Group on Earth Observations /
Committee on Earth Observation Satellites

Minutes of the
Workshop on Calibration & Validation Processes

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1 Welcome & Introduction

1.1 Pascal Lecomte (ESA / WGCV Vice-chair)

Lecomte welcomed everyone to the workshop on behalf of the organising committee. He introduced **Achache**.

1.2 José Achache (GEO Secretariat)

Achache welcomed the workshop participants on behalf of the Group on Earth Observations (GEO). He identified that the Committee on Earth Observation Satellites (CEOS) has become a much more efficient and active coordination body within GEO in working towards the establishment of an operational Global Earth Observation System of Systems (GEOSS). GEO coordinates global activities by making these mechanisms and their priorities clearer and easier to understand at a political level. **Achache** stressed that GEOSS is not in itself a tool dedicated to a single application but a collection of 'systems' serving a multitude of disparate applications. He went on to say that for GEOSS to be fully successful, the calibration, validation and intercalibration between all instruments is of key importance. This, and the idea of the virtual constellation, would not 'fly' if the calibration cannot be executed properly. Soon, the choice between a heavily architectured GEOSS or a 'U-Tube' type of system would have to be made. If we had the former it will be very rigid and complicated but would ensure a well-calibrated and traceable system. The U-tube type of system would be more flexible in that data could more easily be made available, but those data may not necessarily be entirely trustworthy. The choice of system requires careful consideration as GEOSS is for users and decision makers, not for scientists, and as such the data needs to be trusted and reliably used without the risk of basing a wrong decision upon it. These are not small issues and the hope for the workshop was that it would build practical additions into the GEOSS process. **Achache** concluded by wishing everyone a constructive meeting.

Lecomte reflected on the very encouraging words from **Achache**. He then introduced **Cao**, the chair of the CEOS Working Group on Calibration and Validation (WGCV) and, as such, one of the key figures in making the aspirations of GEO and GEOSS a reality.

1.3 Changyong Cao (NOAA / WGCV Chair)

Cao established the background to the workshop and the underlying issues to be addressed. He explained that the WGCV is a very successful technical working group, established in 1984, and that this workshop was a major milestone for the group and for CEOS. The GEOSS 10-year implementation plan identifies that 'The success of GEOSS will depend on data and information providers accepting and implementing a set of

interoperability arrangements.' However, data accessible does not necessarily mean data usable. Cal/Val is critical to data quality assurance and data usability. GEO task DA-06-02 is led by the WGCV and the Institute of Electrical and Electronics Engineers (IEEE) and aims to 'Develop a GEO data quality assurance strategy, beginning with space-based observations and evaluating expansion to *in situ* observation, taking account of existing work in the area'. This task is much more cross-cutting than many of the other GEO tasks. The importance of the task has been recognised within CEOS and has been inserted into the CEOS implementation plan.
Cao concluded by thanking Lecomte (ESA), Rast (GEO Secretariat), Ungar (NASA/Task DA-06-02 lead), the workshop organisers and all those participating in the workshop.

Lecomte thanked Cao for his introduction and then introduced **Rast** to provide the background to the workshop from the GEO perspective.

1.4 Michael Rast (GEO Secretariat)

A recent IEEE article posed the question: "How do you get thousands of Earth-observation systems that were built at different times by different people for diverse purposes and that use dissimilar data formats and communications techniques to operate together smoothly and from a coherent system?". **Rast** explained that GEO was established to answer such a question and that the only real answer is harmonisation. There are two pillars to harmonisation – data availability and data quality – and these are essential to each other. If either of the two pillars are missing then we cannot achieve harmonisation. For example, increasingly, data from multiple sensors are used to gain a more complete understanding of land surface processes at a variety of scales. Any single problem requires many datasets; a single dataset will serve many communities. The aim of GEO is to assure communication and provide systems interoperability and easier and more open data access through GEOSS.

The creation and formalisation of GEO and the GEOSS concept were the outcome of a series of Earth Observation Summits beginning in 2003 in Washington D.C. and in early 2005 in Brussels. GEO comprises 77 member counties and the GEOSS 10-year implementation plan has been translated into 73 tasks. GEOSS is a global coordinated, comprehensive and sustained system of observing systems that attempts to bring the community together. GEOSS is a global distributed system, including satellite observation systems, global *in situ* networks and systems, and local and regional *in situ* networks. GEOSS will deliver the benefits of EO to both data and information providers and consumers worldwide. The GEO web portal (and clearing house) offers access to data and services, Cal/Val data and tools to work with the data. The aim is for all data made available through the clearing house to have a quality-assured stamp to it and the Cal/Val portal is seen as a valuable addition to this effort. This workshop was an important forum as its results will be taken by GEO, GEOSS and Global Monitoring for Environment and Security (GMES). Once the resulting guidelines and practises are

adopted, it would become impossible to put non-conforming data into GEOSS, thereby assuring the quality of the data within.

GMES and GEOSS is an excellent example of science serving society. The focus of GEOSS is to address societal benefits through more coordinated observations, better data management and increased data sharing. Over time, GEOSS will provide an important scientific basis for sound policy and decision making in every sector of our society, including energy, public health, agriculture, transportation and numerous other areas that shape the quality of everyday life.

Rast suggested that in order to achieve harmonisation in Cal/Val processes we should not despair at the enormity of the job in hand. The degree of coordination presents many challenges, but it is necessary for our efforts to be effective. It is also the type of coordination that needs to be continued among the various global earth observation systems. There would be a permanent feedback loop in this process. The best data may not always be available, but if it is properly documented then improvements can be made and you may get to the ideal eventually. GEO is a voluntary process and we should develop 'adaptor plugs' to accept all (properly documented) data no matter what form it takes. GEOSS aims to allow the provision of, and the access to, the Right Information, in the Right Format, at the Right Time, to the Right People, to Make the Right Decisions.

2 Workshop Outline, Logistics & Objectives
Pascal Lecomte (ESA)

Lecomte provided an introduction to the workshop and explained its format and how it would be run. It was not the purpose of this workshop to go into absolute details. The desire was to address the general principles of the best practices within the workshop forum; the detail would come later. The workshop participants were asked to bear this in mind throughout the sessions.

The workshop was extremely relevant to CEOS and to GEO. The exposure at a political level is apparent. At another level it is important to get the guidelines and practices together into a living document that could be adopted and implemented by the agencies. CEOS has become the space arm for GEO and the reporting path follows the route from the WGCV, who will report on the workshop to the CEOS plenary, through CEOS to GEO. The CEOS Strategic Implementation Team (SIT) is also of part of the process; the SIT chair is currently in transition from ESA to National Oceanic and Atmospheric Administration (NOAA).

Morisette identified the need for clearer definitions of the actual requirements, and that these should come from the users. To some extent the Cal/Val community does not know what the requirements are and GEO may provide the mechanism to find the answers. We can put error bars on data, and we should do this, but we need to know what the requirements are. **Lecomte** added that documentation of the products and data is important. It almost does not matter what quality the data is as long as it is properly documented; every single dataset is useful if it is properly documented. If we can document everything then we may find that the user will come back and suggest changes or ways to improve that data; communication has to go both ways between CEOS and the users. **Rast** suggested that in the first round one would not be able to satisfy all the users and their requirements. The key would be to find a way within the guidelines to be tolerant and to serve the whole range of societal benefit areas, scientists, etc.. **Cao** added that DA-06-02 is one of 73 tasks and the majority of the tasks are broken down into societal benefit areas. Task DA-06-02 is a cross-cutting task and will support a lot of the other areas.

Lecomte outlined a set of working terms and definitions to be used throughout the workshop. The CEOS WGCV was tasked to review these working terms and definitions and propose new definitions where necessary (***Action 18***).

3 Cal/Val Site Characterisation & Classification Gregory Stensaas (USGS)

Stensaas presented the session on **Cal/Val Site Characterisation & Classification**. To illustrate the concept and process, he used land based radiometric test sites as an example. He provided a comprehensive list of prime candidate terrestrial targets for consideration as benchmark sites for the post-launch radiometric calibration of space-based optical sensors. The U.S. Geological Survey (USGS) has worked with partners around the world to establish an online catalogue of prime candidate test sites in support of an IVOS initiative as a pre-cursor to this workshop. **Stensaas** presented the IVOS core test site catalogue (http://calval.cr.usgs.gov/), which included 36 initial sites. The online catalogue provides easy public web access to this vital information for the global community.

As a baseline, the following site selection criteria have been proposed for the IVOS radiometric calibration sites, although these criteria will be refined to provide a framework for other subgroups to follow:

1. The site should have high spatial uniformity, relative to the pixel size, to minimise the effects of scaling radiometric data to the size of the entire test site. This is especially important for cross-calibration between instruments because it minimises the effects of misregistration. The site should also be centred in an area large enough to accommodate the sampling of a large number of pixels and to minimise atmospheric adjacency effects due to light scattered from outside the target region.
2. The site should have a surface reflectance greater than 0.3 in order to provide higher signal-to-noise ratio (SNR) and reduce uncertainties due to the atmospheric path radiance.
3. The surface of the site should have flat spectral reflectance. This becomes important if the multiple instruments involved in cross-calibration have spectral bands with different response profiles.
4. The surface properties of the site (reflectance, BRDF, spectral) should be temporally invariant. Otherwise, adequate accuracy would be obtained only if these properties were measured for every calibration. This implies that the site should have little or no vegetation.
5. The surface of the site should be horizontal and have nearly Lambertian reflectance to minimise uncertainties due to differences in solar illumination and observation geometries. It should also be flat to minimise slope-aspect effects.
6. The site should be located at high altitude (to minimise aerosol loading and the uncertainties due to unknown vertical distribution of aerosols), far from the ocean (to minimise the influence of atmospheric water vapour), and far from urban and industrial areas (to minimise anthropogenic aerosols).

7. The site should be in an arid region to minimise the probability of cloudy weather and precipitation that could change the soil moisture and hence the surface reflectance. The low probability of cloud coverage also increases the probability of the satellite instruments imaging the test site at the time of overpass.

The online catalogue lists 36 terrestrial sites used on a regular or occasional basis for the radiometric calibration of space-based optical imaging instruments used for Earth observation. The list was put together based on various sources that have been published or have been "floating around" in the calibration community. The incompleteness of available information on even these prime test sites is an indication that much more coordination and documentation is needed to facilitate the wider use of calibration test sites in remote sensing. Although the type of ground target is currently restricted to playas and desert sand areas, it should nevertheless be noted that it is advantageous to have multiple targets with a range of intensities to obtain calibration points that cover a significant portion of the dynamic range of the instrument.

In the Cal/Val context, a test site could either be a single site or may well be a series of linked (by common protocols and facilities) 'sites', e.g. the Network for Detection of Atmospheric Climate Change NDACC series would be regarded as a 'test site'. **Ungar** suggested that changing the word 'site' to 'scenario' may help to include more people, particularly the atmospheric community.

There was general consensus that, as a minimum, there was a need to define a set of global Cal/Val reference (test) sites spanning a variety of conditions. Regular monitoring of all necessary information would be a requirement across the sites, as would be a clear understanding of the specific characteristics of the site itself. Knowledge of the variability of the site (cloud cover, etc.) would also be important in order to understand what that site would be good for, depending on the changing environment in and around the site.

From a land imaging, radiometric calibration perspective, the ideal implementation strategy would be to take advantage of the processes already carried out by another subgroup e.g. for synthetic aperture radar (SAR), where the Amazon rainforest has been established as a core CEOS reference test site. Automation of monitoring would allow continuous measurements and the prospect of cost savings. It was noted that the sites should be maintained as part of the overall support infrastructure to underpin the broader based societal needs, e.g., climate measurements. If these sites are to be used as long-term calibration sites in the future we would have to establish the process for deciding what makes a good site, what instrumentation needs to be included there and what information needs to be acquired to ensure the traceability of the data. The meeting agreed that long-term maintenance and long-term monitoring are very important. It was therefore felt that the IVOS test sites would be better classified into "equipped and maintained" and "non-equipped and maintained" rather than use the current draft

classifiers of “absolute calibration”, “pseudo-invariant calibration” and “cross-calibration” (***Action 1***).

There was general agreement that there would be value in limiting the number of sites and prioritising them (for specific applications and performance) as long as it is remembered that it is the processes, characteristics and facilities that one is emphasising for that particular site, and some of these can be subject to change. However, in the context of “best practices”, these processes and facilities should not exclude alternative approaches. It is important not to make these best practices the only way of doing things at the expense of other valid techniques, but to provide them as a guide that can be followed and allow evaluation against.

Stensaas presented a template for use in the definition of a test site. It was agreed to adopt this template, after a slight re-ordering of its constituent points (see Action 2), and ask each WGCV subgroup to define the requirements / characteristics to allow test sites to be identified within each subgroup domain (***Action 3***). The IVOS subgroup was tasked to finish the evaluation of the radiometric site process and make it available as an example for other subgroups to consider during their template development (***Action 2***). In addition to characterisation best practices and test site requirements, the WGCV subgroups were also asked to define criteria for test site classification with reference to its suitability for a particular application (***Action 4***).

The concept of CEOS endorsing sites based on a particular set of demonstrated characteristics and criteria was broadly accepted. If it was felt that a network should be endorsed then this should also be included. Just because a site is endorsed does not necessarily mean that everyone has to use it, but it would mean that it had met a set of baseline criteria. The WGCV subgroups should define the key characteristics that a site should have and if that site met those characteristics then it would be endorsed. Having a list of endorsed sites would help the agencies to invest their money in a more appropriate way and make it obvious where there are any gaps.

Within the process, there would be the requirement that the site owners would maintain the site and make the data freely available to Cal/Val users. Good data is useless unless it is freely available and a site should not be endorsed unless the data is freely available for Cal/Val purposes. The site would also have to be reviewed frequently (perhaps annually) in order to ensure that continued endorsement is justified.

It was agreed that a Cal/Val component should be recognised as an integral part of the mission activity throughout the lifetime of that mission funded under the space segment. All sensors should be encouraged to view a set of key core sites and contribute their results to the Cal/Val web portal..

It was noted that a CEOS test site dossier was defined around 10 years ago and this was not maintained. **Morisette** suggested that it may be worth investigating what happened and to learn from anything that went wrong with this project (***Action 6***). **Fox** explained that the sites contained in that dossier were not quality controlled and so we should be careful about taking information from it.

Cao identified that the Virtual constellation concept is a major user and we should work with those teams (Ungar is our representative on one of these). It was agreed to formulate a request to the Constellation leads to evaluate their requirements for Cal/Val needs (***Action 5***).

4 Satellite and *in situ* Cal/Val data access
Bojan Bojkov (NASA)

Bojkov explained that there needs to be some control on Cal/Val data but it is important that the system is transparent to know who is playing and what they are contributing. If there are contractual obligations in place then it is easy to police but otherwise there has to be a certain amount of trust in adhering to the data protocols and in the use of the data. A feedback mechanism should be established to allow users to respond to Cal/Val providers on issues that they discover but also on the positives as this encourages the Cal/Val teams. **Ungar** identified that in the specific issue of Cal/Val data, totally open access can hurt the Cal/Val activity dramatically if users erroneously 're-do' calibrations. It is also important not to inhibit new countries from working with us just because their data does not fully meet our standards, but we should be aware what the limitations are. A set of principles should be established where we can openly exchange this type of data; there will always be the potential to misuse the data. A high level GEOSS data sharing principles and guidelines document has recently been compiled and **Rast** agreed to distribute this document (***Action 19***). The principles address access, reuse and redistribution, international law, consistency, reduction of time delay and development of matrices and indicators. **Rast** recommended trying to steer away from too many restrictions. There has to be some specificity tied to Cal/Val but it would be good to try to be open in granting access to data and processes. The aim would be to have one set of principles and one set of guidelines. It was agreed that the general notion of CEOS being in line with the GEO data principles was a sound one. It was agreed to draft a WGCV data policy (code of use) for Cal/Val data that would be consistent with the GEO data sharing principles guidelines (***Action 16***).

Ungar identified the only reason there is hesitancy about early release of data is that there is a worry that erroneous results may be misinterpreted as the error bars could be so large at the beginning of a mission, but not always visible or recognised by the viewer. There needs to be complete documentation of the entire process to ensure that there is full traceability. There should also be caveats attached to early release data and if people want access to this data on the premise of Cal/Val then it should be a default that they need to feed their results back for comment and review by the mission team.

Lecomte identified the need to define what Cal/Val data encompasses and who exactly the Cal/Val community is. Within this community there needs to be some kind of code so that people do not, e.g., publish results from early data without feeding them back into the mission.

Ungar suggested that a set of criteria and guidelines could be set up to specify a list of Cal/Val users. A set of rules could be established and a signing process implemented whereby people would sign up to contribute to the process, not just take away from it.

Brockmann identified that within the 'code of good behaviour' for Cal/Val users there should be guidelines for data formats that include metadata. **Muller** suggested that we should concentrate on providing on-demand processing of Cal/Val datasets. Rather than cookie cutting subsets, we should maybe work on tools that allow one to burrow down through the data (requiring some interoperability protocols) to pull out specific data over specific areas for specific purposes. Once the user has visited the archives and worked out what is required, then the extraction will only be done once a request is made to do so from the data archive.

It was widely suggested that the Cal/Val portal should be the mechanism to provide data to the Cal/Val community. One benefit of this would be that duplication of datasets would be avoided. **Lecomte** suggested that the WGCV subgroups should define the requirements for the Cal/Val portal. It would be important to ensure that the Working Group on Information Systems and Services (WGISS) / WGCV Test Facility (WTF) and the lessons learned there are included in this process.

5 Methodology and Guidelines for Cal/Val
Nigel Fox (NPL)

Fox presented the session on Methodology and Guidelines for Cal/Val. As a starting point, issues of terminology and their consequential implications of these were discussed. Particular emphasis was given to the meaning of 'traceability' and that it required an unbroken chain of comparisons / calibrations to an internationally agreed reference standard each with an associated uncertainty. It was noted that this new ISO definition, whilst encouraging where possible SI as reference standards, allows the community to establish its own. It was also noted that uncertainties need to be evaluated according to best practise as described by ISO in its "guide to expression of uncertainty of measurement" (GUM). It was agreed to ask the WGCV subgroups to establish and define key Cal/Val terminology as an input into a WGCV dictionary (***Action 7***).

The scope of the workshop and activities was also emphasized in response to earlier queries from participants that we were concerned with all technical disciplines and all activities processed throughout a data products lifetime ranging from data collection, through processing and to distribution and archiving.

It was agreed that there is a need for, and benefit to be gained from, a set of commonly used methodologies / protocols / best practises. Although there will always be some users who have their own way of doing things and may not be able to follow certain procedures, as long as that methodology (set of contents and associated information) is fully traceable and documented then it is acceptable.

For any method / endorsement there needs to be a way of demonstrating its fitness for purpose. **Datla** agreed, but stressed the fact that it should be a living practise and that there should be room for research and development. **Fox** suggested that one could start with a limited set of scenarios and develop a standard set of protocols and methodologies for these scenarios. These protocols and methodologies would be current 'best practise' and could, with time, be improved upon. They were not intended as required practises but 'suggested practises', which could be used and at least provide a baseline for comparing against and provide good guidance to newcomers. Some examples for which an endorsable methodology could realistically be derived were provided by the floor:

- System level spectral response measurement,
- A means of doing a formal comparison between instruments,
- Independent assessment of the repeatability of a calibration process,
- A means of having a procedure of best practises for repeatability of an instrument,
- Land cover intercomparison (LPV),
- Global leaf area index intercomparison (LPV),
- The means of achieving TIR radiances from space, and

- Best practices for defining what information we need to record in order to maintain, e.g. climate quality data depending on its fitness for purpose.

Fleig agreed to begin this process by drafting a recommendation regarding the need to maintain long-term archives of Cal/Val process data to support EO with an emphasis on the needs of climate change (***Action 8***).

Issues associated with how organisations relate and talk to each other in the context of customer / contractor were discussed. **Stensaas** identified that if the best practises are never defined, the earth observation (EO) projects will never be able to provide data of the required quality in a consistent manner, etc., as it would not be easy to specify detailed requirements into every contract and to ensure that the Cal/Val is maintained for the life of a mission and beyond. **Ungar** added that the rules for operational satellites are usually institutional and have long-term budgets, but there are also those on shorter-term budgets. As such we probably need two or three best practices to cover the differences. One benefit for people to provide data based on following best practices (detail on traceability) is that it would then allow for a better intercomparison of methods. Traceability with best practices is very important and we should make sure that we can trace it back to what we did before. Fox agreed to draft a set of guidelines to be used for writing best practices (***Action 9***) and the WGCV Subgroups were tasked with formulating a draft list of key common topics for Cal/Val that could become best practices (***Action 10***).

Fox asked if there would be any benefit in the use of a common set of information (a check list) that needs to be documented in the methodologies / protocols. There needs to be enough information for someone to really understand the process and procedure used in order to show that we are meeting the Cal/Val requirements in a common way. **Ungar** responded that this type of approach would be appropriate to some but not to others, but the principle of defining the minimum contents is something that we could agree to. We need to have some common information to document an activity.

Concerning the sort of evidence that would be acceptable to support a result or process, there was general consensus that we have to have traceability, written procedures and a description of the methodology as part of the evidence to show how we have achieved the result(s). Evidence needed to support a claim needs to contain a description and provide traceability with comparisons being a good mechanism to show tracability. This method could be used in conjunction with models and algorithms also. An example of a database established by the meteorology community that has supporting evidence for a quantity and its uncertainties in a completely traceable way can be found at http://kcdb.bipm.org/.

Fox asked the question: “Can we simply accept at face value the statement that the above has been met? Do we need to have some means of quality controlling the evidence?” **Fox** presented examples of what has been done elsewhere and this could maybe provide

some ideas on how to start the process with comparisons being a key element. **Brugge** identified that if we want to get to the endgame, we need to begin the process, recognising the complexities of it right from the start. **Fox** suggested that it would be important to make the results of comparisons visible to all and this would demonstrate transparency. Comparison in this context is the ability to demonstrate that the number one gets out from the end process is the same as the number someone else gets out when doing the same thing. More importantly, it is imperative that we know what the difference is, or bias is and that we can describe the bias. Ideally, there has to be some umbrella organisation / body that convenes these people together to do this and ensure consistency, best practise of approach, and it was suggested that this should be done under the auspices of CEOS. CEOS (WGCV) is the body responsible for space of GEOSS and, as such, should scope the whole of the EO field. The detailed implementation should be carried out regionally by national or groups of national agencies but under the auspices of the CEOS subgroups. These subgroups would ensure that comparisons are linked between geographical regions and that the results are made visible. A best practise guidance on the organisation and analysis of comparisons should be developed and it was suggested that this could be based on one developed by national standards laboratories.

Concerning the need for an overall documentary standard, a type of International Organization for Standardisation (ISO) standard for Cal/Val was discussed. The ISO groups know how to develop such documentary standards in a general sense but would need our specific expertise to make it happen. There was general agreement that we should seek to set the guidelines up as along the principles of an ISO-type documentary standard. **Bojkov** agreed that there is a need for a mechanism to endorse the processes, procedures and traceability but alongside this would be the need for a body to administer that process and to ensure that operators are following that standard. The ISO process has a group of auditors that check this kind of thing but they are mainly non-specialists and looking at process documentation, but not understanding what process documentation is required. **Morisette** added that ISO is an interesting concept and falls within WGCV given that we are moving towards more commercial satellites in lower orbits. These are all outside the government agencies to some extent so there is obviously some benefit in having a sort of ISO standard and an auditor to confirm that standard. **Fox** emphasised that, whilst a supporter of ISO and that this maybe a long-term goal, there was no reason why CEOS could not become the 'standards or endorsing' body for the EO community, under the auspices of GEO, since the requirements are in general relatively specialised and it will require our expertise to draft the guidelines. It is also perfectly acceptable to ISO for CEOS to have this role even if we seek to have these guidelines formally adopted as an ISO standard later, but it was important that we did not lose momentum in starting the process. It was agreed upon by the group that a discussion should be included at the joint WGCV / WGISS meeting in February 2008 on the idea of adopting a standard set of best practices and the means to establish an authority to endorse them, possibly with a CEOS, ISO or similar authorisation stamp (***Action 12***).

6 Cal/Val Portal
Philippe Goryl (ESA) & Carsten Brockmann (Brockmann Consult)

Goryl presented the Cal/Val portal, an ESA internal project initiated in support of an IVOS action and this is why it is currently biased to that theme. He asked the community to communicate and feedback on it. The WTF is to be incorporated into the portal. The portal uses SensorML (an Open Geospatial Consortium standard markup language (using XML schema) for providing descriptions of sensor systems) and this is a very powerful tool for interoperability. **Ungar** identified that Earth Observation-1 (EO-1) was very involved in Sensor Web, a type of sensor network comprising spatially distributed sensor platforms (pods) that wirelessly communicate with each other. This is especially well suited for environmental monitoring and control as the architecture allows every pod to know what is going on with every other pod throughout the Sensor Web at each measurement cycle. **Ungar** offered data from that for inclusion into the Cal/Val portal (***Action 21***).

Brockmann demonstrated the portal and showed that it has the capability to take data either from the data host over the web or from a local file server source. The policy is that everything that is available for open public access and it is only when one wants to download the data that you are obliged to login. The system works with number of pixels, not kilometers, to specify sizes of image and the data are in the units as provided by the operator. There is no L0 data planned for optical at least; L0 will possibly be included for SAR.

Morisette said that the web services linking to outside data was an impressive tool and is something that the WTF does not do. He offered assistance in potentially incorporating Moderate Resolution Imaging Spectroradiometer (MODIS) tools and Earth Observing System (EOS) field data into the portal (***Action 20***). He went onto suggest that the Level L0 / L1 services could be integrated into a dedicated lab (e.g. NASA Oakridge National Laboratory (ORL), USA). NASA ORL services can be used for reprojecting and subsetting and this is done on the fly in user defined file formats. ORL can also unpack the bits for QC assessment.

Muller asked if tools were being developed, which require a registration process, to allow the addition of content from other sources. **Brockmann** explained that currently the user management is based on projects and only those people that belong to that project can upload. **Ungar** saw the need to expand the portal and offered NASA's help in furthering the process. The WGCV subgroups were additionally asked to define their 'wish list' of requirements for functionality from the Cal/Val portal and feedback to the Cal/Val portal maintainers (ESA) (***Action 13***).

Cao asked if the plan was for the portal to be a centralised system (have all data stored locally) or a distributed system (providing an entry point to different places). **Lecomte** explained that the portal is an entry point and behind this there are a series of databases. There is work is currently underway on a Generic Environment for Cal/Val Analysis (GECA), which is a third generation database to include all Cal/Val data that exists in ESA. It is a practical system and there is some database facility behind the portal, but essentially it is an entry point and a tool that allows access to other databases. **Rast** added that the portal is a harmonisation effort and is a contribution to GEOSS. The aim was not to try and bring everything together into one place but to provide harmonised access. It is an evolving system that belongs to everyone and, as such, should carry the CEOS and GEO logos and be hosted at a more appropriate URL (***Action 15***). It was agreed that the Cal/Val portal prototype should be presented at the CEOS plenary and GEO summit (***Action 17***). **Lecomte** added that the Cal/Val portal is a CEOS WGCV tool and if the system is to evolve it needs to be used, tested and ways to improve it proposed.

Alber asked if the release of the portal would be extended to the broader technical communities or just the ones related to CEOS and GEO, thinking particularly with IEEE in mind. **Ungar** saw the definite need to broaden this activity first into the Cal/Val community and then further afield; the IEEE's involvement is important. **Smith** asked if there was a process for users to feed their recommendations into the portal. In getting people to use the portal, people must own it for themselves. **Stensaas** responded that the mechanism to provide such requirements comes through the subgroups and they were tasked with channelling this information to the portal maintainers (***Action 13***). To ensure two-way communication, **Goryl** agreed to establish some mechanism to feedback portal development information to the subgroups (user community) (***Action 14***).

7 Harmonisation of Quality Information
Pascal Lecomte (ESA)

Lecomte presented the session on Harmonisation of Quality Information. He explained that we do not need to harmonise the methods but the quality information. Just because a process is harmonised does not mean that it cannot evolve. It should be fit for purpose and there should be room for people to do things together. **Fox** added that it is agreement of the content that is the key factor, not the methodology. All processes need to contain all the key information needed to understand the procedures used to get the data in order to go forward and this is the thing that we need to endorse.

Lecomte tabled a discussion about the need for an 'accountability chain', either with or without an actual legal framework. **Fox** identified that it is about putting a "qualifier" with the product. If a product does not have a qualifier with it then there is a great risk. **Stensaas** was in agreement that there needs to be an uncertainty measure associated with each parameter to allow one to make a statement about what is being measured. **Brugge** added that the measure of success is when data becomes more useable on a system and if we can have a quality stamp on that data and its products then people will have more confidence in using it.

The need for a dictionary of definitions across the board to help drive interoperability and use across all areas was agreed. This would be a CEOS WGCV Cal/Val dictionary endorsed be CEOS. It would be important to identify the boundaries for these definitions and where to stop, but we would need both high level and detailed definitions. Those definitions to be defined by the WGCV subgroups (***Action 7***) would provide a starting point.

Concerning the harmonisation of information flow, not all users need all data but, it was agreed, there should be full traceability.

The issue of CEOS endorsement / certification was raised. **Morisette** identified that it would be up to an agency or user to implement any certification as CEOS is not a certification body. CEOS wants to endorse generic procedures that can be adapted and updated. **Bojkov** asked about the scenario in which sites that were endorsed are no longer up to standard. **Fox** informed that for (IVOS) test sites the aim was to renew the endorsement on a regular basis to ensure that the site was properly maintained. There would be a kind of time stamp (expiration date) on the endorsement for the test sites after which it would either be re-endorsed or not. **Mango** suggested that if we had an endorsed set of guidelines then that would be best way forward. We want a process but we don't want it to be too onerous and too difficult. **Rast** agreed that it is important not to deter people by having too rigid a framework right from the beginning. **Ungar** suggested that

we should set guidelines and influence standards; possibly ISO-type standards, within CEOS. If the procedures become endorsed then the certification may follow later through a standards body and applicable agencies. The actual certification would be completed against the standards that we would have set up and influenced. **Fox** suggested that the WGCV would be the appropriate body to set the guidelines, best practises and standards for these processes. ISO is not necessary. If an agency wants to adopt these guidelines then it is up to that agency to decide how to implement these guidelines and if they want to certify the process then it is up to them to establish the process. There has to be a transitional process implemented because, at the moment, we cannot enforce but only recommend that people adopt best practices or guiding principles. However, we should be showing that we are moving in this direction. **Ungar** identified that there are at least three different agencies who have a mandate to put ISO standards on calibration. The WGCV should be involved and influence that process. **Fox** suggested that one of the reasons is that ISO is recognised for standards and the agencies are pushing this, however, people may not have considered that another body may be responsible for standards. There is no reason why the WGCV cannot be recognised as the standardising body for Cal/Val rather than ISO and in practise ISO would look to CEOS WGCV for this information anyway. **Alber** suggested that a committee be set up to explore options on how we are able to establish authority for the endorsement of best practices for Cal/Val (***Action 11***).

As a baseline conclusion the community agreed to the need to *establish a set of Cal /Val guidelines based on the adoption of 'best-practises' that can be endorsed by CEOS under the auspices of GEO and for implementation by the agencies.*

8 Wrap up & future
Steve Ungar (NASA; GEO task DA-06-02 lead)

Ungar presented the wrap up and future. He suggested that there are three main ways to initially address GEOSS Cal/Val needs:

- Define or identify test scenarios (aka "sites") for Cal/Val of Earth Observation (EO) measurements
- Establish best practices procedures incorporating internationally recognised standards
- Populate and evolve the GEO/CEOS Cal/Val portal

A set of recommendations coming out from the workshop would be drafted and presented at the GEO summit and the CEOS plenary.

Ungar stressed the important achievement of the GEO/CEOS Cal/Val portal. He also requested that an action be taken to work on Cal/Val requirements with the CEOS constellations (***Action 5***).

All contributions to the seed documentation, action items, etc. should be sent through the WGCV Secretariat (Petya Campbell).

A further workshop is planned in Washington DC, USA, in April 2008. **Stone** added that the Cal/Val portal would be the face of the group. If it is done well then we can raise the profile of the group and it is up to us to keep it alive.

Ungar thanked GEO and ESA for hosting the workshop and he thanked all the chairs and organising committee. He finally thanked everyone for participating.

9 Actions

Number	Action	Responsibility	Due Date	Description
1	Categories for the test site catalogue to be transformed into “equipped and maintained” and “non-equipped and non-maintained” rather than use “absolute cal”, “pseudo-invariant cal” and “cross-cal”.	Chander, IVOS Subgroup	01-Nov-07	This action is related to the Radiometric test site classification and the process of categorizing sites. It was decided that site could be re-categorized as equipped and maintained and non equipped
2	Provide the current IVOS Cal/Val site list & baseline characteristics list as an example to the other subgroups	Chander	15-Oct-07	The generic template developed and agreed to in the meeting would be updated and used as a baseline for other sub-groups. The IVOS sub-group will finish the evaluation of the radiometric site process and make it available as an example for other to consider during other system test site template development.
3	Review & establish test site template to define (best practices) requirements for test site identification within the subgroup domain.	WGCV Subgroups	WGCV-28	Each sub-group will define test site criteria and requirements of systems within the sub-group purview, and provide this information for use. The generic template could be considered as starting point.
4	Define criteria for test site classification for suitability for a particular application.	WGCV Subgroups	Next workshop	In addition to best practices and test site requirements suggested above, the sub-group will provide a method to classify sites for use as discriminator. This is important so that system owners can provide full data over test sites for interoperability.
5	Formulate a request to the Constellation leads to evaluate their requirements for Cal/Val needs.	Bojkov, Stensaas, Campbell, Cao	01-Nov-07	Suggest that CEOS constellations provide Cal/Val requirements for evaluation and update by the WGCV.
6	Investigate Jim Butler’s CEOS Information Server (http://spsosun.gsfc.nasa.gov/calval/index.html) and see if it contains any useful for the portal	ESA	02-Nov-07	The Cal/Val portal developers will evaluate the usefulness of the information on the CEOS information server and any lessons on why it failed.

Number	Action	Responsibility	Due Date	Description
7	Establish & define key Cal/Val terminology as an input into a WGCV dictionary.	WGCV Subgroups	WGCV-28	Each sub-group will define Cal/Val terminology associated with specific systems and measurements within their sub-groups purview, and provide it to the WGCV.
8	Draft a recommendation regarding the need to maintain long-term archives of Cal/Val process data to support EO.	Fleig	01-Nov-07	Provide the long term requirement for Cal/Val data and metadata. Long term climate change will be the primary focus point in defining the requirements.
9	Draft guidelines for writing best practice	IVOS/FOX	30-Nov-07	IVOS will provide a guideline template (key content) to other sub-groups for potential use in writing Cal/Val best practices associated with systems and data used in the sub-groups purview.
10	Formulate a draft list of key common best practices for Cal/Val.	WGCV Subgroups	WGCV-28	Each sub-group will provide a list of best practices used for Cal/Val in measurement, evaluation, assessment, and applications used within the sub-groups. This list will support and prioritise the writing of best practices for each item in the list.
11	Establish a committee to explore options on how we are able to establish authority for the endorsement of best practices for Cal/Val.	WGCV Chair	05-Oct-07	The WGCV chair will establish a committee to assess the basis for adopting and standardizing Cal/Val best practices to meet CEOS and GEO requirements, and present the recommendation from the established committee at the next meeting.
12	Include a discussion at the joint WGCV / WGISS meeting in February 2008 on the idea of adopting a standard set of best practices and the means to establish an authority to endorse them, possibly with a CEOS, ISO or similar stamp.	WGCV Chair	WGCV-28	See previous action description.

Number	Action	Responsibility	Due Date	Description
13	Define wish list of requirements for functionality from the Cal/Val portal and feedback to the Cal/Val portal maintainers (ESA).	WGCV Subgroups	WGCV-28	Each sub-group should define functionality requirements needed within the Cal/Val portal and provide them to the sub-group lead for submission to the Cal/Val portal developer.
14	Establish some mechanism to feedback portal development information to the subgroups (user community).	ESA	01-Nov-07	Develop a newsletter or news page with notification or subscription to subgroups users will be provided. Allowing the users to keep up with new developments and provide appropriate feedback.
15	Make the Cal/Val portal front end a more CEOS / GEO one and change the website URL.	ESA / NASA	10-Oct-07	Establish a CEOS url address for the portal via NASA CEOS domain and present the portal as GEO/CEOS component with appropriate logos and caveats.
16	Draft a WGCV data policy (code of use) for Cal/Val data that will be consistent with the GEO data sharing & principles guidelines.	Stensaas, Bojkov	WGCV-28	Write a draft agreement for users and use of Cal/Val data in the portal consistent with the GEO Data Sharing policy.
17	Present Cal/Val portal prototype to CEOS and GEO plenaries [but restrict open access until data policy (Action 16) has been agreed upon].	WGCV Chair	CEOS & GEO plenaries	Allow presentation of the Cal/Val portal but restrict use until user and data policy agreements are established.
18	Review terms and definitions list used for the workshop.	Workshop Chairs	10-Oct-07	Update the definition list to be consistent with definition discussed in the workshop and in accordance with official standards definitions
19	Distribute GEOSS data sharing principles & guidelines document	Rast	05-Oct-07	This document will be used in conjunction with writing the Cal/Val data sharing policy.
20	Evaluate the possibility of including MODIS tools and EOS field data to the Cal/Val portal	Morisette, Brockmann	WGCV-28	Evaluate the availability of Cal/Val tools and discuss them with Cal/Val portal developer for potential use.
21	Evaluate the potential of incorporating EO1 tools & data into the Cal/Val portal	Stensaas, Brockmann	WGCV-28	Evaluate the availability of Cal/Val tools and discuss them with Cal/Val portal developer for potential use.

Annex A: Recommendations to CEOS plenary

A Group on Earth Observations (GEO) / Committee on Earth Observation Satellites (CEOS) workshop on Calibration and Validation (Cal/Val) Processes was held from 2 – 4 October 2007 in Geneva. A set of activities were formulated based on consensus decisions made at the workshop. These activities constitute the initial steps towards the development and implementation of a data quality assurance strategy as required by GEO task DA-06-02. CEOS and its members, as the space arm of GEO, is the key group with responsibility and capability to ensure that EO data derived from space is available, accessible and useable in order to meet the needs of the societal themes of GEOSS. For data to be useable it must have associated with it a quality descriptor that makes clear its suitability for particular applications 'fitness for purpose'. A quality descriptor can only be assigned through an appropriate quality assurance (QA) process, which itself is dependent on the results of calibration and validation activities performed, traceable to internationally accepted standards. The Working Group for Calibration and Validation (WGCV) of CEOS is thus the most appropriate existing body with the necessary expertise and authority to establish, coordinate and harmonise efforts needed to establish an international framework to QA EO data products. To initiate this process the WGCV puts forward the following recommendations for adoption by CEOS plenary.

The recommended activities should be implemented by the members under the authority / endorsement of CEOS WGCV and the auspices of GEO.

Recommendation 1

Background

User communities increasingly rely on information products from multiple satellite sensors. The founding principles of GEOSS require the provision of 'information products' based on the transparent use and combination of a wide range of data sources: different satellite sensors, aircraft and *in situ*. This can only be achieved if each data source and processing step has a set of unequivocal quality parameters ascribed to it. Thus, the establishment of a Quality Assurance framework based on the identification and use of 'best practices' is required. Such a framework is a prerequisite to the practical implementation of GEOSS and an essential component of any 'data sharing principle'. The latter, currently in draft form, addresses issues such as distribution, reuse, international law, etc..

WGCV Requirements

A key component within any QA strategy is the ability to evaluate and demonstrate performance against an agreed 'reference' and, where possible, to gain operational efficiencies from the establishment and reuse of common procedures. The Cal/Val community agreed that there is a priority need to identify a set of 'Cal/Val guidelines' based on commonly used methodologies / protocols / best practises, which can be 'endorsed' by CEOS for specific activities. These endorsed 'best practises' would be 'living', allowing scope for improvement and adaptation based on the progress and needs of the community. One overarching 'best practise', underpinning the overall strategy, is a means to demonstrate 'fitness for purpose'. This requires each activity (data collection and / or processing) to have associated with it an uncertainty statement based on its traceability to an internationally-agreed reference standard. This, together with documentary based records describing the processes involved and the evidence to support these claims would allow the results of such activities to have a CEOS 'endorsement'.

It was also noted that Cal/Val and QA (both pre- and post- launch) should be regarded as an integral part of any mission and funded throughout its lifetime under the space element and where such activities relied upon external infrastructures, e.g. test sites, that these should transcend the limitation of individual missions.

Recommendation

The WGCV recommends that CEOS members support the establishment of a QA framework based on the identification and adoption of Cal/Val best practices that are necessary to allow data to have an ascribed 'quality' associated with it. These best practices should include all aspects of the data processing chain from acquisition to delivery and archiving and be based upon the demonstration of traceability to

internationally-agreed reference standards. The established Cal/Val best practices should become published guidelines, endorsed by CEOS under the auspices of GEO and implemented by agencies to meet the needs of GEOSS.

WGCV follow-up actions

1. The WGCV subgroups will define a list of best practices used for Cal/Val in terms of measurement, evaluation, assessment and applications used within their subgroup domain. This list will support and prioritise the writing of the best practices for each item on the list.
2. A WGCV dictionary will be established and this will include key Cal/Val terminology associated with specific systems and measurements to encourage harmonisation within the Cal/Val community.
3. The WGCV will explore options on how to establish an authority for the endorsement of best practices for Cal/Val.
4. The WGCV will, via its subgroups, identify appropriate 'reference standards', where possible traceable to SI units to underpin this QA framework, and a means to 'endorse' them.

Recommendation 2

Background

Dedicated Cal/Val campaigns together with permanent fixed sites making correlative measurements of bio/geophysical parameters, whilst key to any satellite mission, remain resource-intensive activities. These often consist of remote test sites, networks of instruments and / or expensive support infrastructure, e.g. aircraft, ships etc. Less expensive complementary approaches can provide more frequent calibration updates and enable the monitoring of sensor performance trends, even without surface measurements, but do not always have sufficient accuracy. Future global monitoring systems, using increasingly complex constellations of satellites with multiple sensors, such as the Global Earth Observation System of Systems (GEOSS), will amplify the need for such sites to allow intercomparison, transcend data gaps and, of course, validate or calibrate sensor performance in order to provide GEO societal benefits. At present it is difficult for agencies to prioritise resources to support the wide variety of sites in existence. A means needs to exist to ensure maximum benefit is gained from such activities. This will also allow agencies to 'guarantee resources' to facilitate the maintenance and continued upgrade of a set of 'core sites', encouraging their use until they can become *de facto* reference standards to support the QA of datasets for GEOSS.

WGCV Requirements

The WGCV recommends the establishment of a global set of CEOS-endorsed sources of Cal/Val data, which span all required disciplines, including the right to access the data and the guarantee of maintenance. This endorsement will take the form of a 'classification' and be based on a set of key criteria discriminating between sites in terms of relative suitability for particular activities.

Recommendation

The WGCV recommends that it should define a set of global Cal/Val reference (test) sites to be classified and endorsed by CEOS. These should span a variety of conditions in support of the characterisation needs of satellite sensors. The WGCV further recommends that all missions of member agencies should view a prioritised set of core sites as an integral part of the space segment and provide unencumbered access to the results to all CEOS members.

Follow-up Actions

1. The WGCV subgroups will review and establish test site templates to define (best practices) requirements for test site identification and classification within their subgroup domain.

2. The WGCV will define a list of core reference (test) sites necessary for Cal/Val and to be viewed by all satellite sensors.

Recommendation 3

Background

One of the principle aims of GEO is to facilitate the access to information from a multitude of sources through single point of entry portals. Such portals need to be unique and with sufficient breadth and depth (in content) to minimise their number. In general, they are likely to provide access to information stored on a variety of independent, globally distributed systems / databases, but with in-built tools and functionality to ensure that similar types of information can be accessed and viewed in a consistent but transparent manner. To simplify aspects of this interoperability in the longer-term, it is noted that there may need to be some harmonisation in how information is stored on the accessed computer systems.

It is noted that GEO intends to establish a "primary entry point portal", which will then provide the framework to link together the necessary additional portals required to service the users of GEOSS.

Over the last few years CEOS WGCV has (through ESA support) been developing a dedicated Cal/Val portal (http://calvalportal.ceos.org). This portal is likely to be one of the key 'top-level' portals of GEOSS, providing access to the crucial information necessary to underpin the QA of all EO data-based information. It will also provide access to the knowledge to allow the community to develop and share best practises and coordinate efforts to maximise operational efficiency. Although the existing GEO / CEOS Cal/Val portal is already operational and has a wide range of functionality, it is at present biased towards the needs of optical sensors (as this was the starting point), and is limited in content. This, in part, reflects the current state of the art in terms of availability of suitable information, e.g., best practises and its relative maturity in terms of operational availability.

When fully operational the GEO / CEOS portal should provide a single entry point for all Cal/Val information for all sensor domains. This will incorporate existing infrastructure such as NILU and AVDC databases, together with precursor CEOS initiatives such as the WGCV / WGISS test facility. It is anticipated that this portal will also provide the stimulus and focus for many other systems currently under development and / or planning.

WGCV Requirements

The WGCV requests that CEOS members provide support and encouragement to their staff to ensure that this crucial web portal is populated with appropriate information and has the necessary functionality to enable it to be established as the reference point for QA

information of GEOSS. This will require, for example, information on 'best practises', Cal/Val data from satellites and supporting correlative data.

Since the functionality of the portal is at present limited, additional resource is required to extend its capabilities and scope, particularly towards meeting the needs of other sensor / application domains. It is also noted that to ensure that the portal and its information is maintained, up-to-date and is itself appropriately quality assured, a significant commitment from the agencies in general, but most importantly ESA who have pioneered the development of this project, is required.

Recommendation

The WGCV recommends that CEOS members endorse the establishment of the Cal/Val portal and encourage its further development and use as the single 'point of entry' for all associated EO Cal/Val information. To facilitate this, the WGCV recommends that each agency establish a named individual to act as a local point of contact.

In view of its importance to CEOS and GEOSS, as a key tool towards the harmonisation of data quality, the WGCV also encourages ESA to provide the necessary resources for its continued maintenance and development.

Follow-up Actions

1. The WGCV subgroups will define a 'wish list' of requirements for functionality from the Cal/Val portal.
2. Feedback mechanisms between the portal maintainers and the Cal/Valcommunity will be set up to ensure that the portal is maintained as a living system.
3. A request to the Constellation team will be made to evaluate their requirements for Cal/Val.
4. WGCV subgroups will establish and / or collate the necessary information to populate the database, e.g., best practises.
5. The WGCV will consider the means to ensure all accessible information meets an appropriate quality level.

Recommendation 4

Background

The use of Cal/Valdata is currently typically governed by the data provider's own contractual code of practise. Currently, there is no globally recognised policy for data providers to adopt and for users to adhere to.

WGCV Requirements

In order for a more open and accessible Cal/Val system to be put in place for GEOSS, a clear data policy needs to be adopted to ensure that users of Cal/Val data have easy and open access in a timely manner. This policy would need to include feedback mechanisms to ensure that data users feed their data / results back into the mission and a two-way dialogue between users and operators is maintained. There needs to be some control on Cal/Val data but it is important that the system is transparent to know who is participating and what they are contributing.

Recommendation

The WGCV recommends the establishment of a data policy (code of use) for the use of Cal/Val data. This should be consistent with the GEOSS data sharing principles and guidelines.

Follow-up Actions

1. The WGCV will draft a data policy (code of use) for the use of Cal/Val data that would be consistent with the GEOSS data sharing principles and guidelines.

Annex B: Agenda

Tuesday 02 October 2007

09:00 *Registration*

09:30 **Welcome & Introduction**

- **Pascal Lecomte (ESA)**
- **Jose Achache (GEO Secretariat)**
- **Changyong Cao (CEOS WGCV chair)**
- **Michael Rast (GEO Secretariat)**

10:45 *Coffee*

11:15 **Workshop outline, logistics & objectives**
Pascal Lecomte (ESA)

12:30 *Lunch*

14:00 **Session 1**
Cal/Val Site Characterisation & Classification
Chair: Gregory Stensaas (USGS)

15:45 *Coffee*

16:15 **Session 1 continued**

18:00 *Close*

20:00 **Dinner at la Perle du Lac**

Wednesday 03 October 2007

08:30 **Session 2**
Satellite and *in situ* Cal/Val data access
Chair: Bojan Bojkov (NASA)

10:15 *Coffee*

10:45 **Session 2 continued**

12:30 *Lunch*

14:00 **Session 3**
Methodology and guidelines for Cal/Val
Chair: Nigel Fox (NPL)

15:45 *Coffee*

16:15 **Session 3 continued**

18:00 *Close*

Thursday 04 October 2007

08:30 **Session 3**
Harmonisation of quality information
Chair: Pascal Lecomte (ESA)

10:15 *Coffee*

10:45 **Session 3 continued**

12:30 *Lunch*

14:00 **Wrap up & future**
Chair: Steve Ungar (NASA; GEO task DA-06-02 lead)

15:45 *Coffee*

16:15 **Wrap up continued**

18:00 *Close*

Annex C: Participation List

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