WMO RTCs, and can come under the categories of university degree courses, postgraduate studies, non-degree tertiary studies, specialized training courses, on-the-job training, and technical training for the operation and maintenance of equipment. Applications cannot be accepted directly from individuals. Instead, they must be endorsed by the Permanent Representative with WMO of the candidate’s country. A clear definition must be given of the training required and priorities. Given that it takes an average of eight months to organize a candidate’s training programme because of the complex consultations between the Secretariat and the donor and recipient countries, applications are required well in advance of the proposed training period. This is only a summary of the conditions. Full information and nomination forms are available from the WMO Secretariat. Conditions are stringent and complete documentation of applications is required.

5.5.3 Other training opportunities

5.5.3.1 Technical training in other countries

Other than WMO fellowships, agencies in some countries offer excellent training programmes which may be tailored to the needs of the candidate. Instrument specialists should enquire about these opportunities with the country or agency representative in their own country.

5.5.3.2 Training by equipment manufacturers

This type of training includes the following:

(a) New data-acquisition system purchase: All contracts for the supply of major data-acquisition systems (including donor-funded programmes) should include an adequate allowance for the training of local personnel in system operation and maintenance. The recipient ~~Meteorological Service~~NMHS representatives should have a good understanding of the training offered and should be able to negotiate in view of their requirements. While training for a new system is usually given at the commissioning stage, it is useful to allow for a further session after six months of operational experience or when a significant maintenance problem emerges.

(b) Factory acceptance/installation/commissioning: Work concerned with the introduction of a major data-acquisition facility, for example, a satellite receiver or radar, provides unique opportunities for trainees to provide assistance and learn the stringent technical requirements.

Acceptance testing is the process of putting the system through agreed tests to ensure that the specifications are met before the system is accepted by the customer and despatched from the factory.

During installation, the supplier's engineers and the customer's engineers often work together. Other components, such as a building, the power supply, telecommunications and data processing, may need to be integrated with the system installation.

Commissioning is the process of carrying out agreed tests on the completed installation to ensure that it meets all the specified operational requirements.

A bilateral training opportunity arises when a country installs and commissions a major instrumentation system and trainees can be invited from another country to observe and assist in the installation.

5.5.3.3 International scientific programmes

When international programmes, such as the World Climate Programme, the Atmospheric Research and Environment Programme, the Tropical Cyclone Programme ~~or the Tropical Ocean and Global Atmosphere Programme,~~ conduct large-scale experiments, there may be opportunities for local instrument specialists to be associated with senior colleagues in the measurement programme and to thereby gain valuable experience.

5.5.3.4 International instrument intercomparisons sponsored by the Commission for Instruments and Methods of Observation

From time to time, CIMO nominates particular meteorological measurements for investigation as a means of advancing the state of knowledge. Instruments of diverse manufacture and supplied by Members are compared under standard conditions using the facilities of the host country. An organizing committee plans the intercomparison and, in its report, describes the characteristics and performance of the instruments.

If they can be associated with these exercises, instrument specialists would benefit from involvement in some of the following activities: experimental design, instrument exposure, operational techniques, data sampling, data acquisition, data processing, analysis and interpretation of results. If such intercomparisons can be conducted at RICs, the possibility of running a parallel special training course might be explored.

5.5.4 Budgeting for training costs

The meteorological engineering or instrumentation department of every NMHS should provide an adequate and clearly identified amount for staff training in its annual budget, related to the Service's personnel plan. A lack of training also has a cost: mistakes, accidents, wastage of time and material, staff frustration, and a high staff turnover resulting in poor quality data and meteorological products.

5.5.4.1 Cost-effectiveness

Substantial costs are involved in training activities, and resources are always likely to be limited. Therefore, it is necessary that the costs of various training options should be identified and compared, and that the cost-effectiveness of all training activities should be monitored, and appropriate decisions taken. Overall, the investment in training by the NMHS must be seen to be of value to the organization.

5.5.4.2 Direct and indirect costs

Costs may be divided into the direct costs of operating certain training courses and the indirect or overhead costs of providing the training facility. Each training activity could be assigned some proportion of the overhead costs as well as the direct operating costs. If the facilities are used by many activities throughout the year, the indirect cost apportioned to any one activity will be low and the facility is being used efficiently.

Direct operating costs may include trainee and tutor travel, accommodation, meals and daily expenses, course and tutor fees, WMO staff costs, student notes and specific course consumables, and trainee time away from work.

Indirect or overhead costs could include those relating to training centre buildings (classrooms, workshops and laboratories), equipment and running costs, teaching and administration staff salaries, WMO administration overheads, the cost of producing course materials (new course design, background notes, audiovisual materials), and general consumables used in training.

In general, overall costs for the various modes of training may be roughly ranked from the lowest to the highest as follows (depending on the efficiency of resource use):

(a) On-the-job training;

(b) ~~Correspondence~~Online learning courses~~;~~, and webinars (development costs may vary);

~~(c) Audiovisual courses;~~

(c) Online learning resources (development costs may vary);

(d) Travelling expert/roving seminar, in situ course;

(e) National course with participants travelling to a centre;

(f) ~~Computer-aided instruction~~Interactive online learning modules (high initial production cost, but low cost over the lifecycle);

(g) Regional course with participants from other countries;

(h) Long-term fellowships;

(i) Regional course at a specially equipped training centre.

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~~ANNEX. REGIONAL TRAINING CENTRES~~

~~TABLE: Table horizontal lines~~

~~*Country*~~	~~*Name of centre*~~	~~*WMO Region*~~
~~Algeria~~	~~Hydrometeorological Institute for Training and Research (IHFR), Oran~~	~~I~~
~~Angola~~	~~Instituto Nacional de Meteorologia e Geofísica, Luanda~~	~~I~~

~~Egypt~~	~~Egyptian Meteorological Authority, Cairo~~	~~I~~
~~Kenya~~	~~Institute for Meteorological Training and Research, Nairobi; and Department of Meteorology, University of Nairobi, Nairobi~~	~~I~~
~~Madagascar~~	~~École supérieure polytechnique d'Antananarivo, University of Antananarivo; and École nationale d'enseignement de l'aéronautique et de la météorologie, Antananarivo~~	~~I~~
~~Niger~~	~~African School of Meteorology and Civil Aviation (EAMAC), Niamey; and Regional Training Centre for Agrometeorology and Operational Hydrology and their Applications (AGRHYMET), Niamey~~	~~I~~
~~Nigeria~~	~~Meteorological Research and Training Institute, Lagos; and Department of Meteorology, Federal University of Technology, Akure~~	~~I~~
~~South Africa~~	~~South Africa Weather Service, Pretoria~~	~~I~~
~~China~~	~~Nanjing University of Information, Science and Technology, Nanjing; and China Meteorological Administration Training Centre, Beijing~~	~~II~~
~~India~~	~~Central Training Institute and National Water Academy, Pune; India Meteorological Department Training Centre, New Delhi; and Indian Institute of Technology Roorkee, Roorkee~~	~~II~~
~~Iran (Islamic Republic of)~~	~~Islamic Republic of Iran Meteorological Organization, Tehran~~	~~II~~
~~Iraq~~	~~Iraqi Meteorological Organization, Baghdad~~	~~II~~
~~Qatar~~	~~Qatar Aeronautical College, Doha~~	~~II~~
~~Republic of Korea~~	~~Korea Meteorological Administration, Seoul~~	~~II~~
~~Uzbekistan~~	~~Tashkent Hydrometeorological Professional College, Tashkent~~	~~II~~
~~Argentina~~	~~Department of Atmospheric and Ocean Sciences, University of Buenos Aires, Buenos Aires; and Department of Education and Training of the National Meteorological Service, Buenos Aires~~	~~III~~
~~Brazil~~	~~Department of Meteorology, Federal University of Pará, Belém~~	~~III~~
~~Peru~~	~~Universidad Nacional Agraria La Molina, Lima~~	~~III~~
~~Venezuela (Bolivarian Republic of)~~	~~Department of Meteorology and Hydrology, Central University of Venezuela, Caracas~~	~~III~~
~~Barbados~~	~~Caribbean Institute for Meteorology and Hydrology, affiliated with the University of the West Indies, Bridgetown~~	~~IV~~
~~Costa Rica~~	~~Section of Atmospheric Physics, School of Physics, University of Costa Rica, San José~~	~~IV~~
~~Indonesia~~	~~Meteorology, Climatology and Geophysics Agency, Tangerang; and Research Centre for Water Resources, Bandung~~	~~V~~
~~Philippines~~	~~Department of Meteorology and Oceanography, University of the Philippines; and Training Centre of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Quezon City~~	~~V~~
~~Israel~~	~~Postgraduate Training Centre for Applied Meteorology, Bet Dagan~~	~~VI~~
~~Italy~~	~~National Research Council Institute of Biometeorology, Florence~~	~~VI~~
~~Russian Federation~~	~~Roshydromet Advanced Training Institute, Moscow; Moscow Hydrometeorological College, Moscow; and Russian State Hydrometeorological University, St Petersburg~~	~~VI~~
~~Turkey~~	~~Turkish State Meteorological Service, Ankara~~	~~VI~~

~~Note: For the most recent information on RTCs and their components, please visit: https://www.wmo.int/pages/prog/dra/etrp/rtcs.php.~~

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ANNEX 5.A COMPETENCY FRAMEWORK FOR PERSONNEL PERFORMING METEOROLOGICAL OBSERVATIONS

The provision of the Meteorological Observations function within a National Meteorological and Hydrological Service (NMHS) or related agency may be accomplished by a variety of skilled personnel, including meteorologists, climatologists, geographers, meteorological instrument technicians and meteorological technicians. It can also be accomplished by a range of other more amateur people, such as farmers, police, clerical workers, or private citizens. Third party organizations (for example, universities, international and regional institutions and research centres) and private-sector organizations might also contribute to this function.

This document sets out a competency framework for personnel (primarily professional meteorological observers) involved in the provision of meteorological observations function, but it is not necessary that each person has the full set of competencies as set out in the framework. However, within specific application conditions (as set out below), which might be different for each organization or region, it is expected that any institution providing meteorological observations services will have staff members somewhere within the organization who together demonstrate all the competencies. The Performance Components as well as the Knowledge and Skill Requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

It is recommended that professional meteorological observers performing meteorological observations should have successfully completed the Basic Instruction Package for Meteorological Technician (BIP-MT) (Detailed information on BIP-MT is shown in the Guide on the Implementation of Education and Training Standards in Meteorology and Hydrology (WMO, 2013) which is available at: http://library.wmo.int/pmb_ged/wmo_1083_en.pdf).

Application Conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization.

A. The organizational context, priorities and stakeholder requirements;

B. The way in which internal and external personnel are used to provide meteorological observations services;

C. The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;

D. National and institutional legislation, rules and procedures;

E. WMO guidelines, Meteorological observation procedures and ISO requirements;

F. Regional variations, i.e.:

(i) The range of weather phenomena experienced in the region;

(ii) Local climatology;

(iii) Extent of automation of observing and sensing systems;

(iv) Available communication technologies.

Meteorological Observations: High Level Competencies

1. Monitor the meteorological situation.
2. Perform a surface observation.
3. Perform a balloon-borne upper air observation.
4. Utilize remote sensing technology in making observations.
5. Monitor the performance of instruments and systems.
6. Maintain the quality of observational information.
7. Maintain a safe work environment.

Competency 1: Monitor the meteorological situation

Competency description

Appraise meteorological conditions to identify the significant and evolving situation that is affecting or will likely affect the area of responsibility throughout the watch period.

Performance components

1. Assess the evolving local meteorological situation.
2. Understand the potential influence of the evolving meteorological situation on subsequent observations.
3. Identify meteorological symptoms that may lead to the onset of significant weather.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT) including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations.
2. Identification of clouds and other meteors using the WMO International Cloud Atlas Manual on the Observation of Clouds and Other Meteors (WMO, 2017b) as guidance.
3. Meteorological factors leading to the evolution of significant weather.
4. Standard Operating Procedures and prescribed practices for monitoring weather conditions.

Competency 2: Perform a surface observation

Competency description

Perform surface observations of meteorological variables and phenomena, and their significant changes, according to prescribed practices.

Performance components

1. Observe and accurately record:

    - precipitation
    - atmospheric pressure
    - temperature
    - humidity
    - wind
    - cloud
    - present and past weather
    - visibility
    - solar radiation
    - sunshine duration
    - evaporation
    - soil temperature
    - state of the ground
    - other specialised observations as required (for example, soil moisture, sea state, atmospheric composition, wind shear, leaf wetness, phenology)

2. Encode and transmit surface observations using prescribed codes and methods.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT) including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations.

2. Cloud classification as defined in the WMO International Cloud Atlas Manual on the Observation of Clouds and Other Meteors (WMO, 2017b).

3. Past and present weather identification.

4. Standard Operating Procedures and prescribed practices for performing surface observations.

5. Onsite instrumentation and systems (including software).

6. Care in handling instruments.

7. Accuracy in reading instruments and recording observations.

8. Use of meteorological codes to record observations (for example, according to the Manual on the Global Data-processing and Forecasting System (WMO, 2017c) and Manual on Codes (WMO, 2011)).

Competency 3: Perform a balloon-borne upper air observation

Competency description

Perform a balloon-borne upper air observation, according to prescribed practices and procedures.

Performance components

1. Prepare and deploy balloons and their payloads:
    - Balloon shed safety check
    - Balloon preparation and filling
    - Instrument ground check
    - Balloon release
2. Track balloon flight.
3. Compute and record:
    - Upper air pressure, temperature and humidity
    - Upper air wind speed and direction
    - Other specialised upper air observations as required (for example, ozone)
4. Encode and transmit upper air observations using prescribed codes and methods.

Knowledge and skill requirements

1. Hydrogen safety and generation.
2. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT) including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations.
3. Standard Operating Procedures and prescribed practices for performing upper-air observations.
4. Onsite instrumentation and systems (including software).
5. Care in handling instruments.
6. Accuracy in reading instruments and recording observations.
7. Use of meteorological codes to record observations.

Competency 4: Utilize remote sensing technology in making observations

Competency description

Make observations utilizing remote sensing technology, for example, satellite, weather radar, radar wind profiler, wind lidar, ceilometer, microwave radiometer, lightning detection system, etc.

Performance components

1. Interpret information derived from remote sensing technology in making observations (for example, ceilometer for cloud base height in SYNOP/METAR).

2. Cross-check observations obtained from alternative observing techniques (for example, remote sensing versus in situ measurements) to ensure consistency (for example, compare visibility information recorded by visibility meters with satellite imagery (fog, sandstorms) and manual observations).

Knowledge and skill requirements

1. Understanding of the physical principles of operation, the particular technical configuration and the limitations of surface-based and space-based remote sensing technology being utilized (for example, weather radar, wind lidar, ceilometer, lightning detection system, radar wind profiler, microwave radiometer).

2. Knowledge of the use of different meteorological and oceanographic information derived from remote sensing technology (for example, imagery from different channels of satellites, Doppler wind field from weather radars).

Competency 5: Monitor the performance of instruments and systems

Competency description

Monitor the status and performance of observational instrumentation and communications systems[10].

Performance components

1. Regularly inspect meteorological instruments (for example, raingauge, wet bulb thermometer), automated observing systems (for example, AWS, weather radar fault status), communications systems and backup systems (for example, power).

2. Conduct routine maintenance tasks as prescribed (for example, change wet bulb wick or recorder charts, clean pyranometer dome or ceilometer window).

3. Conduct first-in fault diagnosis and alert technical staff.

4. Undertake action under guidance from remote technical staff.

5. Record interventions and irregularities in a maintenance log / metadata repository.

[10] See also Competency 2 in Instrumentation Competencies

Knowledge and skill requirements

1. Standard Operating Procedures and prescribed practices for carrying out inspection of instruments and communications systems, etc.

2. Accuracy requirements for instrumentation and measurements (for example, as specified in this Guide and other WMO or ICAO regulatory and guidance materials).

3. Onsite instrumentation and systems (including software).

4. Care in handling instruments.

5. Accuracy in reading instruments and recording observations.

6. Use of meteorological codes to record observations.

7. Hazard awareness in the vicinity of instruments and communications systems (for example, near electrical cables, working at heights, electromagnetic radiation).

8. Prescribed contingency plans (for example, failure of power and communications systems, damage to infrastructure during severe weather events).

Competency 6: Maintain the quality of observational information

Competency description

Maintain the quality of meteorological observations at the required level by applying documented quality management processes.

Performance components

1. Monitor all observations to check for errors and inconsistencies, correct errors or flag data in accordance with prescribed procedures and take follow-up action.

2. Record corrections, flags and follow-up actions in metadata repository.

3. Check observational messages for format and content before issuance and make corrections if required.

4. Ensure all observations are successfully sent and received.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT) including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations.

2. Standard Operating Procedures and prescribed practices for treating suspect observations.

3. Accuracy requirements for measurements (for example, as specified in this Guide and other WMO or ICAO regulatory and guidance materials).

4. Onsite instrumentation and systems (including software).

5. Use of meteorological codes to record observations.

6. Prescribed contingency plans. (for example, data transmission failure, power failure).

Competency 7: Maintain a safe work environment

Competency description

Perform all observing tasks in a safe and healthy working environment, at all times complying with occupational safety and health regulations and procedures.

Performance components

1. Safely handle, store and dispose of hydrogen and the chemicals used for generating hydrogen.

2. Safely handle, store and dispose of mercury, and equipment containing mercury.

3. Safely handle, store and dispose of other toxic or dangerous substances, and equipment containing these substances (such as wet cell batteries).

4. Perform safely in the proximity of electrical hazards.

5. Safely perform all observing tasks while minimizing exposure to hazardous environmental conditions (severe weather, lightning, flood, hurricane, fires, etc.).

6. Safely perform all observing tasks in the presence of safety hazards (working at heights, in the proximity of microwave radiation, compressed gases, etc.).

7. Maintain a register of hazards and hazard management.

Knowledge and skill requirements

1. Occupational safety and health requirements and procedures (for example, hydrogen, mercury, chemical, electrical safety and working at height).

2. Hazard identification and mitigation.

3. Hazard register summarizing all potential hazards and control measures in the workplace to enhance occupational safety.

ANNEX 5.B COMPETENCY FRAMEWORK FOR PERSONNEL INSTALLING AND MAINTAINING INSTRUMENTATION

The provision of instrument installation and maintenance services within a National Meteorological and Hydrological Service (NMHS) or related services might be accomplished by a variety of skilled personnel, including meteorologists, instrument specialists and technicians, engineers and IT personnel. Personnel in third party organizations (for example, private contractors, communication services providers and instruments maintenance agents) and other providers might also supply installation and maintenance services for various meteorological observing instruments.

This document sets out a competency framework for personnel involved in the installation and maintenance of meteorological observing instruments[11], but it is not necessary that each person has the full set of competencies. However, within specific application conditions (see below), which will be different for each organization, it is expected that any institution providing the instrument installation and maintenance services will have staff members somewhere within the organization who together demonstrate all the competencies. The Performance Components as well as the Knowledge and Skill Requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

It is recommended that personnel involved in the installation and maintenance of meteorological observing instruments should have successfully completed the Basic Instruction Package for Meteorological Technician (BIP-MT) (Detailed information on BIP-MT is shown in the Guide on the Implementation of Education and Training Standards in Meteorology and Hydrology (WMO, 2013) which is available at: http://library.wmo.int/pmb_ged/wmo_1083_en.pdf).

Application conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization.

A. The organizational context, priorities and stakeholder requirements;

B. The way in which internal and external personnel are used to provide the instrument installation and maintenance services;

C. The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;

D. National and institutional legislation, rules and procedures;

E. WMO guidelines, recommendations and procedures for instrument installation and maintenance services.

Instrumentation: High Level Competencies

1. Install instruments and communications systems.

2. Maintain instrument and system performance.

3. Diagnose faults.

[11] In this document, the competency refers to the performance required for effective installation and maintenance of minor pieces of observing instruments. The competencies for large meteorological observing infrastructure such as those including radars and wind profilers are covered under Observing Programme and Network Management competencies.

4. Repair faulty instruments and systems.

5. Maintain a safe work environment.

Competency 1: Install instruments and communications systems

Competency description

Install, test and commission meteorological observing instruments and communications systems.

Performance components

1. Assemble and test instruments before transport to site.

2. Transport instruments to site.

3. Install instruments and communication systems (including simple site preparation).

4. Coach observing/technical staff in operation and maintenance of the instruments (including provision of Standard Operating Procedures (SOP), Standard Operating Instructions (SOI), systems manuals, wiring diagrams, etc.).

5. Thoroughly test on-site instrument and communications performance, prior to operational cut-over.

6. Complete site classification for variable(s) concerned, prepare and submit instrument and variable metadata to the WMO Integrated Global Observing System (WIGOS) via the Observing Systems Capability Analysis and Review Tool (OSCAR).

7. Switch instrument(s) to operational mode.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT).

2. Detailed understanding of meteorological instruments and methods of observation.

3. Use of meteorological codes to record observations (for example, according to the Manual on the Global Data-processing and Forecasting System (WMO, 2017c) and Manual on Codes (WMO, 2011)).

4. World Meteorological Organization Information System (WIS) setup.

5. Careful handling of instruments, including during transportation.

6. Electronics and Information Communications Technology (ICT).

7. Correct and safe use of mechanical and electrical tools.

8. Standard Operating Procedures, practices and quality management systems.

9. Occupation safety and health requirements for instruments and systems.

Competency 2: Maintain instrument and system performance

Competency description

Perform preventive maintenance on instruments and communications systems in accordance with Standard Operating Procedures to ensure quality and availability of observational information[12].

Performance Components

1. Schedule and carry out preventive maintenance and site inspection following prescribed procedures (for example, change wet bulb wick or recorder charts, clean pyranometer dome or ceilometer window, change anemometer bearings, and carry out preventive maintenance on more sophisticated pieces of equipment like radars and automatic weather stations as specified in the Standard Operating Procedures).

2. Ensure availability of prescribed spare parts inventories.

3. Monitor data availability and the performances of instruments and communications systems[13].

4. Routinely verify correct functioning of instruments, following prescribed procedures.

5. Perform on-site calibration checks to ensure that instrument performance is within tolerance, following prescribed procedures.

6. Provide guidance and refresher training, remotely if necessary, to on-site staff, to maintain compliance with prescribed methods of operating the instruments, for making observations and with procedures for the reduction of observations.

7. Inspect the exposure of instruments and remove any obstacles nearby if necessary.

8. Record maintenance and site inspection[14] events, calibrations, sensor/instrument replacements in maintenance log / metadata repository.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT).

2. Detailed understanding of meteorological instruments and methods of observation and particular familiarity with those employed at the site.

3. Care in handling instruments.

4. Accuracy in reading instruments.

[12] See also Competency 5 in Observing Programme and Network Management Competencies.

[13] See also Competency 5 in Meteorological Observations Competencies.

[14] For site inspection tasks, refer to Guide to Meteorological Instruments and Methods of Observation (WMO - No. 8), particularly Volume I, Chapter 1, 1.3.5.1 and Volume IV, Chapter 1, 1.10.1; Guide to the Global Observing System (WMO - No. 488), particularly 3.1.3.8 and 3.1.3.11; Manual on the WMO Integrated Global Observing System (WMO - No. 1160), particularly 3.4.8.

5. Maintenance and site inspection manuals, Standard Operating Procedures, practices and quality management systems.
6. Electronics and Information Communications Technology (ICT).
7. Measurement uncertainty of instruments and calibration traceability.
8. Occupation safety and health requirements for instruments and systems.

Competency 3: Diagnose faults

Competency description

Diagnose faults in the performance of the observation system (instruments, communications, power supply and auxiliary infrastructure).

Performance Components

1. Detect abnormality in data acquisition and system operation.
2. Inspect observational instruments, communications systems, power supply facilities and auxiliary infrastructure for faults.
3. Provide guidance, remotely if necessary, to on-site staff to identify and diagnose minor faults.
4. Record all faults and their occurrence time in a maintenance log / metadata repository.
5. If repair is required, order delivery of requisite spare parts.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT).
2. Detailed understanding of meteorological instruments and methods of observation and particular familiarity with those employed at the site.
3. Use of meteorological codes to record observations (for example, according to the Manual on the Global Data-processing and Forecasting System (WMO, 2017c) and Manual on Codes (WMO, 2011)).
4. World Meteorological Organization Information System (WIS) setup.
5. Standard Operating Procedures, practices and quality management systems.
6. Ability to interrogate the system both on-site and remotely.
7. Electronics and Information Communications Technology (ICT).
8. Occupation safety and health requirements for instruments and systems.
9. Contingency plans to ensure continuity of observations (for example, in event of power failure, sensor failure, system failure, backup sensors and communications systems).

Competency 4: Repair faulty instruments and systems

Competency description

Repair faulty instruments and systems in the observing network.

Performance components

1. Provide guidance, remotely if necessary, to on-site staff to repair minor faults.

2. Assess spare parts requirements and ensure availability.

3. Repair faulty components following prescribed procedures and processes.

4. Perform tests after repair to ensure compliance with performance requirements.

5. Record repair actions taken and time of resuming data acquisition in a maintenance log / metadata repository.

Knowledge and skill requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT).

2. Detailed understanding of meteorological instruments and methods of observation.

3. Use of meteorological codes to record observations (for example, according to the Manual on the Global Data-processing and Forecasting System (WMO, 2017c) and Manual on Codes (WMO, 2011)).

4. World Meteorological Organization Information System (WIS) setup.

5. Care in handling instruments including during transportation.

6. Instrument/system design and operation.

7. Repair manuals, Standard Operating Procedures, practices and quality management systems.

8. Ability to interrogate the system both on-site and remotely.

9. Electronics and Information Communications Technology (ICT).

10. Occupation safety and health requirements for instruments and systems.

Competency 5: Maintain a safe work environment

Competency description

Perform all tasks in a safe and healthy working environment, at all times complying with occupational safety and health regulations and procedures.

Performance components

1. Conduct hazard identification and risk assessment.
2. Raise safety awareness among other employees and visitors to site.
3. Continuously monitor the workplace for occupational safety and health hazards and correct or mitigate non-conformances.
4. Secure remote site to ensure public safety.
5. Make use of personal protective equipment (PPE).
6. Safely handle, store and dispose of all hazardous chemicals (for example, mercury, hydrogen and the chemicals used for generating hydrogen, batteries).
7. Perform safely in the proximity of electrical hazards, microwave radiation, weather related hazards and when working at heights or in confined spaces.
8. Maintain a register of hazards and hazard management.

Knowledge and Skills Requirements

1. ISO 31000 (Risk management: principles and guidelines on implementation).
2. Safety procedures in handling hazardous materials (for example, mercury, hydrogen and the chemicals used for generating hydrogen, batteries).
3. Safety procedures for electrical hazards, microwave radiation, weather related hazards and when working at heights or in confined spaces.
4. General occupational safety and health requirements.
5. Hazard identification, mitigation and registration.

ANNEX 5.C COMPETENCY FRAMEWORK FOR PERSONNEL PEFORMING INSTRUMENT CALIBRATIONS

The provision of instrument calibration services within a National Meteorological and Hydrological Service (NMHS) or related services might be accomplished by a variety of skilled personnel, including meteorologists, instrument specialists, technicians and engineers. Third party organizations (for example, private contractors, calibration service providers and laboratories) might also provide calibration services for various meteorological observing instruments.

This document sets out a competency framework for personnel working in calibration laboratories and/or providing centralized calibration services for meteorological observing instruments, but it is not necessary that each person has the full set of competencies. However, within specific application conditions (see below), which will be different for each organization, it is expected that any institution providing the instrument calibration services will have staff members somewhere within the organization who together demonstrate all the competencies. The Performance Components as well as the Knowledge and Skill Requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

Application conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization.

A. The organizational context, priorities and stakeholder requirements;

B. The way in which internal and external personnel are used to provide the instrument calibration services;

C. The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;

D. National and institutional legislation, rules and procedures;

E. WMO guidelines, recommendations and procedures for instrument calibration services.

Calibration: High Level Competencies

1. Calibrate instruments.

2. Check instrument performance.

3. Manage the laboratory work programme.

4. Manage the laboratory infrastructure.

5. Develop and maintain Standard Operating Procedures.

6. Manage the data and record archival[15].

7. Maintain a safe work environment and laboratory security.

[15] The meaning of the term “archival” in this context is the function of storing, keeping secure, and ensuring discoverability, accessibility and retrievability of data and information.

Competency 1: Calibrate instruments

Competency description

Execute calibrations in accordance with standard calibration procedures, from item handling to editing of calibration certificates.

Performance components

1. Execute routine calibrations on day-to-day basis in accordance with standard calibration procedures.

2. Compute the calibration uncertainty in conformity with the Standard Operating Procedures.

3. Prepare a draft of calibration certificate (not including approval or issuance).

4. Handle calibration items appropriately.

5. Conduct intermediate checks of working standards in calibration laboratory.

6. Participate in internal and external audits.

Knowledge and skill requirements

1. Laboratory facilities and standards (including software).

2. Standard Operating Procedures for performing calibration and computation of calibration uncertainty.

3. Care in handling instruments.

4. The basics of Metrology and uncertainty computation including knowledge of the International Vocabulary of Metrology (VIM), International System of Units (SI), measurement standards and traceability, measurement uncertainty and errors and calculation of uncertainty using prescribed methods.

5. The basics of meteorological instrumentation including understanding of the working principles of common meteorological instruments and their characteristics and accuracy requirements for measurements (for example, as specified in this Guide and other WMO or ICAO regulatory and guidance materials).

Competency 2: Check instrument performance

Competency description

Check instrument performance in the laboratory using measurement standards in accordance with Standard Operating Procedures.

Performance components

1. Prepare the standards to be used for checking instrument performance.

2. Handle standards and items appropriately.

3. Compare the instrument with standards and evaluate its functionality.

4. Record and analyse the measurement errors.

5. Prepare instrument performance reports as required.

Knowledge and skill requirements

1. Handling and use of measurement standards.

2. Standard Operating Procedures for performing instrument checks.

3. Care in handling instruments.

4. The basics of Metrology and uncertainty computation including knowledge of the International Vocabulary of Metrology (VIM), International System of Units (SI), measurement standards and traceability, measurement uncertainty and errors and calculation of uncertainty using prescribed methods.

5. The basics of meteorological instrumentation including understanding of the working principles of common meteorological instruments and their characteristics and accuracy requirements for measurements (for example, as specified in this Guide and other WMO or ICAO regulatory and guidance materials).

Competency 3: Manage the laboratory work programme

Competency description

Develop, prepare, organize and manage the calibration activities of the calibration laboratory.

Performance components

1. Manage the work of the calibration laboratory, including quality and technical aspects (covering traceability of standards, uncertainty budget evaluation) in accordance with ISO/IEC 17025.

2. Plan and organize the regular calibrations (either internal or external as required) of reference standards following the Standard Operating Procedures and/or the relevant WMO guidance.

3. Prepare, plan, design, procure the physical infrastructure for calibration activities (test chambers, standards, fixed point cells, pressure generators, etc.) and the applications required to conduct calibration activities.

4. Monitor the quality of the laboratory calibration activities and determine the laboratory's applicable Calibration and Measurement Capability (CMC).

5. Provide on-going training to ensure maintenance of competency of the calibration laboratory staff (training, qualification, etc.).

6. Communicate with customers on calibration issues, including explaining the results of calibrations.

7. Conduct internal audits, external audits and where possible interlaboratory comparisons as recommended by ISO/IEC 17025.

Knowledge and skill requirements

1. Laboratory facilities and standards (including software).

2. Standard Operating Procedures for managing the calibration activities of the laboratory.

3. Advanced metrology and uncertainty computation including, in addition to the basics, detailed knowledge of the "Guide to the expression of uncertainty in measurement" (GUM) or equivalent, application of the GUM uncertainty framework to measurement uncertainty evaluation.

4. Standard Operating Procedures for inter-laboratory comparison and assessment of Calibration and Measurement Capability (CMC).

5. Quality-related requirements (for example, ISO 9001, ISO/IEC 17025, Good Laboratory Practice (GLP)).

6. Meteorological instrumentation covering the knowledge of the performance characteristics of common meteorological instruments.

7. Current technologies and emerging trends of laboratory instruments.

Competency 4: Manage the laboratory infrastructure

Competency description

Install and maintain the physical infrastructure for calibration activities (test chambers, standards, fixed point cells, pressure generators, etc.) and the applications required to conduct calibration activities.

Performance components

1. Install and set up the physical infrastructure for calibration activities, including software.

2. Test the equipment to ensure its compliance with the requirements.

3. Maintain the laboratory infrastructure in optimal operational condition.

4. Maintain the quality of the laboratory reference standard instruments.

5. Conduct preventative and corrective maintenance.

6. Manage site environment (air conditioning, secure electric power, etc.).

Knowledge and skill requirements

1. Laboratory facilities and standards (including software), and their maintenance.

2. Asset management.

3. Care in handling instruments.

4. Standard Operating Procedures for managing the laboratory infrastructure.

5. The basics of Metrology including knowledge of the International Vocabulary of Metrology (VIM), International System of Units (SI), measurement standards and traceability.

6. The basics of meteorological instrumentation and its maintenance.

Competency 5: Develop and maintain Standard Operating Procedures

Competency description

Develop, assess and maintain Standard Operating Procedures necessary for the achievement of calibrating activities, including computing calibration uncertainties.

Performance components

1. Develop Standard Operating Procedures taking into account available laboratory facilities and quality management requirements.

2. Establish uncertainty budget for calibration operating procedures.

3. Develop calibration certificate templates.

4. Maintain and upgrade Standard Operating Procedures (including in support of maintenance).

Knowledge and skill requirements

1. Knowledge of best practices relating to Standard Operating Procedures.

2. Advanced metrology and uncertainty computation including, in addition to the basics, detailed knowledge of the Guide to the expression of uncertainty in measurement (GUM), (ISO/IEC 2008) or equivalent, application of the GUM uncertainty framework to measurement uncertainty evaluation, conducting interlaboratory comparisons and determination of the Calibration and Measurement Capability (CMC) of the laboratory.

3. Laboratory facilities and standards (including software).

4. Quality requirements (for example, ISO 9001, ISO/IEC 17025, Good Laboratory Practice (GLP)).

5. Meteorological instrumentation, in particular, those in the national network.

Competency 6: Manage the data and record archival

Competency description

Ensure the archival of calibration activity measurements, calibration certificates and records.

Performance components

1. Archive calibration activity measurement data and metadata and the associated records.

2. Archive calibration certificates of calibrated instruments.

3. Archive calibration certificates of laboratory instruments.

Knowledge and skill requirements

1. Knowledge of prescribed practices for managing the data and record archival.

Competency 7: Maintain a safe work environment and laboratory security

Competency description

Perform all calibration tasks in a safe and healthy working environment, at all times complying with occupational safety and health regulations and procedures, and security requirements.

Performance components

1. Safely handle, store and dispose of mercury, and equipment containing mercury.
2. Safely handle, store and dispose of other toxic or dangerous substances, and equipment containing these substances (such as wet cell batteries).
3. Perform safely in the proximity of electrical hazards.
4. Safely perform all calibration tasks in the presence of safety hazards.
5. Ensure the security (access restrictions, etc.) of the calibration laboratory and instruments under test.

Knowledge and skill requirements

1. Mercury safety procedures.
2. Chemical safety procedures.
3. Electrical safety procedures.
4. Occupational safety and health requirements.
5. Standard Operating Procedures for maintaining staff safety and laboratory security.

ANNEX 5.D COMPETENCY FRAMEWORK FOR PERSONNEL MANAGING OBSERVING PROGRAMMES AND NETWORKS

The management of observing programme and network operation within a National Meteorological and Hydrological Service (NMHS) or related services might be accomplished by a variety of skilled personnel, including programme planners and managers, meteorologists, instrument specialists and technicians, engineers and IT personnel. Personnel in third party organizations (for example, private contractors, communication services providers and instrument maintenance agents) and other providers might also supply consultancy and management services for the observing programme and/or equipment maintenance services for the observing network.

This document sets out a competency framework for personnel involved in the management of observing programme and network, but it is not necessary that each person has the full set of competencies[16]. However, within specific application conditions (see below), which will be different for each organization, it is expected that any institution managing the observing programme and network operation will have staff members somewhere within the organization or external service providers who together demonstrate all the competencies. The Performance Components as well as the Knowledge and Skill Requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

In planning and managing the observing programme and network operation, the relevant regulatory requirements and guiding principles from the Manual on the WMO Integrated Global Observing System (WMO, 2015b) should be taken into account (for example, Appendices 2.1 and 2.5). The WMO Rolling Review of Requirements (RRR) process (http://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html) in combination with the Observing Systems Capability Analysis and Review Tool (OSCAR) (https:/oscar.wmo.int) should be used so that the capabilities of the observing programme can be reviewed and improved to meet the relevant data requirements under various WMO Application Areas.

APPLICATION CONDITIONS

The application of the competency framework will depend on the following circumstances, which will be different for each organization.

A. The organizational context, priorities and stakeholder requirements;

B. The way in which internal and external personnel are used to provide the observing programme and network management services;

C. The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;

D. National and institutional legislation, rules and procedures;

E. WMO guidelines, recommendations and procedures for observing programme and network management.

Observing Programme and Network Management: High Level Competencies

1. Plan the observing programme.

[16] In this document, the competency refers to the performance required for effective management of an observing programme involving large meteorological observing networks such as those including radars and wind profilers.

2. Procure equipment.
3. Select and acquire sites.
4. Install network components.
5. Manage the network operation.
6. Manage the observing programme.

Competency 1: Plan the observing programme

Competency description

Ascertain observation requirements and formulate observing programme development plans that satisfy these requirements taking into account the technical, financial and human resources required for implementation, continuous operation and long-term sustainability.

Performance components

1. Assess user requirements for observations (Rolling Review of Requirements).
2. Perform an observation system gap analysis using Observing Systems Capability Analysis and Review Tool (OSCAR).
3. Identify the required observational instrumentation to fill the identified gaps.
4. Design network topology/structure required to fill the identified gaps taking into account the inclusion of external (so-called 3rd party) data sources.
5. Identify the associated human resources required (quantities and competencies) for the sustainable operation of the proposed observing programme.
6. Identify the required supporting infrastructure (for example site, buildings, communications).
7. Prepare a fully costed life cycle plan for the sustainable operation of the proposed observing programme.
8. Document in detail the proposed observing programme and develop the implementation plan.
9. Check that the final observing programme satisfies the original specified requirements (review and obtain feedback from users).
10. Develop (or update existing) contingency plan and business continuity plan for the observing programme.

Knowledge and Skill Requirement

1. Users' requirements for data under various WMO Application Areas.
2. Meteorological instruments and communications systems installed in the observing network, commercially available alternatives and emerging developments.
3. Programme management including knowledge of programme planning, organizational structure, design and scheduling of tasks, liaison with stakeholders, etc.

4. Financial planning and management including knowledge of different financial accounting models for example, accrual and cash accounting, asset versus recurrent costing, costs benefits analysis, and whole-life costing.

5. Understanding of human resource management including knowledge of planning and developing of human resources, etc.

6. Contingency planning and existing observing system contingency plans.

7. Familiarity with WMO regulations, guidelines and activities (for example, Guide to Meteorological Instruments and Methods of Observation (WMO - No. 8), Guide to the Global Observing System (WMO - No. 488), Manual on the WMO Integrated Global Observing System (WMO - No. 1160), Rolling Review of Requirements (RRR), Observing Systems Capability Analysis and Review Tool (OSCAR), Instrument Testbeds).

8. Familiarity with the Implementation Plan for the Evolution of the Global Observing System (EGOS-IP) and any national observing system strategies.

9. ISO 9001 (Quality Management Systems).

Competency 2: Procure equipment

Competency description:

Procure instruments and the associated infrastructure (including communications systems, initial spares and staff training) as specified for the implementation, continuous operation and long-term sustainability of the observing programme.

Performance components:

1. Confirm procurement scope with the planning team, including availability of funds meeting capital and operational costs.

2. Conduct market survey to identify the suitable models of instruments meeting observation requirements.

3. Conduct engineering design and/or draw up functional specifications of the instruments to be procured.

4. Initiate tender or purchasing processes for equipment and infrastructure (obtain the necessary approvals) and prepare and issue procurement documents.

    - Tender evaluation
    - Purchase recommendation
    - Appoint supplier

5. Conduct factory acceptance tests.

6. Conduct site acceptance tests (if required).

7. Authorize payments subject to satisfactory fulfilment of the contract terms.

Knowledge and Skill Requirements

1. Observing programme including meteorological instruments and communications systems installed in the observing network.

2. Observing technology options (as described in this Guide).

3. Information Communications Technology (ICT) options.

4. National and organizational procurement rules and guidelines.

5. Project Management (especially with significant procurement projects).

6. ISO 31000 (Risk management: principles and guidelines on implementation).

7. Occupational safety and health requirements for instruments and systems.

Competency 3: Select and acquire sites

Competency description:

Select, acquire and commission observing sites for installation of instruments and communications systems.

Performance Components:

1. Identify suitable site for long term observations which meets observational requirements. (for example, conduct site survey to ensure representative measurements of the required variables can be taken to satisfy the data requirements of relevant WMO Application Areas).

2. Detailed site planning and site acquisition. (Ensure reliable power supply, communications, ascertain best form(s) of communications (satellite, copper cable, optical fibre, microwave link, GPRS, private wire), road access, site exposure, granting of site lease, acquisition of formal land allocation notification, etc.).

3. Prepare site/enclosure (for example, civil works: clear and level the site, establish power, communications, fencing of site, road access).

4. Provide site plan, layout diagrams of observing equipment, power supply, communication links, etc.

5. Conduct joint site inspection and acceptance tests.

6. Confirm site conditions, for example, flatness of site, earthing conditions (< 10 ohms) for lightning protection, low EM wave background for lightning location detector, quality of power supply, communications bandwidth, roadways, fencing.

7. Complete the handover of site (for example, obtain site acceptance certificates).

8. Prepare and submit site metadata to WMO Integrated Global Observing System (WIGOS) via the Observing Systems Capability Analysis and Review Tool (OSCAR).

Knowledge and skills requirements

1. Guide to Meteorological Instruments and Methods of Observation (WMO - No. 8) (for example, Volume 1, Chapter 1, in particular 1.3, and Annex 1.D, WMO/ISO Siting Classification for Surface Observing Stations on Land; Annex 1.G: Station exposure description).

2. WIGOS, in particular OSCAR requirements and data submission process.

3. Information Communications Technology (ICT).

4. Site leasing process and negotiation skills.

5. Project Management.

6. Occupational safety and health requirements.

Competency 4: Install network components

Competency description

Install, test and commission major[17] components of observing networks (for example weather radars, vertical wind profilers).

Performance components

1. Assemble, test and calibrate network components (for example, instruments, communications, support systems) before transport to site.

2. Transport network components to site or coordinate delivery by supplier.

3. Install network components and carry out user acceptance tests.

4. Ensure training is conducted to meet user or operational requirements. (Including Standard Operating Procedures and instructions, systems manuals, wiring diagrams, etc.).

5. Complete site classification for variable(s) concerned, prepare and submit instrumentation metadata to the WMO Integrated Global Observing System (WIGOS) via the Observing Systems Capability, Analysis and Review Tool (OSCAR).

6. Switch network components to operational mode.

Knowledge and Skill Requirements

1. Understanding of general meteorology as described in the Basic Instruction Package for Meteorological Technician (BIP-MT) including meteorological codes, and World Meteorological Organization Information System (WIS) setup.

2. Observing programme including existing network components or new components to be installed in the observing network.

[17] Those which comprise a significant investment for an organization, and so require a structured project management approach, as opposed to the implementation of minor pieces of observing infrastructure, the competencies for which are covered under Instrumentation competencies.

3. Careful handling of network components, including during transportation.

4. Electronics and Information Communications Technology (ICT).

5. Correct and safe use of mechanical and electrical tools.

6. Standard Operating Procedures, practices and quality management systems.

7. Occupation safety and health requirements.

Competency 5: Manage the network operation

Competency description

Manage the observing network (observations, instrument calibration and maintenance, etc.) to ensure its continuous operation and timely delivery of quality observations.

Performance components

1. Implement network maintenance (preventive, corrective, adaptive), site inspection and instrument calibration programmes[18] to ensure correct and sustainable functioning of all equipment.

2. Develop and employ quality assurance tools (for regular diagnosis of system functions and parameters) for all instrumentation both in-situ and remote sensing.

3. Develop and maintain a data quality monitoring system (for example, manual and/or automated data QC systems) to ensure data traceability and metadata accuracy.

4. Coordinate with external sources (partners, volunteers and other 3rd party sources such as crowd sourcing) regarding the provision of their data to ensure data quality and homogeneity of the integrated network.

5. Prepare contingency plans for network operation and data acquisition including periodic testing of effectiveness.

6. Monitor network performance using appropriate tools and schemes and devise indicators to measure network performance (for example, data availability, timeliness).

7. Document all operational procedures (for example, network maintenance, instrument calibration, data QC algorithms, contingency plans).

8. Maintain an asset register.

Knowledge and Skill Requirements

1. Meteorological instruments and communications systems installed in the observing network.

[18] Including for remote sensing equipment: note, for example, detailed guidance on maintenance of radars and wind profilers is given in Guide to Meteorological Instruments and Methods of Observation – (WMO - No. 8), Volume II, Chapter 7, 7.7, and Operational Aspects of Wind Profilers Radars – (WMO/TD No. 1196), Section 4 respectively.

2. Familiarity with WMO guidelines and regulations on meteorological observations (for example, Guide to Meteorological Instruments and Methods of Observation (WMO - No. 8), Manual on the WMO Integrated Global Observing System (WMO - No. 1160), WIGOS Framework Implementation Plan).

3. Detailed knowledge of operational programme management and organizational structure, etc.

4. Contingency plans (to ensure continuity of the observing network).

5. Asset management standards, for example, ISO 55000 and Global Forum on Maintenance and Asset Management (GFMAM).

6. Occupation safety and health requirements for the observing network.

Competency 6: Manage the observing programme

Competency description

Manage the observing programme (technical, financial and human resources, etc.) to ensure observing programme requirements are met safely and sustainably.

Performance Components

1. Develop financial and human resource plans and secure the resources that ensure sustainability of the observing programme.

2. Regularly evaluate and re-assess staff performance and provide on-going training (in liaison with the Training Section if necessary) to ensure maintenance of competency of all staff involved in the observing programme.

3. Co-ordinate with users and as required update data requirements of the observing programme (for example, real-time observations, NWP applications and climate monitoring).

4. Regularly review short-term and long-term goals of the observing programme, identify areas for its continuous improvement (for example, improved standardization, network optimization and development).

5. Explore and implement technical solutions to address improvement areas identified taking into account technological change of instrumentation and data communication methods.

6. Promote awareness and compliance of all staff with occupational safety and health requirements.

Knowledge and Skill Requirements

1. Financial planning including knowledge of different financial accounting models, for example, accrual and cash accounting, asset versus recurrent costing, costs benefits analysis, and whole-life costing.

2. Detailed knowledge of programme monitoring and evaluation techniques.

3. Understanding of human resource management including knowledge of performance management and developing of human resources, etc.

4. Meteorological instrumentation and Information Communications Technology (ICT).

5. Familiarity with WMO regulations, guidelines and activities (for example, WMO Technical Regulations (WMO - No. 49), Guide on the Global Observing System (WMO - No. 488), Manual on the WMO Integrated Global Observing System (WMO - No. 1160), Observing Systems Capability Analysis and Review Tool (OSCAR)).

6. Occupation safety and health requirements.

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