Guidelines on Best Practices for Achieving User Readiness for New Meteorological Satellites

2017 edition

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1187

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REFERENCE USER-READINESS PROJECT

1. BACKGROUND

Nearly all geostationary meteorological satellite systems in the world have been or will be replaced by a new generation in the 2015–2022 time frame, by China, Japan, the Republic of Korea, the Russian Federation, the United States of America and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The new-generation satellites carry advanced imagers providing at least 16 spectral channels and flexible rapid-scan capabilities, with additional innovative payloads, such as lightning mappers and sounders for some of the programmes (see Table 1). Other new-generation systems will be deployed in polar and other orbit types in the coming decade.

Table 1. New-generation meteorological satellites in geostationary orbit, 2015–2022 (status at April 2017)

Satellite	*Operator*	*Launch date*	*Longitude*	*Imager*	*Number of spectral channels*	*Spatial resolution (km)*	*Temporal resolution (full disk) (minutes)*	*On-board sounder/ lightning mapper*
Himawari-8*	JMA	7 Oct. 2014	140E	AHI	16	0.5–2	10	- / -
Electro-L N2*	ROS-HYDROMET	11 Dec. 2015	78E	MSU-GS	10	1–4	15	- / -
INSAT-3DR*	ISRO	8 Sep. 2016	74E	Imager	6	1–8	30	S / -
GOES-R	NOAA	19 Nov. 2016	137W	ABI	16	0.5–2	15	- / L
Himawari-9	JMA	2 Nov. 2016	140E	AHI	16	0.5–2	10	- / -
FY-4A	CMA	10 Dec. 2016	86.5E	AGRI	14	1–4	15	S / L
GOES-S	NOAA	2018	75W	ABI	16	0.5–2	15	- / L
Geo-KOMPSAT-2A	KMA	2018	128.2E	AMI	16	0.5–2	10	- / -
FY-4B	CMA	2018	105E	AGRI	14	0.5–4	15	S / L
MTG-I/S	EUMETSAT	2020–22	9.5E	FCI	16	0.5–2	10	S / L

Notes:
ABI: Advanced Baseline Imager; AGRI: Advanced Geosynchronized Radiation Imager; AHI: Advanced Himawari Imager; AMI: Active Microwave Instrument; CMA: China Meteorological Administration; FCI: Flexible Combined Imager; ISRO: Indian Space Research Organization; JMA: Japan Meteorological Agency; KMA: Korea Meteorological Administration; MTG: Meteosat Third Generation; MSU-GS: Multispectral Scanner-Geostationary; NOAA: United States National Oceanic and Atmospheric Administration; ROSHYDROMET: Russian Hydrometeorological Service
* Himawari-8, Electro-L N2 and INSAT-3DR are operational

Source: Observing Systems Capability Analysis and Review Tool (OSCAR)/Space-based Capabilities – OSCAR/Space (status at April 2017)

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 order of magnitude higher than today, 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.

The WMO Commission for Basic Systems [CBS] Guidelines for Ensuring User Readiness for New Generation Satellites, 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), on user preparation for the new generation of meteorological satellites, urge (Annex I to para. 4.2.36 of the general summary): "Establishment by each concerned [National Meteorological and Hydrological Service] NMHS 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) – Preparation for new satellite systems, 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 information, specifications, and data and tools used in satellite system development. Therefore, to establish a user-readiness project, it is important to consider in detail the life cycle of satellite system development and its relation to user-readiness planning.

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. Even though user-readiness activities are explicit elements of ongoing satellite system development programmes, such as for Himawari-8/9 or GOES-R, satellite operators often do not systematically provide up-to-date planning schedules of deliverables to the user community.

For this reason, the Seventeenth World Meteorological Congress (Resolution 37) also urged "satellite operators to provide regular and timely updates on their new systems through appropriate means and in particular through inputs to [the Satellite User Readiness Navigator] SATURN and OSCAR".

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 2). 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.

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 3) and satellite operators (section 5).

The primary audiences for this publication are Members of the Coordination Group for Meteorological Satellites (CGMS) and WMO, but the broader user community can equally benefit from the information.

3. ACTIVITIES BY USERS TO ACHIEVE READINESS

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

3.1 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.

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.

The project must also include a detailed assessment of opportunities and risks.

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.

3.2 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.

3.3 Research and development

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 numerical weather prediction (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 analysis of the effects of instrument spectral response functions (SRFs), field of view (FOV) and the radiative transfer models used to simulate instruments. 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 series can be shortened considerably and some steps (for example, simulated data) can be dropped completely. In the case of totally new instruments however (for example, the Infrared Sounder on MTG-S), a first-guess SRF could be useful as early as two years before launch date, and for these, simulated data would also be very useful.

3.4 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 and the Regional Meteorological Data Communication Network) needed for handling increased data rates. The activity also encompasses upgrades to observational databases, short- and long-term archives, as well as 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.

3.5 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 the new satellite. These may include:

(a) The local processing chain of direct-broadcast (DB) data into levels 0 (L0) and 1 (L1) products;

(b) Data conversion into intermediate local formats for observations databases and archiving;

(c) Data monitoring and assimilation into NWP models;

(d) The processing chain for local generation of higher-level products for specific applications;

(e) 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.

Planning of such activities varies widely according to the needs and capabilities of user organizations.

3.6 **Training**

Different subjects and 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. Generic satellite skills and knowledge for operational forecasters recommended by WMO should serve as guidance to frame training schedules.

Identified training subjects are:

(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, 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.

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. With the advancement of e-learning technology, emphasis is clearly shifting from long-term planned classroom training towards “just-in-time training” based on webinars and self-study online, among other forms.

The increasing importance of continuing training activities after launch needs to be emphasized. Training needs to cover critical real-weather situations for all seasons and it must be based on the real characteristics of the satellite systems. Emphasis should be given to training formats that can be integrated into ongoing operations, such as short training modules for “as-it-occurs” training of operational forecasters on or between shifts. This approach is, for example, reflected in the NOAA GOES-R training planning (see Figure 1), extending baseline training activities until one to two years after launch.

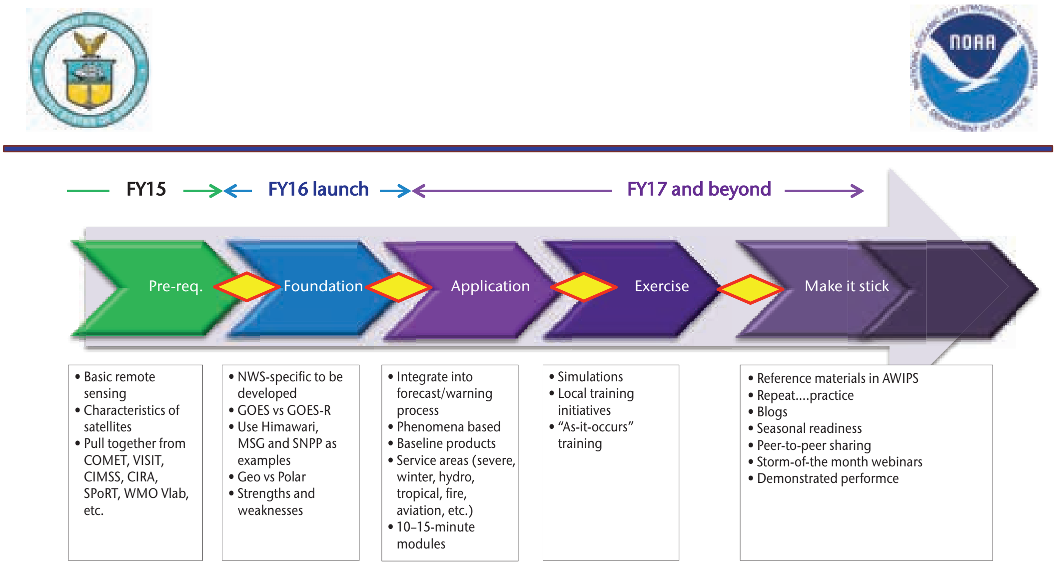


Figure 1. NOAA GOES-R training plan

The new-generation geostationary Earth orbit (GEO) satellites 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 national training programme run by the Australian Bureau of Meteorology Virtual Laboratory for Education and Training in Satellite Meteorology (VLab) training centre to prepare users nationally and in WMO Region V (South-West Pacific) for the effective use of new-generation Himawari-8 data is a good example of assistance to user readiness (http://www.virtuallab.bom.gov.au/training/hw-8-training).

In collaboration with VLab and the COMET/MetEd programme, SATURN now links to online training material on Himawari-8 and GOES-R, in English and Spanish (where available). For example, the COMET/MetEd module "Advanced Himawari Imager (AHI): What's Different from GOES-R Advanced Baseline Imager (ABI)" (http://www.meted.ucar.edu/satmet/himawari_ahi/) is very effective in comparing these two imagers, and a module exists (https://www.meted.ucar.edu/goes_r/abi_es/) explaining the GOES-R ABI in Spanish. Translation of more training material is planned and is a high priority for WMO and VLab.

The VLab strategy 2015–2019 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.

3.7 **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 the Regional Association (RA) I Dissemination Expert Group and the EUMETSAT User Forum in Africa, the RA II WMO Integrated Global Observing System project on satellite utilization, or major projects providing technical and scientific infrastructure and training for less-developed WMO Members (for example, the projects African Monitoring of the Environment for Sustainable Development and Monitoring of Environment and Security in Africa).

Capacity-building should also engage 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.

3.8 Contributions to calibration and validation

Participation of NWP centres in instrument calibration and validation activities has become standard practice both for low Earth orbit (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.

4. SATELLITE SYSTEM DEVELOPMENT PHASES

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 2), 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

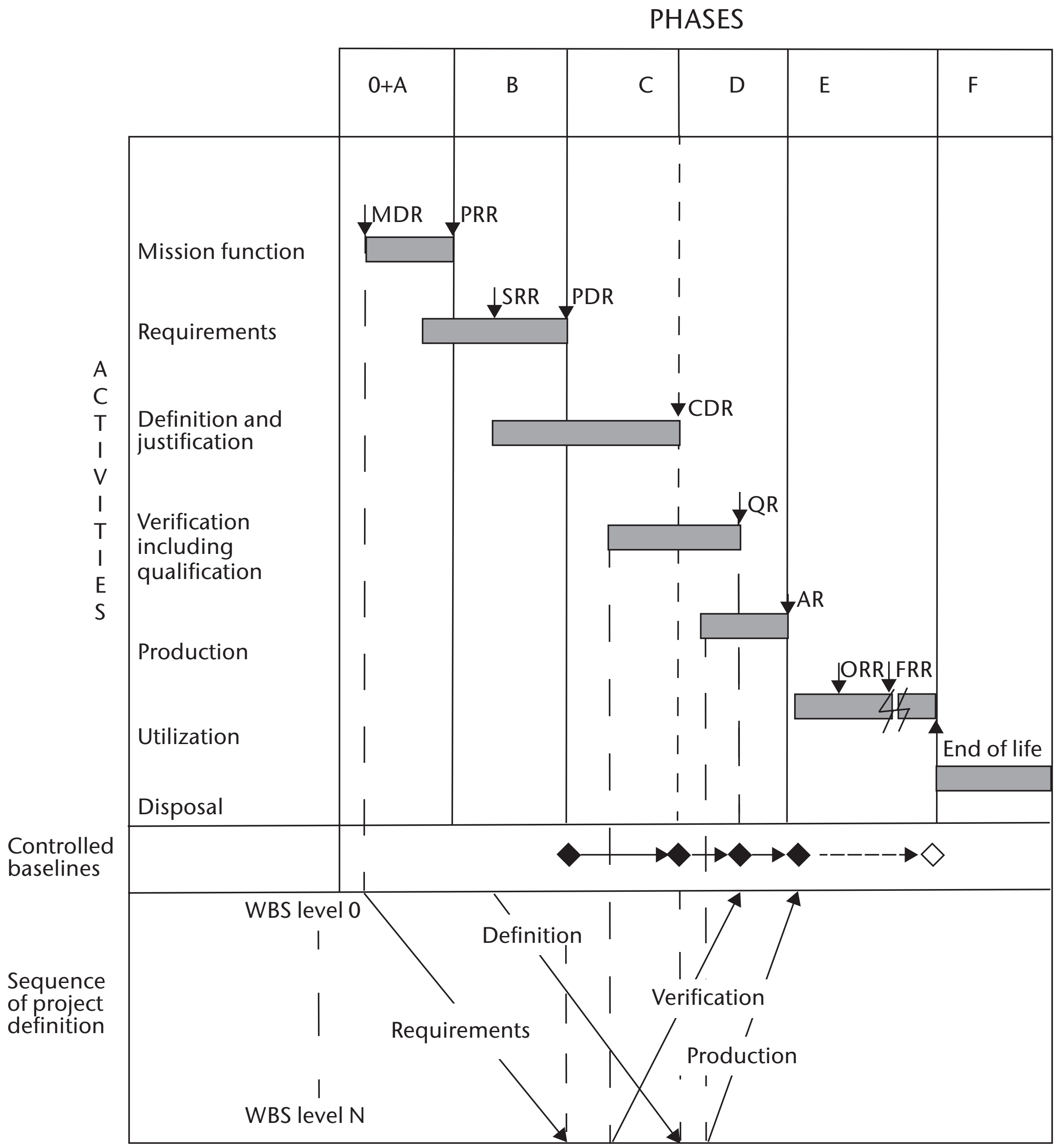
(f) Phase E – Utilization

(g) Phase F – Disposal

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 Meteostat Second Generation (MSG) and COMS, and also the status and planning for GOES-R and MTG. Variations do exist for specific programmes; for example, the planning for Himawari-8 development was somewhat 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).



AR: Acceptance review
CDR: Crititial design review
DR: Decommissionary review
FRR: Flight readiness review
MDR: Mission definition review
ORR: Operational readiness review
PDR: Preliminary design review
PRR: Production readiness review
QR: Qualification review
SRR: System requirement review
WBS: Work breakdown structure

Figure 2. Reference satellite system development life cycle according to the European Cooperation for Space Standardization

5. 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 2.

5.1 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.

The new generation of satellite instruments employs increasingly complex focal planes, often with two dimensional detector arrays and innovative read-out schemes producing large amounts of data. Despite this increasing instrument complexity, satellite instrument prelaunch testing must still 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. To facilitate proper and efficient use by the international remote sensing community, these 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;

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

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

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

(e) Pixel sampling distance/time intervals;

(f) 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;

(g) 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;

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

(i) Expected mission and instrument lifetimes;

(j) 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);

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

(l) 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.

5.2 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.

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 should be noted that for the online Product Access Guide (http://www.wmo.int/pages/prog/sat/documents/SAT-GEN_PAG-concept-v1.0-final.pdf#10) WMO has introduced a standard classification of L2 products.

5.3 Data access mechanism specifications

These specifications include mechanisms for DB- and for digital video broadcast (DVB)-based dissemination. These specifications 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.

Also required are specifications of other near-real-time dissemination mechanisms employing terrestrial communication, and of offline data access mechanisms, including archive retrieval and other on-demand means.

Where user registration is required 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.

5.4 Software tools 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.

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 and the SATURN portal, 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 Souonder (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) Preoperational 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 during post-launch commissioning activities.

5.5 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.

Details on recommended due-by dates are provided in the timeline contained in Table 2.

5.6 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 enquiries 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.

Such communication should include regional satellite-user coordination mechanisms (such as the WMO Coordination Group on Satellite Data Requirements for Regions III and IV; and the Regional Association I Dissemination Expert Group), regional user conferences (such as the Asia–Oceania Meteorological Satellite Users' Conference) and training events (such as the GOES-R Event Week), as well as provide support for enquiries and feedback from individual users.

5.7 Training resources

For new satellite systems, the provision of training material from satellite operators is crucial. Online training resources are of increasing importance and give the possibility of dynamic adaptation when new information about the satellite and its applications 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 several languages. An event week on preparing for new-generation satellites was held in November 2015, to which CMA, EUMETSAT, JMA, KMA and NOAA all made contributions (presentations and recordings are available at http://www.wmo-sat.info/vlab/next-generation-of-satelliles/). More events of this nature are planned by VLab.

5.8 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; for example, the list published by the United States National Institute of Standards and Technology.

6. TIMELINE FOR THE REFERENCE USER-READINESS PROJECT

Table 2 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. Each user deliverable in the reference project has an associated subcategory in SATURN, so that the portal will provide up-to-date links to all deliverables when these become available from the satellite system development.

Table 2. 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	– Overall specifications of user segment, including high-level definition of migration path from existing user segment – Preliminary schedule for deliverables to users
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 – Training on specific application areas, based on proxy data	– Specifications of instruments and their performance, including planned SRFs, noise and FOV size – Simulated test data – 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

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-2y -> L-1y	Ground system acceptance	– Procurement, installation and acceptance testing of systems – Software design for data-processing, including NWP ingest	– 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
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 preoperational data) – Support to operators calibration/validation activities, in particular through NWP assimilation	– Early dissemination of unvalidated L1 data – Early switch-on of DB – Preoperational 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

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