CGMS/WMO Best Practices for Achieving User Readiness for New Satellite Systems

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CGMS/WMO Best Practices for achieving user readiness for new meteorological satellites (endorsed by CGMS-44 plenary, June 2016)	2017	N/A	Initial version.
CGMS/WMO Best Practices for achieving user readiness for new satellite systems	2023	N/A	The proposed revision of the Best Practices (WMO-No. 1187) reflects lessons learned from the satellite systems that have become operational over the last 5-10 years, novel types of LEO missions, the increasing role of commercial satellite data providers, as well as evolutions in the user needs.

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1. BACKGROUND

The space-based component is an essential contribution to the WMO Integrated Global Observing System (WIGOS) as outlined in the Vision for WIGOS in 2040. The new generation of satellites will bring significant improvements to satellite-based products and services delivered by WMO Members, provided that users can effectively reap their benefits. Integrating the new data types into operational schemes, with overall data volumes one or more orders of magnitude higher than for the previous satellite generation, will have major impacts on user infrastructure, systems, applications and services, and require coordinated action at the scientific, technical, financial, organizational and educational levels. Timely and careful preparation by satellite-data users is essential to avoid any disruption of operations during transition to these new systems, and to ensure that Members take advantage of the new capabilities as effectively and early as possible.

New generations of satellite systems contributing significantly to fulfilling the WIGOS vision have been or will in the course of this decade be started by China, India, Japan, the Republic of Korea, the Russian Federation, the United States of America and the European Union, both in geostationary and low earth orbits. It is anticipated that other nations may also start planning their satellite missions in the coming decades.

In Low Earth Orbit (LEO) the core satellite systems in the Early Morning, Mid-Morning and Afternoon sun-synchronous orbits are now providing microwave and hyperspectral infrared sounding and medium resolution IR/VIS imaging, UV spectrometry, radio occultation and scatterometry. In addition, a number of operational LEO satellites in sun-synchronous and drifting orbits are becoming available providing observational capabilities for atmospheric composition, ocean observations, land surface observations and some other observational domains.

The WMO Commission for Basic Systems [CBS] Guidelines for Ensuring User Readiness for New Generation Satellites were adopted at the fifteenth session of the CBS (*Abridged Final Report with Resolutions and Recommendations of the Fifteenth Session of the Commission for Basic Systems*, WMO-No. 1101). They focus on user preparation for the new generation of meteorological satellites and urge (Annex I to para. 4.2.36 of the general summary) “Establishment by each concerned NMHS [National Meteorological and Hydrological Service] or other operational user organization, of a user-readiness project focused on the introduction of new satellite data streams into operations (to be initiated ~5 years prior to launch)”.

Against this background, the Seventeenth World Meteorological Congress (2015), through Resolution 37 (Cg-17) strongly recommended “to all concerned Members to set up user preparation projects in advance of the launches of new satellite systems, in accordance with the CBS Guidelines for ensuring user readiness for new generation satellites”.

One of the main constraints for the planning of a user-readiness project is the timely availability of requirements, specifications and data and tools used in satellite system development.

It is, therefore, crucial that the satellite development entities and operators provide detailed and up-to-date plans for their activities conducted in support of user-readiness projects.

For this reason, the Seventeenth World Meteorological Congress (Resolution 37) also welcomed the implementation of the Satellite User Readiness Navigator (SATURN), which used to serve as a one-stop portal to technical information from satellite operators related to the new systems. This effort was aimed at supplementing satellite operator portals by creating a link between users and satellite operators addressing an important gap. Since that time, satellite operators have worked towards a better usability of their web pages to ensure that user preparation process starts well in advance.

The WMO Space Programme has, therefore, analysed how the typical cycle of satellite system development relates to user-readiness projects, and the outcome of this analysis is a summary of best practices and a generic project schedule (outlined in Table 1). The generic schedule indicates at what time, relative to the planned launch, and what information should be available to both satisfy the user preparation schedule and respect the constraints of satellite system development.

The proposed revision of the Best Practices (WMO-No. 1187) reflects lessons learned from the satellite systems that have become operational over the last 5-10 years (such as Himawari-8/9, GOES-R, GEO-Kompsat-2, FY-4, FY-3 and JPSS), novel types of LEO missions, the increasing role of commercial satellite data providers, as well as evolutions in the user needs.

2. APPLICABILITY

The current publication presents, in an integrated manner, best practices for user-readiness projects performed by user organizations (for example, NMHSs) as well as for satellite development programmes in support of user readiness. Definitions of and a timeline for deliverables are presented that should be made available by the satellite development programmes to user-readiness projects.

The best practices documented here therefore apply to both user organizations (section 4) and satellite operators (section 6).

The best practices should apply to all satellite systems providing sustained observations in response to operational user needs, but with a special focus on satellite systems that provide data critical for operational Earth system prediction, severe weather event warnings and protection of life and property. The user organizations and satellite operators have a shared responsibility for ensuring that satellite data can provide maximum value for the critical application areas.

The best practices focus on the critical timeframe from 5 years before launch to 2 years after launch, but it must be emphasized that this forms part of a continuous User Engagement process, that starts even before formal approval of the satellite program and stretches throughout the program lifetime.

The primary audiences for this publication are Members of the Coordination Group for Meteorological Satellites (CGMS) and WMO, but the broader user community can benefit from the information when shaping user readiness projects in their institutions.

The best practices are a very important guidance for commercial satellite data providers, and both CGMS and WMO will strive to ensure that the practices are followed for User Readiness Preparations for all essential data provision, especially for global numerical weather prediction (NWP) applications.

3. DIALOGUE BETWEEN SPACE AGENCIES AND USERS

An important basis for all user-readiness activities for satellite programs to establish a two-way dialogue between users and data providers early during the system development. This is to inform users of what they can expect from the new observations, as well as for users to plan their preparation activities and express what they require for an efficient and effective exploitation. Areas that benefit especially from such early dialogue include expected data characteristics, format definitions, dissemination routes, proxy data, embedded integration of subject matter experts, end-to-end testing, identifying research and development needs for data applications, training/education needs, as well as identification of “readiness blockers” that require addressing on the user or the provider side.

Efficient practices to facilitate the dialogue include, for instance, Satellite User Conferences, Scientific Advisory Groups, Proving Ground Initiatives, Testbeds, or Early Adopter Programs which engage expert users and space programme developers. The NOAA Proving Ground Initiatives for GOES-R and JPSS, and the EUMETSAT User Preparation projects for MTG and EPS-SG have been demonstrated as a very efficient approach for supporting user readiness.

User groups established through these activities can also play an important role in the early in-orbit evaluation of the data, including early demonstration of new capabilities in data applications.

User engagement workshops can help identify key needs of the user communities and identify recommended user requirements for future observations. Engagement with the wider user community through, for instance, the appropriate CGMS Science Working Groups are essential in order that users are informed about the upcoming data and that user-preparation activities are targeted and efficient.

A critical element of the dialogue is the identification of development needs for data applications, as well as discussions on appropriate resourcing, taking into account budget realities for the satellite programs as well as the users. User engagement that includes R&D and academia helps identify major items of research and development related to the new data. This accelerates the development of new products and applications, and informs upgrades to supporting infrastructure, both on the part of satellite providers and users. The return of investment into space programmes is greatly enhanced if necessary development needs are identified early and sufficiently resourced. Identifying commonalities between different satellite programs (e.g., for radiative transfer modelling, data processing) and the development of community tools through user networks such as the EUMETSAT Satellite Application Facilities can be very cost-effective in this respect.

The level of the required dialogue depends on the degree of novelty of the instrument. More extensive dialogue is needed for establishing user readiness requirements for a system with completely new sensing capabilities.

4. ACTIVITIES BY USERS TO ACHIEVE READINESS

These activities should be performed by user organizations to achieve readiness for new-generation satellites.

4.1 Establishment of a user-readiness project

It is crucial that planning start early. This publication assumes that users need to prepare for an entirely new generation of satellites, in which case the user-readiness project needs to be defined five years prior to launch. In particular, it is crucial to:

a) Clearly define project outcomes and deliverables;
b) Establish clear responsibilities and accountabilities;
c) Ensure adequate budget is available for all activities;
d) Establish a clear go-live planning for upgraded infrastructure and new services;
e) Develop communication networks between satellite operators, key managers, project stakeholders, and users.

The user readiness project needs to address:

a) New capabilities as well as improvements to existing capabilities;
b) Continuity of operational service provision, including critical path analysis for transition;
c) Maximum benefits from existing assets and protection of investment;
d) Maximizing value of service at all times during transition;
e) Opportunities for R&D that underpins or benefits novel products and applications development;
f) Ensure User Transition to new system takes place in a timely fashion.

The project must also include a detailed assessment of opportunities and risks. It can be opportune to embed the project activities within larger-scale activities aimed at upgrading the service and improving its resources.

During the execution of the project, special consideration must be given to:

a) The need for a dedicated project and project manager (overall accountability is important);
b) Maintaining contact with the satellite operator for up-to-date information;
c) Regular communication to key managers and project stakeholders (to maintain momentum and counter misinformation);
d) Monitoring key project milestones with a view to escalating activities when necessary;
e) Ensuring that management support and buy-in is available when needed;
f) Managing expectations regarding availability of new products.

4.2 Budgeting and planning

Budgeting and planning is of paramount importance and needs to start early. A new-generation satellite system can be, in some cases, the driver of significant infrastructure upgrades and increased performance requirements in terms of data acquisition, storage and networks, and should thus be known many years in advance to incorporate the necessary upgrades in the long-term evolution and investment plans. Realistic schedule margins and other provisions should be used to avoid planning difficulties, due, for example, to launch delays.

A main objective for a user organization is to protect the investment made in existing operational programmes, and to understand early where additional investments are necessary or unavoidable to achieve readiness for the new satellite system. Therefore, early information about investment drivers is crucial for budgeting and planning purposes.

4.3 Research and development

Research and development needs should be identified early in the preparation phase in dialogue with the data providers. In this context, “research and development” refers to the phase of activities that prepare the application of new-generation satellite data from the user perspective. This typically includes development of NWP data assimilation methods using the new-generation satellite data where needed, or development of new or specially tailored products for specific application areas, for instance by centres such as the EUMETSAT Satellite Application Facilities. These activities typically include computationally efficient tools to simulate the new observations, an analysis of the effects of instrument spectral response functions (SRFs), field of view (FOV), etc. Where possible, the use of common community software is advisable (e.g., RTTOV, CRTM) to ensure efficient and consistent developments.

Planning such activities depends to a large extent on the degree of novelty of the instrument. The lead times for an upgraded version of an existing instrument series can be shortened considerably and some steps (for example, simulated data) can be dropped completely. In contrast, in the case of totally new instruments, an in-depth analysis of specific development requirements is needed, taking into account the accuracy of forward-modelling tools, expected data volumes, and other processing needs. For instance, if an instrument measures in a different spectral region not previously covered by other instruments, research into the spectroscopy for this region may be needed. Or if instruments will be providing a step-change in the amount of data, efficient methods of representing the information may need to be developed. To enable such research, a first-guess spectral response function could be useful as early as four years before launch date, and for these, simulated data would also be very useful. For observations that are using a completely new measurement method, entirely new forward-modelling tools may need to be developed to enable quantitative exploitation of the data which can mean a substantial development.

Research and development activities do not stop at the end of satellite commissioning of novel sensors as it can take several years for their full capacity to be realized. Continuing to stimulate R&D interests and funding sources to encourage user engagement is important, as is identifying supporting agencies with the capacity to champion research to operations.

4.4 Data-handling development and testing

This activity includes design and procurement of new satellite reception systems, as well as upgrades to terrestrial network access (Internet, the Regional Meteorological Data Communication Network, the National Research and Education Network (NREN)-based push services) needed for handling increased data rates. The activity also encompasses upgrades to observational databases, short- and long-term archives, as well as upgrades to internal networks and general IT capacity for visualization, monitoring and processing.

It is crucial that the procurement of data-handling systems starts early to enable complete testing of all technical and scientific aspects of the processing chain.

4.5 Data-processing development and testing

All aspects of the processing software of satellite observations need to be adapted and potentially upgraded to accommodate data from a new satellite. These may include:

a) The local processing chain of direct-broadcast (DB) data into levels 0 (L0) and 1 (L1) products;
b) Additional software for deriving L2 products;
c) Data conversion into intermediate local formats and data subsetting for smaller regions of interest for observations databases and archiving;
d) Data monitoring and assimilation into NWP models;
e) The processing chain for local generation of higher-level products for specific applications using on-premises systems and/or the Cloud;
f) Integration into the operational user environment, including, for instance, integrated visualization applications (with satellite, radar, surface and altitude observations and model outputs) for forecasters.

For example, adaptation of NWP assimilation to new satellite systems requires long lead times and has specific requirements regarding availability of instrument and product data.

The availability of synthetic test data with realistic size and using the operational formats is essential for conducting end-to-end tests of the data processing systems. These tests should be in the form of "stress-tests" to check that systems are able to deal with the expected data volumes.

Planning of such activities varies widely according to the needs and capabilities of user organizations and require careful coordination with the users.

4.6 Contributions to calibration and validation

Participation of NWP centres in instrument calibration and validation activities has become a standard practice both for LEO and GEO satellites. Monitoring of “first-guess-minus-observation” departures for L1 products is an important contribution to the calibration and validation activities of satellite operators. Feedback and impact analysis from NWP users have become an integrated component of the calibration and validation.

5. CAPACITY-BUILDING

Capacity-building is vital to ensure that all WMO Members are able to exploit the value of the new generation of satellite data to the maximum. Such activities can take the form of bilateral NMHS partnerships, regional collaborative mechanisms such as User Forums or Conferences and WMO Regional Coordination Groups on Satellite Data Requirements. Training is one of the major elements of capacity-building focused on providing skills for using satellite data and products and should be considered of prime importance for both satellite operators and users.

Different aspects of user readiness for various target groups for training exist and it is important to identify the categories needed as these will have different time scales and require different levels of information about the new satellite system. The first type of training focuses on making sure the data can be accessed/received and displayed and is directed towards technical staff that include engineers and information technologies. The training addresses the questions: How and where can data and products be accessed? What types of commercial software or freeware programs/software code are available to read data formats and where are they located?

The second type of training focuses on the research to operations to research loop. It includes testbed and proving ground activities. The overall goal is to evaluate the usefulness of the data or the products in a simulated operational setting and to make sure the data/product can be displayed in the operational display system when the data become operational. These typically consist of workshops or direct research/office interactions and are conducted with proxy data before the satellite launches or with real data after the satellite launches.

The third type of training focuses on application of the new imagery and products in the operational setting. The generic satellite skills and knowledge necessary for operational forecasters should align with the WMO "Guidelines on Satellite Skills and Knowledge for Operational Meteorologists" to inform training development, implementation, and impact assessments, particularly as they relate to imagery interpretation. This type of training takes many forms: workshops, webinars, on-line modules, short reference videos and guides, and others. The best time frame to enhance learning of information is as close to the release of the new imagery and products as possible. The best opportunities to enhance retention of information is after the satellite launch when the user begins to explore the new imagery and products. Increased image spatial resolution is one of the first widely accepted benefits of the new satellite and sets the stage for acceptance of other new products. Following up one-time formal training with regular and repeated informal training on imagery and products that are used for different weather phenomena and significant events increases the adoption of the new satellite products.

A non-exhaustive list of identified training subjects:

(a) Similarities and differences with respect to existing satellites;
(b) Equipment operation and maintenance;
(c) Interpretation of L1 data from satellite payload instruments including:
    (i) Imagery interpretation;

(ii) Passive sounder data usage;

(iii) Active instrument usage;

(d) Use of software tools (for processing, visualization, analysis and assimilation);

(e) Derived L2 product utilization and interpretation;

(f) Understanding of data formats and dissemination;

(g) The physical basis of remote sensing, in particular as it applies to new instruments.

Target groups for training are:

(a) Trainers (using the "train-the-trainers" approach);

(b) Managers of user-readiness projects;

(c) Operational forecasters;

(d) User communities in NWP and other application areas;

(e) Organizational managers;

(f) Technical support personnel;

(g) Research and development personnel, science-to-operations personnel.

The approach for organizing training depends very much on the needs and capabilities of user organizations and on the organizational relationship between satellite operators and users. In 2020, the WMO Education and Training Program published 'Global Campus Innovations', which includes submissions from WMO Members on new learning approaches, curriculum advances, collaboration in educations and training, and technology-enhanced learning. With these advancements, emphasis is shifting towards blended learning approaches that combine in-person courses and workshops, online self-study modules, webinars, peer to peer and mentor interactions, and informal regular Regional Focus Group Sessions that promote communities of practice and continued learning.

The increasing importance of continuing training activities after launch needs to be emphasized. Training needs to cover both normal and critical real-weather situations for all seasons and it must be based on the real characteristics of the satellite systems. Emphasis should also be given to management support of the blended learning approaches and Training for Trainers to enhance the development and delivery of training materials.

The new-generation geostationary Earth orbit (GEO) satellites launched in the 2015-2025 timeframe have strong similarities in instrumentation (for example, similar spectral, temporal and spatial resolution of imagers and lightning mappers). Therefore, there are substantial potential benefits to users and satellite operators in developing common training material and in fostering common development of applications.

The WMO-CGMS Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) strategy covering the period 2024-2027 places high emphasis on building capacity among WMO Members for understanding and exploiting data from the new-generation satellites. VLab is expected to play a key role over the coming years in addressing the training needs of meteorologists in this regard, and strong support from CGMS members will be required.

Capacity-building should engage not only operational forecasters and satellite operators, but also the academic community. It is important to ensure that researchers and students participate in scientific activities related to the new instruments, in particular since this will benefit the operational exploitation of the instruments in the longer term by engaging the next generation of developers and users. In order to exploit the innovation potential of next-generation data, early engagement with the research community and their funding agencies is to be encouraged. By bringing together operational forecasters, product developers, academic community and forecast users, the diversity contributes significantly to rapid transition from research to operations and vice versa.

It is recognised that training and user support is required beyond the user preparation phase. The user preparation phases shall be seen as one period of activity within a broader and sustainable user engagement and capacity building process.

6. SATELLITE SYSTEM DEVELOPMENT

In executing a satellite system development programme, the following activities are typically performed by satellite operators, in cooperation with research and development satellite agencies and industry partners.

The life cycle of space projects is typically divided into seven phases (see Figure 1), as follows:

(a) Phase 0 – Mission analysis and needs identification
(b) Phase A – Feasibility
(c) Phase B – Preliminary definition
(d) Phase C – Detailed definition
(e) Phase D – Qualification and production
(f) Phase E – Utilization
(g) Phase F – Disposal

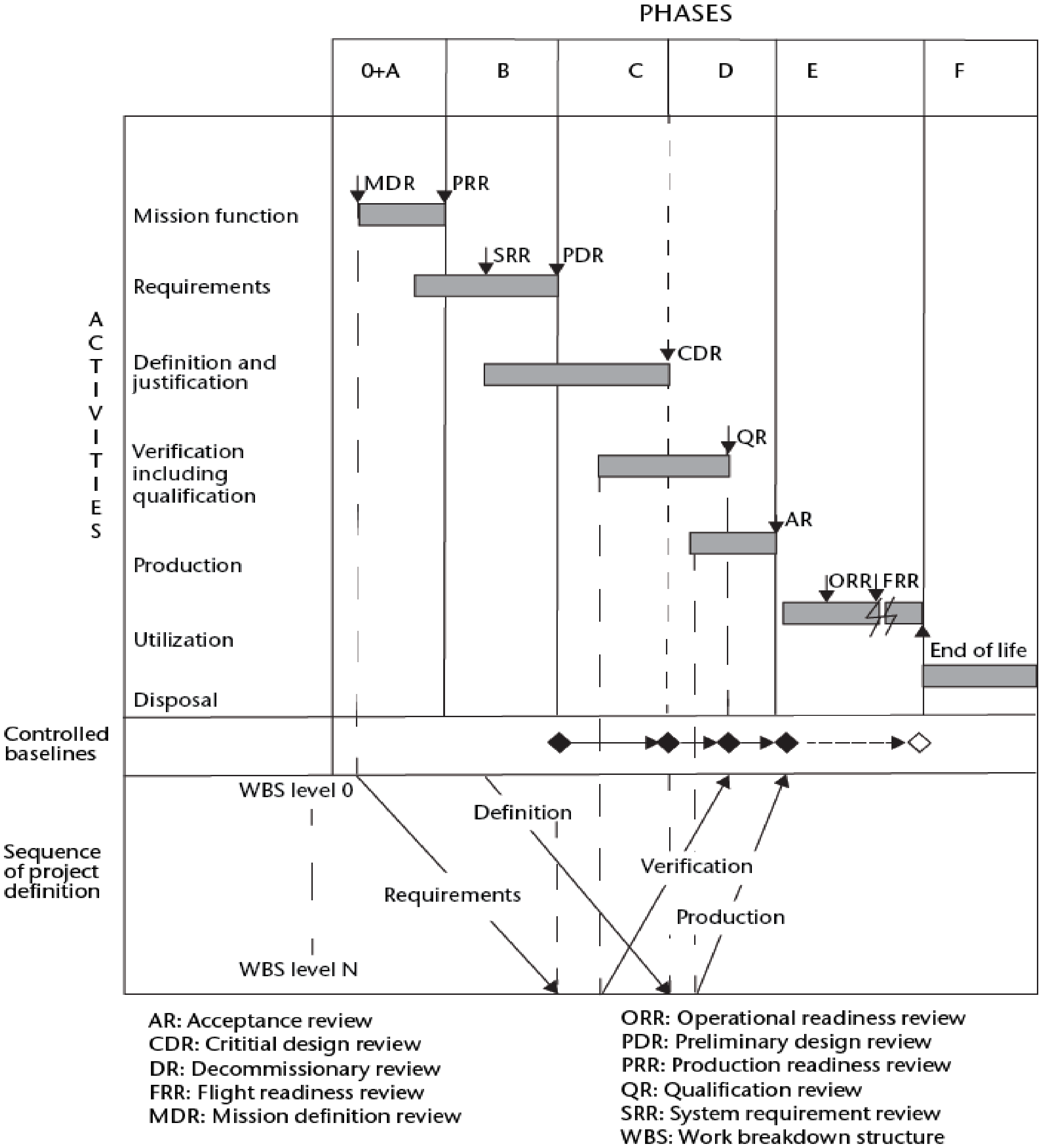

Figure 1. Reference satellite system development life cycle according to the European Cooperation for Space Standardization

Phase C (detailed definition) is concluded with the system critical design review (CDR), at which point the definition of the system (satellite and ground segment) will be complete down to the lowest level, and after which full production (Phase D – qualification and production) of the system will start. If development follows a nominal schedule, the system CDR will take place three years before launch. Phase E (utilization) starts with the shipment of the satellite to the launch site and the start of launch preparations, and is subdivided into Phase E1 (launch and commissioning), typically lasting until 6–12 months after launch, and Phase E2 (routine operations).

The most significant consequence of this life cycle with respect to the user community is that the system specification and other information made available to the user community before the system CDR (that is, at the end of phase C) will be based on requirements, whereas deliverables based on the real characteristics of the system will only become available after this time, during Phases D and E1.

This life cycle reflects actual experience from Meteosat Second Generation (MSG), COMS and GOES-R and also the planning for Meteosat Third Generation (MTG). Variations do exist for specific programmes; for example, the planning for Himawari-8 development was compressed: the system CDR was completed in January 2012, only 30 months before the planned launch in summer 2014 (the satellite was successfully launched on 7 October 2014).

7. DELIVERABLES FROM SATELLITE DEVELOPMENT PROGRAMMES TO USER-READINESS PROJECTS

This part of the publication considers high-level specifications for the different items produced by the satellite development programmes that should be delivered to user-readiness projects. The timeline of the deliverables can be found in section 6, Table 1.

7.1 Instrument prelaunch calibration and characterization

Prelaunch calibration and characterization data for satellite remote sensing instruments, being of general interest to the remote sensing data user community, are critical for the production of calibrated and geolocated L1 data and their adaptation by NWP and climate applications. The uncertainty, reproducibility and stability of these data are driven by operational and research remote sensing applications and requirements. For instruments built and/or tested by industry, provision of prelaunch test data to systems engineers, satellite operators and the remote sensing community are often subject to contractual constraints.

Satellite instrument prelaunch testing should strive to reproduce as closely as possible instrument operation in the predicted in-orbit environment. This is also known as "testing as you fly". The calibration and characterization data produced by this testing ensure that the instrument to be flown is fully understood at launch and will meet its performance requirements when in orbit. The need for pre-launch instrument characterisation is all the more important given increasingly complex design of the new generation of instruments.

Estimates of several key performance parameters listed below, including spectral response function characteristics, radiometric accuracies derived from pre-launch tests and the radiometric characterisation of onboard black bodies will benefit from considering the property of metrological traceability. This requires that all measured quantities influencing the estimate of a parameter are linked, through an unbroken chain of comparisons, to recognised measurement standards, ideally the SI. Establishing such traceability enables the robust determination, and optimisation, of uncertainties in these key performance parameters.

To facilitate proper and efficient use by the international remote sensing community, pre-launch characterisation data should include the following:

(a) Channel naming and numbering convention and channel science application(s);

(b) Spectral response function (SRF) (also known as relative or absolute radiometric spectral responsivity (RSR)):

   (i) Channel central frequencies/wavelengths and bandwidths, together with detailed measured spectral responses from pre-launch instrument characterisation;

   (ii) Responsivity versus wavelength as a function of channel (that is, average) and detector;

(c) Polarisation for each channel, verified by pre-launch measurements;

(d) Along-scan and in-track field of view (FOV) pixel size or full point spread function (PSF)/modulation transfer function (MTF);

(e) Instantaneous field of regard/view (IFOR/IFOV)/swath coverage, repeat cycle/orbit configuration;

(f) Measured antenna pattern (for MW instruments)

(g) Pixel sampling distance/time intervals;

(h) System-level instrument noise (that is, noise expressed as a variation in radiance and brightness temperature (NEdL and NEdT, respectively)) as a function of instrument and focal plane temperature and spacecraft voltage;

(i) Radiometric calibration and characterization:
   (i) Gain and offset as a function of instrument and focal plane temperature;
   (ii) Polarization sensitivity;
   (iii) Radiometric resolution, dynamic range, linearity and quantization;
   (iv) Response versus scan angle for scanning radiometers;

(j) Instrument pointing, geometric accuracy and band to band calibration/registration (that is, geometric performance);

(k) Expected mission and instrument lifetimes;

(l) Key parameters of on-board calibrators (that is, black-body emissivity and temperature uniformity, solar diffuser spectral bidirectional reflectance or transmittance distribution function (BRDF or BTDF) and uniformity);

(m) Target and realized measurement uncertainties for the above data;

(n) In all the above, the level of maturity of the determination of instrument testing parameters should be indicated. This is accomplished by identifying if the data were determined using analysis/modelling, demonstration or inspection, or testing at the part, sub-assembly, subsystem, system or observatory (that is, spacecraft plus instruments) level.

Prelaunch test data should be provided for the primary, redundant and all potential cross-strap instrument in-orbit operational configurations.

Mechanisms must be established for providing users with information about events that affect the in-flight instrument performance. To address this, the Global Space-based Inter-calibration System (GSICS) project coordinates the implementation of operational instrument event logs.

7.2 Product specifications

Product specifications include scientific specifications of the product algorithms, detailed specification of formats for dissemination, as well as on-demand requests, information on timeliness and expected data volumes, all for both L1 and L2 products.

Community standard formats should be adopted for products. If not WMO's BUFR and GRIB, then netCDF with CF convention. For the latter, WMO is in the process of introducing netCDF CF profiles, and the concept of WMO-approved formats is evolving in that respect. It is also important to consider the flexibility which will come with the advent of WIS 2.0. There is a need for a more standardized approach to describe both L1 and L2 products, potentially through the development of standard templates for product description. It is highly recommended that nicknames be avoided to describe the products. This leads to confusion among the users (e.g. it was reported by trainers that tropical users initially ignored using the "snow/ice" band at 1.6 µm because they did not experience snow and ice on the ground. They later realized it was useful for detecting ice phase in clouds).

7.3 Product guides

In addition to formal product specifications (e.g. algorithm theoretic basis document (ATBD)), several operators have successfully implemented product handbooks/User Guides, that helps the users in assessing fitness-for-purpose of the products. A good example of these is the Meteosat Third Generation Product User Guides, generated by EUMETSAT. Content includes information that is helpful in receiving, processing, and reading, for example level 0-2 data and using it as input to algorithms, products, and display systems.

7.4 Data access mechanism specifications

The methods for accessing satellite products are developing rapidly, with increasing use of Cloud technology. There is however a need for a range of access methods, so that users who do not have reliable access to the Cloud can retrieve products reliably.

The methods for accessing satellite products directly typically include Direct Broadcast (DB) from the satellite itself and/or digital video broadcast (DVB)-based dissemination from telecommunications satellites. Specifications for these are required for the procurement of user reception systems.

System requirements for DB reception systems, including both antennas, front-end components and computer systems for acquisition and L1 processing need to be available to users in time for starting procurement activities, typically three years before launch. The processing system requirements are becoming increasingly demanding with the complex processing of DB data for the new generation of satellites; the impact on users' systems is significant. If the satellite operator can offer a remotely accessible (possibly cloud based) processing solution for the DB data, then the DB reception system would not necessarily need L1 processing capabilities. This approach is already being assessed by the China Meteorological Administration (CMA).

Also required are specifications of other near-real-time dissemination mechanisms employing terrestrial communication and cloud technology and for offline data access mechanisms, including archive retrieval and other on-demand means. For example, for data disseminated via the GTS, abbreviated bulletin headers are needed to organize the routing, and for data via WIS 2.0, pub/sub infrastructure the relevant topic(s) are needed for configuring the consumers' subscription.

Where user registration is needed for access to products and services, detailed description of the user registration process is required before launch so that the registration process can be exercised by the users already during the commissioning phase.

7.4 Software tools, documentation, and test data

Level 1 preprocessing software is required for the development of the user data-processing functions, but in many cases is only available from an operator after ground segment acceptance. Any contracts for procurement of data-processing systems need to take this need into account to allow early deliveries.

Documentation for software is important, such as format book, users menu, algorithm theoretic basis document (ATBD), those need to be made available to users along with the software and test data.

Software tools can also be developed by experts in the user community, but for a new generation of satellites, these software tools will always depend on L1 processing kernels developed as part of the satellite system development.

Different categories of test data exist with different life cycles. A universal categorization is not in use, but for the purposes of this publication, the following terminology is used:

(a) Synthetic data: No scientific value, but realistic sizes and formats; used for user data-flow testing;

(b) Simulated data: Data simulated by forward radiative transfer model calculations. Simulated data are used to test processing and visualization tools. These data are produced based on NWP-model output; they generally do not contain realistic spatial structure and temporal variability;

(c) Proxy data: Actual datasets from relevant precursor instruments – for example, 2.5-minute data from Meteosat-10 for MTG-Flexible Combined Imager (MTG-FCI), 1-minute super-rapid scanning data from GOES for GOES-R ABI, and Infrared Atmospheric Sounding Interferometer (IASI)/Atmospheric Infrared Sounder (AIRS) data for FY-4A Geostationary Interferometric Infrared Sounder (GIIRS) and MTG-Infrared Sounder (MTG-IRS). Proxy data are used in early training on capabilities and application areas. It is also possible to use proxy data to construct test data similar to simulated data by adding data simulated by radiative transfer models for channels to the ones present in precursor missions or by using interpolation in time and space;

(d) Pre-operational data: Real satellite data generated as part of the commissioning activities, but before full validation has been completed.

The operators should provide all of these categories of test data, use consistent terminology to describe them, and also provide software tools for the use of test data, both during prelaunch development and testing (where the focus should be on data for format familiarisation and data flow testing) and during post-launch commissioning activities (where pre-operational data are to be provided). Advanced users can also provide test data, and there is scope for the integration of such data with the test data provision of operators.

7.5 Operations plans and schedules

To ensure user readiness, it is important that both long-term plans as well as routine schedules are made available before the start of operations. This includes the following elements:

(a) Fly-out plan for the overall satellite programme, including planning for launches, orbital positions and end-of-life dates, and information about overlap with existing operational satellites;

(b) Routine operations schedule, including areas of coverage for flexible scanning operational scenarios and information on the process for scenario switching; for example, activation of super-rapid scanning operations for severe storms and tropical cyclone tracking;

(c) If appropriate, conditions for user input to the operations schedule (for example, requests for special mode-targeted operations);

(d) Planning for routine spacecraft maintenance activities, such as orbital manoeuvres, seasonal spacecraft reorientation (yaw-flip), instrument decontamination, and the like;

(e) Schedules for activation of LEO DB where applicable;

(f) Schedules for routine dissemination for both DB and re-broadcast via telecommunications satellites.

Dialogue with key users is crucial when establishing the initial operations plans.

Details on recommended due-by dates are provided in the timeline contained in Table 1.

7.6 Data access during early mission phases

A critical element of ensuring user readiness is the early provision of satellite products and the overlap with the previous system. Satellite products must be provided at the earliest opportunity following the necessary calibration-validation activities and the data provision must in all phases as far as possible be using the operational data access infrastructure. A sufficient overlap with the existing operational satellite system must be provided to support the operational introduction of the new satellite data. The critical needs are:

a) Periods of pre-launch dissemination of test data to support test of users' data acquisition infrastructure
b) Access to non-validated data by selected users supporting calibration-validation activities
c) Early post-launch dissemination of pre-validated data and products

d) Parallel Level-1 data dissemination, from both old and new satellites (as long as possible, but minimum 6 months after the end of commissioning (typical until L+1y))

More details are included in the Reference User-Readiness Project timeline.

7.6 User notification and feedback

It is essential that the satellite operator establish two-way communication channels to the user community to provide general and specific information, and to allow users to make inquiries and provide other feedback during the preparation phase. Such channels are also necessary to provide routine user support starting from the commissioning phase and continuing throughout the routine operations phase. Identifying and mapping the networks that reach different user communities allows for strategic and efficient communication.

Such communication should include and are not limited to the WMO Regional Coordination Groups on Satellite Data Requirements, regional forums and user conferences, and training events. The communication channels should also provide for enquiries and feedback from individual users.

7.7 Training resources

For new satellite systems, the provision of training material from satellite operators is crucial. Blended training approaches are of increasing importance and provide flexibility when delivering new information about the satellite and its applications when the information becomes available. It is also essential to capitalize on the contributions of the user community and promote training resources that are made available by user groups. WMO-CGMS VLab plays a key role in developing and delivering online training material to users worldwide in native languages. It is now recognized that Regional Forums and User Conferences held annually or every other year by Satellite Operators provide the best opportunity for delivering information on new-generation satellites and gathering user input to inform the requirements of the next generation satellites. Training workshops are coordinated with the conferences and can be targeted to specific user groups. Blending and interleaving workshops, courses, webinars, online modules, blogs, and regular regional Focus Group Sessions promotes continued learning and uptake of satellite imagery and products. VLab is actively engaged in these activities.

7.8 Other deliverables

For many applications, it is important to have the set of fundamental constants that have been used to derive satellite data and products, and satellite operators should make this available to users. It is planned to propose a common standard to be used by CGMS operators.

8. TIMELINE FOR THE REFERENCE USER-READINESS PROJECT

Table 1 shows the overall timeline of user preparedness activities, and the planning for the different deliverables from the satellite system development needed to support these activities.

Table 1. Timeline for the reference user-readiness project

Time relative to launch date (L) in years (y) or months (m)	*Satellite system development: Activities and milestones*	*User-readiness project: Activities and milestones*	*Needed deliverables from satellite operators*
L-5y -> L-4y	Ground segment development Phase C	– Initiation of user (e.g., NMHS) readiness project – Initiation of cooperative projects addressing needs of less-developed WMO Members	- Identified likely and potential users – Overall specifications of user segment, including high-level definition of migration path from existing user segment – Preliminary schedule for deliverables to users - Identified Research and Development needs (observation operators/radiative transfer, etc)
L-4y -> L-3y	System CDR	– Identification of drivers for investment and running costs – Planning and allocation of human resources and budgets for investments and running costs – Establishment of prioritized data requirements, as clear priorities for current and future products allow the best preparations to be made for establishing data access and delivery capabilities – Initial training on capabilities for trainers and decision-makers	– General description of instruments – General description of near-real-time dissemination mechanisms – Detailed specifications of L2 and L1 products to be available at start of operations (Day-1 products) – Proxy test data – Plans for evolution of products after start of operations (Day-2 products)
L-3y -> L-2y	– System production – On-ground characterization of instruments	– Design of new reception system – Design of communications network changes, including Global Telecommunication System/Regional Meteorological Data Communication Network (GTS/RMDCN) capacity – Design of new data-handling and processing functions	– Specifications of instruments and their performance, including planned SRFs, noise and FOV size – Simulated test data – Developed applications where required (e.g., observation operators, methodologies, etc)

Time relative to launch date (L) in years (y) or months (m)	*Satellite system development: Activities and milestones*	*User-readiness project: Activities and milestones*	*Needed deliverables from satellite operators*
		– Training on specific application areas, based on proxy data, for trainers and senior forecasters	– Detailed specifications of near-real-time dissemination mechanisms – Detailed specifications of direct broadcast (DB), including frequency and signal characteristics and hardware specifications for antennas, front-end components and computer systems for acquisition and processing of DB data – General description of offline data access – Data/product volume estimates – Data/product format definitions – Fundamental constants used in processing – Data access conditions (e.g., licensing, key units) – L1 preprocessing software for DB (preliminary version) – Establish and use two-way communication channels for user enquiries
L-2y -> L-1y	Ground system acceptance	– Procurement, installation and acceptance testing of systems – Software design for data-processing, including NWP ingest - Training on specific application areas, based on proxy data, for trainers and senior forecasters	– Full prelaunch instrument characterization information (including SRFs, noise) – Information on radiative transfer models (e.g., RTTOV*) that support instruments – Synthetic test data (including L1B data format details, satellite ID, navigation information) – Continuous periods test dissemination of synthetic test data – Long-term operations plan – Planning for data exchange to serve global community

Time relative to launch date (L) in years (y) or months (m)	*Satellite system development: Activities and milestones*	*User-readiness project: Activities and milestones*	*Needed deliverables from satellite operators*
L-1y -> L-6m	Flight readiness of satellite	End-user training (forecasters)	– Start of regular updating of plans for launch and commissioning
L-6m -> L	Operational system validation and launch preparations	– Data-processing software testing (using proxy data) – Technical training on reception systems and other system elements – Data acquisition system testing (using synthetic data)	– Simulated test data based on prelaunch instrument characterization – L2 data format – DB software package (if DB available) – User documentation for dissemination mechanisms and delivered software tools – Routine operations schedule
L -> L+6m	– Satellite in-orbit verification – Commissioning of L1 products	– Full system and software testing (using pre-operational data) – Support to operators calibration/validation activities, in particular through NWP assimilation	– Early dissemination of unvalidated L1 data – Early switch-on of DB – Pre-operational L1 data dissemination – In-flight characterization of instrument performance – L1 preprocessing software for DB (operational version) – Start of routine user support
L+6m -> L+2y	Commissioning of L2 products	– Scientific data exploitation (iterative, based on increased understanding of real data) – Post-launch training based on real data – Declaration of user operational readiness	– Operational L1 data dissemination, from both old and new satellites (as long as possible, but minimum until L+1y)

* RTTOV: Radiative transfer for TOVS; TOVS: TIROS operational vertical sounder; TIROS: Television infrared observation satellite