Status Levels for New ngVLA Principal Investigator Observing Modes

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Change Record

Version	Date	Author	Reason
01	2018-04-13	J. Hibbard	Original version, with title "Proposed Lifecycle for New ngVLA Observing Modes"
02	2018-04-17	J. Hibbard	Revision after telecon with ngVLA Operations WG; this is the version provided to CSV lead for CSV plan
03	2019-09-27	J. Hibbard	Adopted ngVLA template & assigned document number (based on RID from CSV Plan review); added Summary; removed placeholder & red text; changed "Lifecycle" to "Categories" in title and elsewhere. Added item 1c to Section 2.1
04	2019-10-03	J. Hibbard	Incorporated changes from R. Selina, including definition of ALMA QA levels
05	2019-10-15	A. Lear	Formatted and copy-edited document for author review and further review/approval workflows
06	2019-10-18	J. Hibbard	Reviewed copy-editing and revised text to clarify meanings, define abbreviations, and reorganize Section 2 subsection text slightly
07	2020-02-05	J. Hibbard	Incorporated changes from A. Kepley, including new Sec. 2.1. Changed "Observing Categories" to "Observing Mode Status levels" based on discussion w/E. Murphy & T. Hunter. Changed title accordingly. Rearranged subsections.
08	2020-02-21	E. Murphy	Revised to address questions/comments by Project Director
A	2020-02-24	A. Lear	Prepared PDF for approvals and release as Version A.

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1 Introduction

Based on Atacama Large Millimeter Array (ALMA) "lessons learned," this document defines the different Next Generation Very Large Array (ngVLA) status levels that can be assigned to the Observing Modes offered for Principal Investigator (PI) submitted projects in any given observing cycle, in order to differentiate between:

- projects that use fully technically characterized observing modes, have automated Schedule Block (SB) generation, and are processed via a data reduction pipeline with defined Quality Assurance (QA) metrics and well defined Science Ready Data Products (SRDPs); and
- those that are less well characterized and have some aspects of observing or data reduction that are not fully automated.

In ALMA, the better-characterized observations are classified as Standard Observing Modes (SOMs), while the less well characterized or riskier modes are called Non-Standard Observing Modes (NSOMs). These modes differ by the risk and burden they impose on the Observatory. The time allocated to the risky or burdensome non-standard modes is explicitly limited in each observing season.

Consultation with the ngVLA Operations Working Group has led to a recommendation to adopt these concepts for ngVLA, expanding them to include the concept of SRDPs (recognizing that these take time to fully develop). These concepts will also be expanded to include categories that would allow expert PI involvement for observational modes that are not yet ready for broad use (patterned after the VLA Shared Risk observing program).

In this document we define five different "status levels" to characterize how automated the end-to-end observing process is, from observing script generation through final product production. The idea is that each observing mode to be offered to PIs for an upcoming cycle would be assigned to one of these levels. This serves three purposes:

- The Commissioning and Science Validation (CSV) team would know to what extent each aspect of the mode must be commissioned,
- Science Operations would know what manual effort is required to obtain and process it, and
- PIs would have an expectation of what data products are promised and so how much extra work they may need to invest.

This should allow better resource planning for the rollout of new capabilities, for both observing and data processing.

2 Status Levels

2.1 Observing Modes vs. Observing Mode Status Levels

Following the document "Observing Modes Framework" (020.10.05.05.00-0005-PLA-A), we consider an Observing Mode to be a way of observing that is distinct from other modes due to differences in the hardware, observing sequence, calibration procedure, acquisition software, or data processing that are significant enough to require a separate validation before being offered for general use. Examples of Observing Modes include Interferometric Mode, Total Power Mode, Solar Mode, Pulsar Timing Mode, and so on.

The definition of an observing mode completely specifies all technical characteristics of the observation. However, there are other aspects of the observing and post-processing which can be validated to different levels. For example, SB generation that is fully automated based on information collected from the PI at the time of proposal submission differs from SB generation via "expert mode" where various parameters are set manually. Likewise, data reduction and QA assessment through an automated pipeline differs from reduction via manually modified scripts. These two levels involve a very different amount of work to validate them, so must be defined for each observing mode that will be offered in a given cycle. This allows the CSV team to understand all aspects that must be commissioned before the Mode is handed over to Science Operations, and plan its work accordingly. The assigned level also allows users to understand what quality of product they can expect (Science Ready versus "best efforts").

To specify these different commissioning levels, we define below a small number of discrete Status Levels that can be assigned to each offered Observing Mode, clarifying what level the mode will be commissioned to prior to it being used in a given observing cycle.

2.2 Status Levels for PI-Offered Observing Modes

The five status levels are defined in the subsections below, and their characteristics are summarized in Table 1 (on the next page).

For all levels, the observing sequence and calibration techniques are defined and SBs can be generated using the Proposal Submission or Observing Tool (OT). They will have some well-defined QA criteria, although this will vary by mode and by stage of the evaluation. For the purposes of this document, we will adopt the ALMA Quality Assurance terminology[1], where QA level 0 (QA0) is an evaluation at the individual Execution Block level, assessing the observing conditions and raw data and metadata. QA0 Pass means the data meet the requirements for being reliably calibrated and used for making the science products. QA level 2 (QA2) is an evaluation of final calibration and science products produced from all Execution Blocks associated with an SB, usually indicating how "science ready" the products are.

Reliable data calibration and product generation methods for the modes are provided by CSV, but involve varying amounts of manual tuning (which is what differentiates the levels). They must all be calibration-ready and have products produced by publicly available software.

The amount of observing time made available for riskier or manually intensive status levels will be limited based on how much manual tuning (of SB generation or data reduction) is required (see Section 3).

2.2.1 New Mode Test Observations (NMTO)

This status level is for observing modes not fully explored or likely to have significant risk, and subject to unexplored or poorly understood instrumental effects, but desirable to make available to PIs on a (highly) shared-risk basis. This would usually occur because there is significant community interest in and expertise with the mode. This category may come with the requirement that PI teams spend significant time at the Observatory, and is similar to the EVLA Resident Shared Risk Observing (RSRO) mode. PIs will be provided with the raw data and CSV scripts that worked for commissioning, but which are not general or shown to work under a broad range of observing conditions or to handle all instrumental effects.

For this status level, SBs can be automatically generated using the OT but may require expert tuning by the PI(s) or Observatory staff. Data processing is possible with publicly available software, but there are no automated scripts or pipelines. The raw data will have gone through a high-level QA0 evaluation, but the evaluation may subsequently need to be revised (for example, if the data cannot be calibrated).

[1] The ngVLA will likely adopt a different quality assurance terminology.

Characteristic	NMTO	SRO	NSDR	SMDR
Demonstrated through SV?	Preferably, but not required	Yes	Yes	Yes
Online Hardware/ Software	May be test versions	Production	Production	Production
Observing Parameter Space Demonstrated	Very narrow (proof of concept) to none	Narrow	Critical parameter space demonstrated, but may not be broad	Broad parameter space demonstrated via prior SRO/NSDR
Data Reduction Parameter Space Demonstrated	Very narrow to none	Narrow	Critical parameter space demonstrated, but may not be broad	Broad parameter space demonstrated via prior SRO/NSDR
SB Generation (defines observing script parameters)	Expert mode by PIs with assistance from Observatory Staff	Auto-generated but may require manual tuning	Automated, with no or minor tweaking required	Fully automated
Observing Script for Mode	Test/experimental version available	Fully defined	Fully defined	Fully defined
Initial Data QA Assessment (QA0)	Not reliable	Automated & Reliable	Automated and Reliable	Automated and Reliable
State of User Documentation	None	Some (may be quite technical)	Good	Good
PI Post-Observing Involvement	Significant, possibly on-site	Significant	None	None
Pipeline Readiness	None	May be None	Cannot be run automatically or requires significant tweaking to run	Both cal & imaging pipeline run automatically with little to no manual intervention
Archived Products & Final QA Assessment (QA2)	PI-produced with assistance from Observatory Staff (best-effort basis); data offered as is	Observatory-calibrated via scripts; reference imaging; QA best efforts only	Observatory-produced SRDP using non-automated methods; quality assured.	Observatory-produced SRDP using automated methods; quality assured.
Fraction of Accepted Projects	Probably Low (depends on Observatory effort required)	Low	Limited	Large

Table 1 – Characteristics of proposed ngVLA PI observing mode status levels. Note: for readability reasons, the PIDR level is not included in this table. It may have observing characteristics (i.e., first 8 lines of this table) of any of the four tabulated categories, but all post-observing characteristics are the responsibility of the PI.

These are "shared risk" observations that are *not* subject to Observatory "best efforts." This means the PI(s) accepts the risk; the Observatory may, but will not promise to, invest significant resources to produce science-ready products. If successful, the calibration and final products will be generated via data reduction scripts (starting from scripts or templates provided by the CSV team) that will likely require significant manual tuning by the PI(s). Observatory staff will not do the processing for NMTO projects, but will be available for consultation on a best-efforts basis. Only very coarse QA will be defined (by the CSV team), and no SRDPs are defined. PI input will be solicited to help improve the scripts, QA measures, and SRDPs.

PI scripts and products will be archived and publicly available after a proprietary period (one year after QA0 Pass for raw data; one year after that for final products and scripts). Unlike all other PI-offered status levels, NMTO projects may be observed with test software versions and/or prototype hardware.

NMTOs are made available for the first modes before the pipeline is available, or for new observing modes where there is significant community interest and expertise such that waiting for a standard reduction path to be established is thought to take too long.

The Observatory needs to actively engage PIs who observe in this category in order to get feedback to improve it and, if possible, move it into one of the more automated status levels.

2.2.2 Shared Risk Observing (SRO)

This status level is for observing modes that are offered on a "best efforts" basis, for which the PI shares risk with the Observatory. This means that final science-ready products are not assured, and the delivered data may not meet the PI's stated goals (QA2 SemiPass in ALMA parlance). SBs will be automatically generated, but may require manual customization (by the Observatory). The data will have a reliable QA0 evaluation and be calibrated using Observatory-produced scripts (possibly automatically generated, but could be one-offs).

These modes are considered "shared risk" because if the data cannot be calibrated (QA0 Pass) the project will not be re-observed. They are considered "best effort" because the Observatory will limit the effort devoted to data reduction and QA. Should the production of SRDPs not be possible or require too much effort, the products will be classified as QA2 SemiPass and delivered as-is. This classification will be clearly indicated for the archived products.

Ideally, Observing Modes initially offered at the SRO status level will transition to a more standard status level that includes assured SRDPs. A small number might remain in this category. As with the NMTO status level, the Observatory needs to actively engage PIs and get feedback to improve the SRO and, if possible, move it into one of the more automated categories.

2.2.3 Non-Standard Data Reduction (NSDR)

This status level is for observing modes that can be calibrated and products produced via automatically generated scripts or a proto-pipeline that may need a modest amount of manual tuning. SBs will be generated automatically with minimal need of customization. QA0 will be well defined; QA2 will be defined, but may be refined during the NSDR phase. SRDPs will be defined, but may be refined during the NSDR phase. Scripts use pipeline tasks whenever possible.

2.2.4 Standard Mode Data Reduction (SMDR)

This status level is for observing modes that can be run through pipelines with no or minimal manual intervention. SBs will be automatically generated with minimal need of customization. SMDR modes have well defined QA0 and QA2 scores, and SRDPs are defined and stable.

2.2.5 Principal Investigator Data Reduction (PIDR)

This category of observations will have QA0 performed by the Observatory, but product generation and QA2 will be performed by non-Observatory entities, using their own well-defined (and deterministic) pipelines, QA scores, and SRDPs. They are then ingested into the ngVLA science archive (as currently planned for ngVLA Legacy Science Programs). PIDR is not included in Table 1 as it may have observing characteristics for any of the above four status levels, but all post-observing characteristics are the responsibility of the PI.

2.3 Observatory-Only Status Levels

Before being offered for PI-observations, each Observing Mode must be commissioned, and some may be used to generate early-release science products. These stages can be considered as additional observatory-only status levels that an observing mode goes through, so are described here for completeness.

2.3.1 Observing Mode Commission Phase (CSV)

This category includes observations conducted to commission a new observing mode after it is delivered from the system Assembly, Integration, and Verification (AIV) team and before they are offered for PI observing. All new modes must go through this stage.

An observing mode lifecycle starts after handover from the system AIV team. At this point, the following are assumed to have been demonstrated:

- Hardware readiness,
- Online software readiness,
- Data ingestion into archive, and
- Data import into reduction software.

Once the hardware and acquisition software are believed to be ready, the Observing Mode is handed over to the CSV team to establish successful science operations by looking at sources with deterministic properties (from prior observations or well-motivated expectations). This work includes establishing the calibration requirements (including identifying any required PI input) and demonstrating that the new mode produces scientifically valid results in the spatial and spectral domains, including flux scale and behavior of all Stokes parameters. This is done by observing sources with deterministic properties (from prior observations or well-motivated expectations). CSV is also responsible for identifying any special Technical Justification (TJ) or QA measures that need to be included to validate the successful operations of the mode. CSV is not responsible for defining the required SRDPs from the mode, but must validate key SRDP products.

The initial commissioning observations may initially be constructed, executed, and processed very differently from how the corresponding mode is run during PI observations, but the final commissioning observations should resemble the defined PI Observing Mode Status level as much as possible.

PIs do not apply for CSV time. However, outside experts or teams may participate in CSV (and, in the case of post-construction development projects, may be wholly responsible for CSV). The CSV requirements/deliverables are the same regardless of whether this mode is performed by the Observatory or outside entities.

For observing modes that cannot (yet) be reduced by the pipeline, CSV should produce an "extensible data reduction script." *Extensible* means that the critical calibration, imaging, and QA elements of the scripted reduction parallel how these steps would be implemented in the pipeline, therefore directly serving as the basis for new pipeline development[2].

While CSV validates the observing modes, they must be accepted by Science Operations before they are offered for PI observing. Based on ALMA lessons learned, it is imperative that construction personnel be

[2] This is a "lesson learned" from ALMA, where data reduction paths for manually scripted modes were often quite different from how the pipeline would reduce the same data, meaning that the pipeline paths had to be separately validated before software development could begin.

available to represent science operations on the CSV team, or that there be a construction Science Operations team. The end result of commissioning must be a mode that works in Science Operations. CSV observations are not required to be Quality Assured like science observing modes, although they may have QA assessments (especially as a means of validating the QA methodology).

2.3.2 First Look Science (FLS)

First science observations using a new mode may go through this special category, as decided by Observatory management in consultation with science advisory committees. This permits sharing data in the public domain before the mode is offered for general PI observing. The data products from FLS observations will be made publicly available with no proprietary period. They will be Observatory calibrated and have final products produced by scripts. The scripts will generally be one-offs but using publicly available software/tasks, and will be delivered with the products. The products will be science-ready, and so quality assured, although they need not be the final QA or SRDP defined for the mode.

2.4 Lifecycle for New PI Observing Modes

All new observing modes that will be offered to PIs must go through CSV and eventually transition to one of the following status levels: SRO, NSDR, or SMDR. No mode will remain in the NMTO stage, and staging must occur in the order given in the above list. However, any transition in between is allowed. For example:

- CSV → FLS → NMTO → NSDR (e.g., ALMA polarization)
- CSV → SRO → NSDR → SMDR (e.g., ALMA high frequency)
- CSV → NSDR → SMDR (e.g., ALMA spectral window combination)
- CSV → SMDR (e.g., ALMA Band 5)

All modes must go through meaningful QA0 (well defined for the later stages; developmental for earlier stages). All but NMTO must go through some form of QA2 (well defined for the later stages; developmental for earlier stages).

2.5 Specification of New Observing Modes

CSV will define the calibration plan for each new mode and any special TJ or QA considerations.

Science Operations will define the post-CSV mode lifecycle (whether the mode goes through NMTO or will end up as NSDR or SMDR) and timeline (considering the lifecycle stage of all other offered or to-be-offered modes).

Science Operations will define the final TJ, QA, and SRDP for each mode, considering CSV input. The SRDPs will be tuned to the science driver for the mode, and may not be image cubes. For example, calibrated visibilities and numeric arrays of amplitude and phase as a function of baseline length (for non-imaging goals), or bandpass calibrated but not flux calibrated spectra (for redshift determination), could be completely legitimate SRDP.

Observatory management, in consultation with science advisory groups, will decide if a new mode should go through a FLS stage.

3 Rollout of Categories Based on Preliminary Milestones

This section presents a concept of how the number of PI-accepted observations of the various categories is expected to evolve, based on preliminary construction milestones provided by R. Hiriart and the status level definitions presented above. The key milestones relevant for the different levels are as follows:

- SB generation with expert parameters: March 2027
- CASA adaptation – Manual data reduction: June 2027
- SB execution: Oct 2027
- Fully automated SB generation: March 2029
- Commissioned pipeline: Oct 2029

Two other decisions affect the observing category rollout:

- First Look Science starts when there is ~VLA worth of collecting area; and
- The first time PI access is given to ngVLA, there must be at least one fully commissioned observing mode with SRDP products via an automated pipeline.

Based on these two lists of constraints, it appears that First Look Science will start in mid-2027 and that Early Science with the first PI observing modes can start being observed in October 2029. Initially, the number of observing modes that fall into the SMDR category will likely be quite small but will grow with each subsequent observing season. Similarly, the number of NMTO/SRO modes may be comparatively large at the start of Early Science but will shrink in Full Science Operations. Figure 1 demonstrates these concepts graphically.

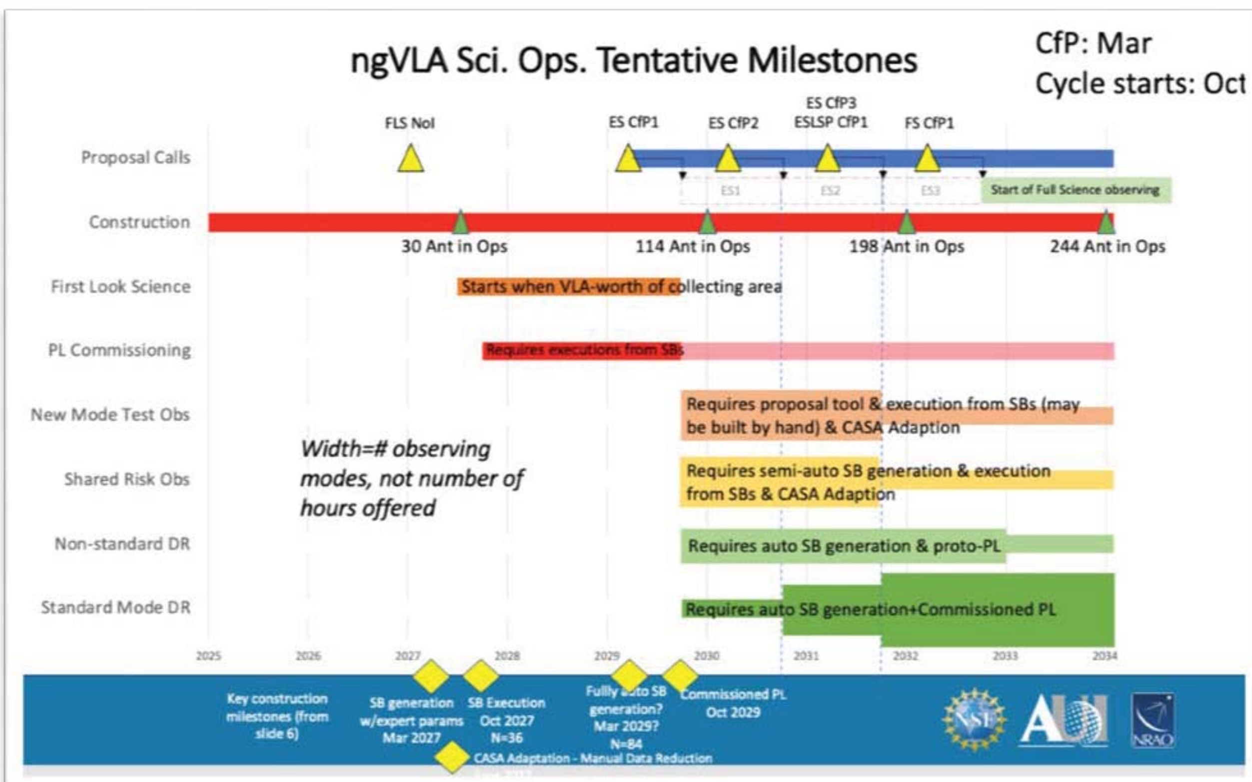

Figure 1 – Concept of observing category rollout, based on current milestones and category requirements from Table 1.

Following ALMA, the number of hours to be allocated to PIs will vary for each status level. Since SMDR should require very few Observatory resources (once it is commissioned and accepted), it is likely that in Full Science, the majority of hours offered on the array will be allocated to modes in this category. Conversely, if an observing mode has not migrated to the SMDR stage, the time allocated for observations with that mode will be capped. Roughly, at least 80% of time is anticipated for projects in SMDR versus all other categories in Full Science. This only addresses time allocated to PI projects because some fraction of time must always be reserved for commissioning new observing modes.

The Observatory will decide how many hours to allocate for NMTO projects. Usually this will be a smallish number, but since this mode may not represent a large drain on Observatory science operations resources, it could in principle be quite large. However, since the final products are generally poorly defined for such modes, they may reduce the value of the science archive, which must also be considered.

4 Construction to Operations Transition

An overarching goal of the ngVLA project is to minimize the entire lifecycle cost. This means the construction project may provide initial capabilities for some operational aspects of the instrument that minimize operations costs on the long term. A specific example where this will occur is the construction team will hand over proto-operations to Science Operations, including the initially offered SMDR modes. Most importantly, the ngVLA project must ensure that construction CSV staff are not completely uncoupled from or unconcerned with data processing requirements of commissioned modes (including TJ, QA, and SRDP requirements).

Consequentially, the initially offered modes for Early Science and the first Full Science observing season will be commissioned by the construction project. Observing modes that represent more capabilities than will be delivered by the construction project must be commissioned by Science Operations staff. SciOps staff will first be trained by the construction CSV staff (preferably by being part of the construction commissioning team), who will then be responsible for CSV of new modes after the construction project has completed.

The Observatory should also be assured the opportunity to retain construction staff with expertise in commissioning and establishing initial science operations into full operations, instead of hiring operations staff that fill these roles while construction is delivering the modes. (The latter occurred with ALMA due to "color of money" issues but also because construction did not take responsibility for delivering proto-operations.) This could be done, for example, by allowing construction staff to charge the time they spend delivering science (proto) operations to operations accounts, or, conversely, allowing SciOps staff to be initially matrixed to the construction CSV team.

5 Acknowledgments

This document was written with significant contributions from the ngVLA Science Operations Working Group, led by L. Ball and including B. Clark, B. Butler, A. Kepley, J. Kern, E. Murphy, L. Sjouwerman, and J. Wrobel, and with additional contributions from T. Hunter and R. Hiriart.

6 Appendix

6.1 Acronyms and Abbreviations

Acronym	Definition
AIV	Assembly, Integration, and Verification
ALMA	Atacama Large Millimeter Array
CASA	Common Astronomy Software Applications
CSV	Commissioning and Science Validation
FLS	First Look Science
NAASC	North American ALMA Science Center
ngVLA	Next Generation Very Large Array
NMTO	New Mode Test Observations
NSDR	Non-Standard Data Reduction
NSOM	Non-Standard Operating Mode
PI	Principal Investigator
OT	Observing Tool
QA	Quality Assurance
QA0	QA Level Zero
RSRO	Resident Shared Risk Observing
SB	Schedule Block
SOM	Standard Operating Mode
SRDP	Science-Ready Data Products
SRO	Shared Risk Observing
TJ	Technical Justification
VLA	Jansky Very Large Array