Science Operations for the VLA and VLBA; Application to SKA

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What is science operations?

Encompasses all areas required to deliver science data to users, from proposal call to data products. Science operations is comprised of three main areas:

• **Telescope Time Allocation and Scheduling (TTAS)**
  – Proposals; call, submission, handling, and time allocation
  – Scheduling the telescope

• **“Telescope” Support (TS)**
  – Monitoring telescope, electronics (including correlator), and software performance
  – Commissioning new instrumentation and observing modes

• **User Support (US)**
  – Help users with software issues
  – Help users implement best practices
  – User training
Science operations workflow

This is the familiar “from scientists idea to published paper” workflow.

This does not describe the entirety of what science operations is concerned with (user training, for instance), but covers the bulk of it.
Organizational structure – NM Ops divisions

New Mexico Operations

NM Ops AD
Mark McKinnon

Business Manager
Skip Lagoyda

Deputy AD for Engineering
Chris Langley

Deputy AD for VLBA Development
Walter Brisken

Deputy AD for Operations
Claire Chandler

ngVLA Project Scientist
Eric Murphy

E&S Division Head
Jon Thunborg

Electronics Division Head
Ephraim Ford

Array Operations Division Head
Gene Cole

VSS Division Head
Bryan Butler
Members of the VSSD are about 2/3 “scientific staff” (with a Ph.D. in astronomy, astrophysics, etc.), and 1/3 Data Analysts (DAs; typically with a B.S. in astronomy, astrophysics, physics, etc...).

Most scientific staff have functional responsibilities in both the TS and US groups (matrix management).

All VLA DAs are in the User Support Group.
What is not science operations?

While the purview of science operations is broad, there are of course many aspects of operating the telescope that it is not directly tasked with ownership of, including:

- Software itself (this is the Data Management and Software Department’s responsibility); though we do have functional (“dotted-line”) management to the software group that maintains the telescope control software, and a number of our scientific staff develop software for particular uses.
- Electronics and Engineering Services (as noted in Peggy’s talk).
- Operating the array (this is the Array Operations Division).

But science operations interacts closely with all of those, so good communication is critical. We do this through meetings, emails, JIRA, phone calls, etc. Some of those are regularly scheduled or recurring, some are as-needed.
Two main groups: VLA operators and VLBA operators. These groups make sure the arrays are running smoothly.

VLBA DAs help with observation preparation and do data QA after correlation, among other duties.

VLBA Technical Manager and DAs help the VLBA Scheduler with daily dynamic scheduling.
TTAS – Proposals

- Everything starts with a Call for Proposals (CfP). NRAO has two CfPs per year (one per semester), which includes all three of VLA, VLBA, and GBT, which go out around January 1 (for a February 1 deadline) and July 1 (for an August 1 deadline).

- ~4 months before the CfP, all capabilities (observing modes) must be decided, and approved with the responsible software group; we make this decision after a meeting with the scientific and technical staff.

- Scientific staff and DAs help users with questions about proposal submission, which is done electronically with our Proposal Submission Tool (PST).

- After the deadline we must organize technical and scientific reviews of the proposals, which are also done in the PST. Note that proposals for all telescopes are reviewed together scientifically.

- We then have software (the Proposal Handling Tool, or PHT) that assigns preliminary scheduling priorities to all "sessions" (which are essentially Scheduling Blocks, the atomic unit of observing on the VLA and VLBA).

- The NRAO Time Allocation Committee then meets, along with NRAO staff, to specifically discuss every proposal and decide whether the PHT has made the proper priority assignment.
TTAS – Proposals

We end up with an approved science program for both VLA and VLBA, which is made up of projects, each of which has a number of Scheduling Blocks to be observed.

SBs each have a scheduling priority: A, B, or C.
An aside – observation preparation

• Proposers are contacted with the results of the TAC deliberations.
• As the semester (VLBA) or configuration (VLA) approaches, users are contacted again, and encouraged to submit their Scheduling Blocks (really, “sessions” for VLBA, but they are equivalent).
• For VLBA this is done with SCHED software; for VLA with the Observation Preparation Tool (OPT).
• DAs and staff scientists (but mostly DAs) provide help with SCHED or the OPT when needed, and must validate all SBs.
• After validation, the SB ends up in the pool of schedulable SBs.
TTAS – Scheduling

• Once we have an approved science program for a semester, and users have submitted their SBs, we must be sure that those actually get observed (to the level of their scheduling priority).
• The VLA and VLBA are dynamically scheduled, for the most part, though details (and software) differ.
• The VLBA schedule is typically made daily (or for the weekend on Friday); sometimes tweaked mid-day when needed, using a software tool called scenario.
• The VLA is typically scheduled in real-time, as each SB concludes its execution, using a software tool called the Observation Scheduling Tool (OST).
Barry Clark made a monthly schedule which was typically completed about a week before the month started. He had software to help, but then adjusted by hand. It was time-consuming, and resulted in observations happening under inappropriate conditions.
The VLA is now (since ~2008) mostly **dynamically scheduled**. The gray areas in the monthly schedule to the right are all dynamically scheduled time. Red is weekly preventive maintenance time; blue is test/commissioning time. The green are “fixed-date” observations, which are not dynamic.
TTAS – Observation Scheduling Tool (OST)

The OST checks the pool of schedulable SBs, filters by time, filters based on observing conditions (wind speed and atmospheric phase stability), and presents an ordered list by priority to the operator, who then queues the next SB to be observed.
In detail, once an SB makes it through the filters, there are many terms which go into the observing priority.

One thing we have learned is that “difficult” observations (requiring strict observing conditions, for instance) must be observed when they can. Given the fixed-length configurations of the VLA, this can present problems.

\[ P = w_p p + w_u u + w_s s + w_o o + w_n n + w_\sigma \sigma + w_l l \]

<table>
<thead>
<tr>
<th>Priority Type</th>
<th>Range of Values</th>
<th>Default Weight</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary* (p)</td>
<td>[1, 3]</td>
<td>( w_p = 3.0 )</td>
<td>From the TAC. Scheduling Priority A-&gt;( w_p = 1 ); B-&gt;( w_p = 2 ); C-&gt;( w_p = 3 ).</td>
</tr>
<tr>
<td>Urgency* (u)</td>
<td>[0, 2]</td>
<td>( w_u = 1.0 )</td>
<td>0=Short time scale transient, 1=Partially completed projects and completion badly needed, 2=Normal science and tests</td>
</tr>
<tr>
<td>Science* (s)</td>
<td>[0, 10]</td>
<td>( w_s = 0.03 )</td>
<td>The Linear-rank score from the Science Review Panel.</td>
</tr>
<tr>
<td>Override (o)</td>
<td>Any</td>
<td>( w_o = 1.0 )</td>
<td>To allow schedulers to make the OST do what they want it to in special cases.</td>
</tr>
<tr>
<td>Nice (n)</td>
<td>[0, 1]</td>
<td>( w_n = 1.0 )</td>
<td>To allow observers to lower priority of their own SBs (not exposed currently).</td>
</tr>
<tr>
<td>Stringency* (s)</td>
<td>( \log_2(API) + \log_2(wind) )</td>
<td>( w_\sigma = 0.33 )</td>
<td>Favors blocks with strict weather limits.</td>
</tr>
<tr>
<td>Length* (l)</td>
<td>( \log_2(SB_length) )</td>
<td>( w_l = -0.25 )</td>
<td>Favors longer Scheduling Blocks.</td>
</tr>
</tbody>
</table>

* = required  
* = calculated
TTAS – tracking how we are doing

To track how we are doing with observing SBs for a configuration, we make a “pressure plot” twice per week (Monday and Friday) for discussion at a meeting. This shows the SBs that are available to the OST (the current queue of schedulable SBs) as a function of LST.

The cyan line is the number of SBs which can be observed at a given LST in the configuration.
We can also retrieve a detailed graphic of what was observed in any given period on the VLA. We also use this at those Monday and Friday morning meeting discussions, to assess what has happened and what is coming up for the VLA. The VLBA is tracked differently, and a weekly email sent out summarizing observing statistics.
TS – monitoring “telescope” performance

- We must make sure that the “telescopes” are running well. This includes the physical telescopes themselves, the electronics, and the software.
- We measure and maintain the system on a number of timescales:
  - Over years, we measure the gains of the antennas, and on rare occasion adjust panels using holography. Gain curve coefficients are provided to post-processing packages for application to data.
  - At VLA configuration changes (~every four months), must determine delays and antenna positions (“baselines”); pointing comes along with this. This is also done as an antenna comes out of preventive maintenance (one every ~two months).
  - Roughly weekly – delays, pointing, baselines are checked. We run two stress tests each week, which measure $T_{\text{sys}}$, antenna gains, sampler performance, and all other parts of the system. Issues that result from this, or from our regular calibration pipeline QA, are diagnosed (JIRA tickets are used to track these). One thing we could do a much better job of in both software and process is automatic fault detection (and fault tree analysis), and tracking of failures.
  - Software is continually checked; as problems arise they are diagnosed.
TS – commissioning new modes

• New observing modes are either pushed by us (pulsar observing, for instance), or by users who put in “RSRO” (Resident Shared Risk Observing) proposals (triggered observing, for instance).

• We advertise things we are working on, and things that we are encouraging observers to work on, in the CfP.

• New modes (at the RSRO stage) start by implementation at a low level in software – they may involve direct correlator manipulation by GUIs, or hand-crafted jython control scripts, or other non-standard uses of the software.

• The Telescope Support Group works closely with software groups to get RSRO modes into standard software. Once an observation can be set up in the software, it is moved from RSRO to SRO.

• When we are confident that the mode works properly, it is shifted from SRO to GO.

• Observing modes that are SRO and GO are noted as such in the CfP.
US – software support

I’ve mentioned previously areas where we provide support to our users for our various software packages. This includes all stages of the workflow:

• NRAO User Accounts (including “visitor” accounts of our post-processing cluster)
• PST
• OPT and SCHED
• Archive search and retrieval (the Archive Access Tool, or AAT)
• Data post-processing (CASA and AIPS), including pipelines

For direct user contact, we use a Kayako helpdesk, with various departments (this system is also used by ALMA). The DAs are typically the front-line for this; if there is a problem they cannot handle, they send it on to scientific staff.
We have a significant program for training of our user community (and those who want to become part of our user community). This includes:

- **Community Day Events (CDEs).** For a CDE, we send several staff to a remote institution where we give presentations on the various aspects of using our telescopes. These are often done in conjunction with ALMA. They are requested by the remote institution and typically involve ~30 attendees from several institutions. We typically do two of these per year, but it is driven by requests so varies.

- **Once every two years we host the NRAO Synthesis Imaging Workshop,** which is a two week intensive course on radio interferometry meant for those not familiar with the concepts and practices (novices).

- **Once every eighteen months, we host a Data Reduction Workshop (DRW) in Socorro,** where users come for two weeks for an in-depth set of presentations on data reduction, and then reduce one of their own datasets. This is not meant for novices.
A lesson – “one observatory”

• On Monday and today, we heard many times the phrase “one observatory” for SKA. In the mid-2000s we had exactly that phrase for NRAO and its three operating telescopes at the time (VLA, VLBA, and GBT), and in anticipation of adding ALMA to the effort (the NAASC anyway).
• Our user support groups were actually re-organized to support this, with a changed management structure, and cross-training so that scientists and DAs could potentially support multiple telescopes.
• There is one area where this was incredibly successful – the TTA effort. Prior to this, each telescope had its own process for handling and determining the disposition of proposals. Going to a unified system was a vast improvement.
• However, the broad goal of having one user support group, and the same software for all telescopes, was not successful. It turned out to be too difficult for staff to become expert enough with multiple telescopes to provide proper user support.
• Ten years later, we are still stuck with some of the vestiges of the re-organization (because organizational restructuring can be difficult when it cuts across groups and telescopes).
• So, “one observatory” can be great for some things, but don’t take it too far!
The future – ngVLA

The ngVLA is a proposed expansion of the VLA and VLBA, covering 1.2-116 GHz with 10 X VLA (and ALMA) sensitivity, baselines to 1000 km (and also VLBA scales), and a dense core for low brightness imaging.

An 850+ page science book has been written, along with a reference design document (3 volumes, ~1500 pages), which includes an Operations Concept document (with a section for Science Operations). We have used the lessons learned from operating VLA, VLBA, and ALMA in writing this operations document.
Summary (part 1)

• Science operations is an important part of running telescopes efficiently.
• Science operations touches nearly all aspects of running telescopes.
• A good blend of people is important – having different skill sets and different levels of ability to support complex support issues (this includes science, software, hardware, people skills, etc.).
• Let folks do what they can at their level; for instance, let DAs do as much as they can, so scientists can focus on potentially more difficult problems.
• Give scientists as much freedom as you can, they are smart folks and will do good things (mostly).
• Think early about what internal software you will need for science operations, and get requirements to the software group(s). This is often an afterthought.
Summary (part 2)

• Automate as much as you can (fault tree diagnosis software; make modules smart at as low a level possible); capture “Defined Failure Modes” and have software to take advantage of that – we haven’t done this and should have. BUT, recognize you can’t automate everything; scientific and engineering expertise is critical.

• Communication is key – keep folks informed and include them before decisions are finalized; regular meetings with cross-group attendance are important at all levels (senior management; division heads; group leads; scientists and DAs with software and hardware engineers; etc.).

• Don’t expect your users to read your documentation!

• Remain as flexible as possible.