JVLA Engineering Operations

Speaker: Peggy Perley

2019 SKA Shanghai Meeting: Concluding Our Past, Realising Our Future
2019 November 23-28

Introduction

Peggy Perley – retired as deputy Asst. Director for Operations in 2018

- Graduated from the University of Maryland, studied engineering and physics
- 40 years experience at NRAO in VLA/JVLA/VLBA Operations
- 1979-1982 joined VLA array Operations during the construction and transition to full operations
- 1982-1993 Formed and led the Data Analyst Group for the VLA in response to over-stressed computing resources.
- 1993-2001 Chief of VLBA Operations and Data Quality Analyst for VLA/VLBA
- 2001- Division Head for JVLA and VLBA Operations, maintained responsibility for Data Quality analysis for both telescopes; assisted in VLA/VLBA scheduling
- 2007-2018 Deputy to the AD for Operations and responsible for Engineering Services, Electronics and Array Operations until retirement.
- 2019 Contributing to the ngVLA Operations Concept and Planning

Topics to be Covered

- Introduction
- Basic Operating Conditions
- Organization of Engineering Operations Staff
- Allocation to Maintenance and Repair/ Development and Upgrades
- Routine (preventative) maintenance vs Repair maintenance allocations and how does this evolve over time
- Allocation of telescope activities (science, maintenance, overhaul, upgrades, testing)
- Reliability, maintenance and repair – expected and unexpected issues

JVLA Engineering Operations – Lessons Learned

Topics to be Covered (cont.)

- Quality Control
- Documentation
- Training
- Safety
- Conclusions
- Bonus topic (if time)– People Management

Introduction

Post-Construction Operations needs to maintain efficiency and reliability

Operations' role in the observatory is to manage the operational aspects and to do so at as close to peak efficiency as is possible. It must be done in a way that is **practical**, **sustainable**, **reliable**, **successful in meeting its mission goals**, and, **accounts for the human factor** so that the **work environment is safe** for users, employees and visitors.

Introduction

Some Challenges:

- Expectations from users increase and there is less tolerance from the user community for poor performance of the array.
- Personnel turnover at the construction-to-operations boundary may increase, resulting in a loss of expertise gained during construction.
- Some elements of the facilities and antenna units have been in service for years and may be showing signs of aging, even though the array has just been declared operational.
- Excitement over the project subsides, so harder to get people to finish up documentation, submit reports.

Introduction

Factors Affecting Efficiency

- Annual budget for operations – less than 10% of the entire annual operations budget, not including salary and benefits. Due to the high cost of modern construction projects, the 10% rule is often unattainable and unsustainable, even if possible in the early operations stages. And as the instrument ages, repairs can become more costly.
- The scope of the maintenance, repair and testing efforts needs to be determined

  i.e. task lists, preventative maintenance, repair, development efforts or, in other words, what needs to be done and how long does it take to do it.
- The manpower needed to perform the maintenance tasks safely
- Weather and other environmental impacts on the maintenance, including remote site logistics, travel to and from the site, food, lodging, etc.
- Response time to address failures, what is acceptable performance levels for the science output? i.e. What repairs can be put off or is an immediate response required.

Introduction

Factors Affecting Efficiency (cont.)

- Safety - can be highly costly, if not taken seriously
- Scheduling requirements of the science observation

  i.e. long tracks, short tracks, set up times dynamic or fixed scheduling, commitments to partners, sub-arraying, reconfiguration will impact maintenance schedules
- Communications – how to ensure all employees know what's going on
- Should you contract out certain tasks or do it yourselves?
- Shipping/Receiving/Ware-housing – how fast can parts get to people, how much is over-supply (or someone thinks is over-supply)?

Basic Operating Conditions

The JVLA, located 50 miles from Socorro NM, consists of 28 identical 25 meter radio telescopes with an effective frequency range of 1 to 50 GHz. JVLA uses 8 cryogenically cooled receivers and one room temperature receiver (P band). The array can be reconfigured by transporting the antennas along a dedicated double railroad track with custom built transporters that can keep the antenna powered so as to minimize return to service. **It is operated 24 hours/day over 363 days a year.**

Technicians are on call after normal working hours in case of equipment failures that affect more than 3 antennas. Many components are modularized, allowing for ease of returning an antenna to service. Engineering technical groups are responsible for rebuild/repair of broken modules.

Engineers are responsible for higher level support, design and for development.

Basic Operating Conditions (cont.)

JVLA has the resources to repair and maintain much of its array and facilities infrastructure, with a few exceptions. Correlator board repair is done by Process Science (in Texas) since we don't have the equipment to do so. But we have labs, shops, etc. to handle most servicing needs.

Decisions are made whether it is cost and/or time effective to perform certain repair or build work in-house. For example, we trained technicians to build cables so that these can be obtained quickly, as needed to our specifications. Some machined items are better and cheaper if done by a commercial shop than if we try to repair them in house. The correlator board repair mentioned above makes it moot for us to try to fix, since the we have no equipment to delaminate the multi-layer boards to diagnose and get to the bad parts.

Organization of Engineering – Function, Location and Skills

Engineering Operations is responsible for all mechanical, electrical and electronic components, as well as most facilities support for the JVLA and VLBA sites. Oversight of engineering ops is assigned to the deputy assistant director of Engineering Operations (currently Chris Langley) and is appointed by the Assistant Director for New Mexico Operations (Mark McKinnon). The Engineering Operations' personnel is sorted out mostly by function and the location where the maintenance/repair effort needs to occur. Specific skills for functions are based on the nature of the work of the group and cross-training among the groups is strongly encouraged. The partitions should have some fluidity since circumstances can change over the course of operations to move groups and function. VLA has have several iterations of this.

Engineering Operations is divided into two Divisions:

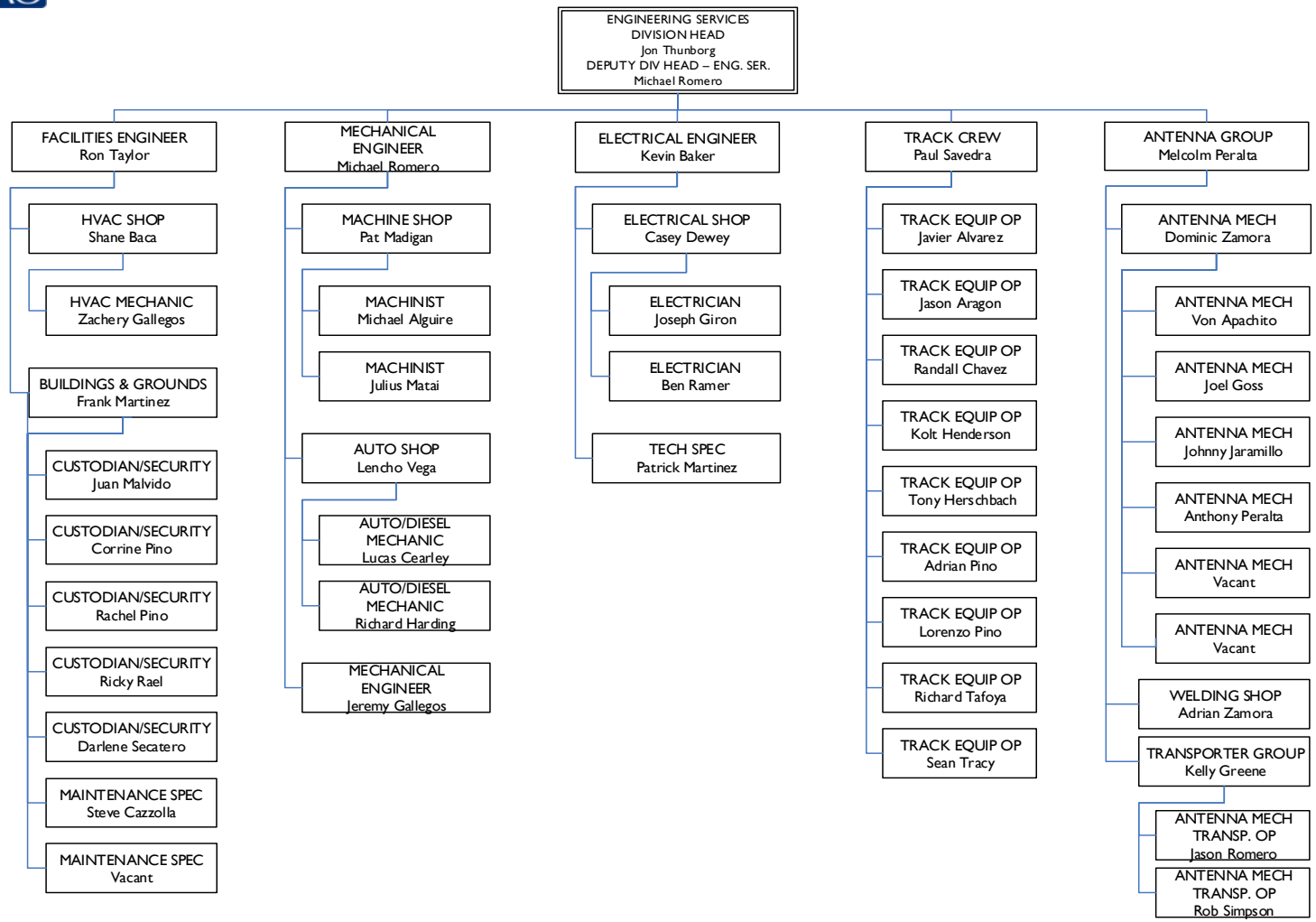
Engineering Services and **Electronics**

Organization of Engineering Staff

Engineering Services

- Supervised by a division head
- Sub-divided into the following groups, generally defined by the function of the group
- Each group has a lead person to direct day-to-day activities.
- Most tasks performed by this division are located at the JVLA site. Because of their efforts require personnel to work on the antennas and/or specific to the JVLA site.

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO OPERATIONS
NM ENGINEERING SERVICES DIVISION
As of November 1, 2019



Organization of Engineering Staff

Engineering Services

Facilities – *10 FTEs (1 engineer and 9 technicians/support personnel*)

Responsibilities are: Buildings and Facilities infrastructure support, including HVAC, Plumbing, Civil work, Carpentry, Custodial and Security work, Grounds maintenance.

Mechanical Engineering – *2 FTEs (2 engineers)*

Responsibilities are: Antenna design and analysis, oversight of the mechanical and civil aspects of the site.

Electrical – *5 FTEs (1 electrical engineer and 4 electricians/techs)*

Responsibilities: all site commercial electrical and power generation equipment, all antenna electrical components.

Organization of Engineering Staff

Engineering Services

Track – *10 FTEs (1 supervisor, 9 track crew workers/heavy equipment operators)*

Responsibilities: Maintain and repair the dedicated double-tracked railroad lines that are used to reconfigure the antennas.

Antenna Mechanics – *12 FTEs (2 welders, 7 mechanics, 3 transporter operators*

Responsibilities: Maintain and repair Antenna structural and mechanical parts, including motors, gears, bearings, dish panels, subreflector hardware. This group also operates and maintains the two transporters that move the antennas.

Organization of Engineering Staff

Engineering Services

Machine Shop – *3 FTEs (3 shop technicians, one is the lead)*

Responsibilities:

Auto Shop – 3 FTEs (3 auto/diesel mechanics)

Responsibilities: The JVLA owns dozens of motor vehicles and other heavy equipment such as trucks, loaders backhoes, man-lifts, cranes, mowers, etc. that must be maintained.

Organization of Engineering Staff

Electronics

- Managed by a division head
- Staff splits time between the JVLA site and the Socorro Science Operations Center (DSOC).
- Includes the 22 VLBA site techs and support personnel as well.
- Two engineers are tasked with working on ngVLA development.

Its primary responsibilities are to maintain, repair and lead development on all electronic components in the antennas, including the WIDAR correlator. The electronic division also support engineering students in cooperation with the New Mexico Tech university school of engineering. As with the engineering services, the division is divided into groups, each with a supervising group lead.

Organization of Engineering Staff

Electronics (cont.)

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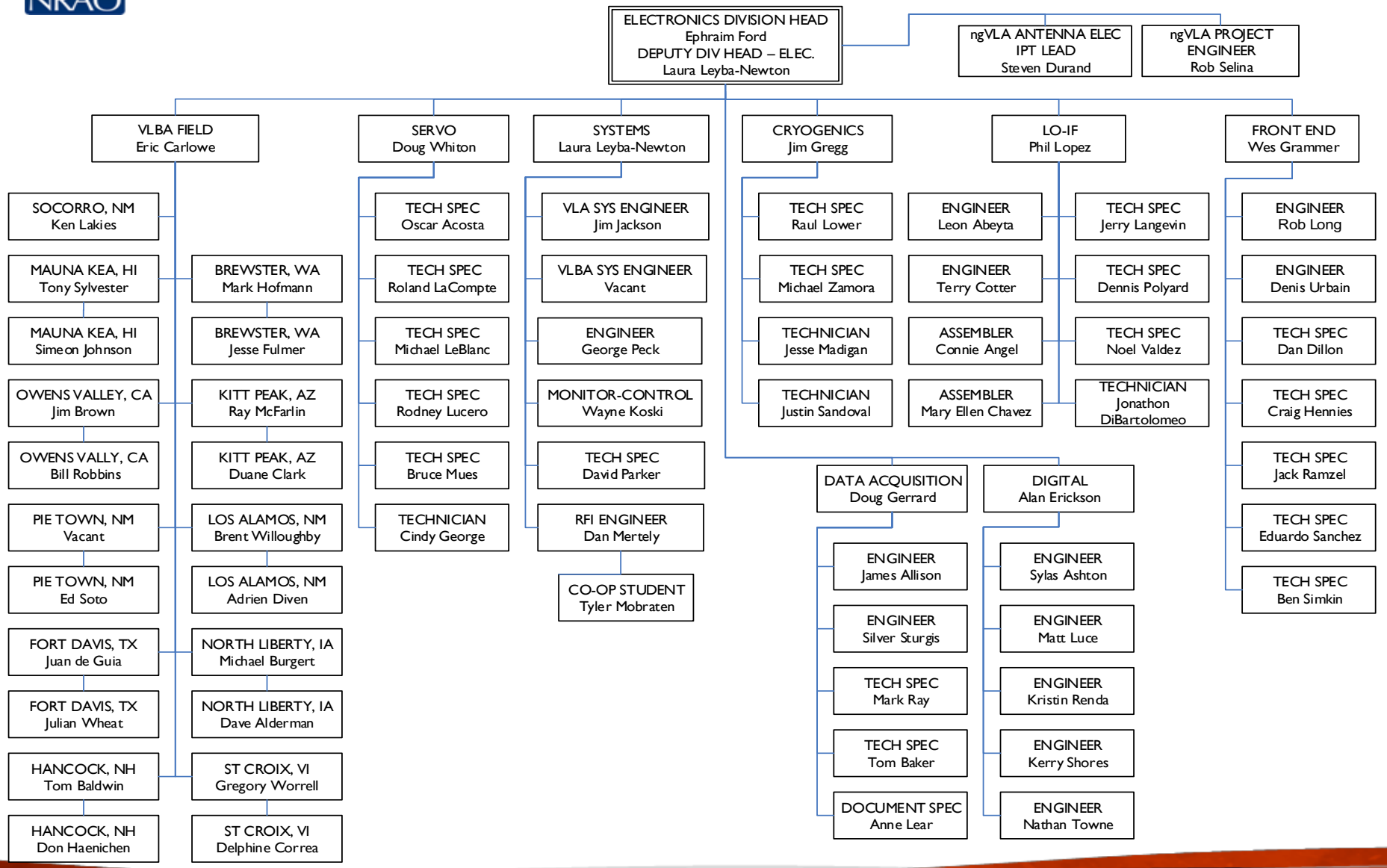


Organization of Engineering Staff

Electronics

Servo/Fiber – *7 FTEs (1 engineer and 6 technicians) (**located at JVLA site**)*

Responsibilities: Maintain and repair the antenna control units, the sub-reflector control units, Fiber Optics support

System Engineering – *7 FTEs (6 engineers and 1 technician)*

Responsibilities: Ensure all electronic equipment integrate appropriately and assist in the diagnosis and resolution of problems that may involve multiple groups. Monitor and Control and RFI mitigation functions are managed in this group. Located at the DSOC

Organization of Engineering Staff

Electronics

Cryogenics – *5 FTEs (1 engineer and 4 technicians)* ***Located at JVLA site***

Responsibilities: Support 8 cryogenics units per antenna, compressors, and spares

LO/IF – *9 FTEs (3 engineers, 2 assemblers, 4 technicians,* ***2 of whom are at JVLA site)***

Responsibilities: Timing, Masers, Intermediate Frequency related electronic equipment

Organization of Engineering Staff

Electronics

Front End – *9 FTEs (4 engineers, 5 technicians)*

Responsibilities: Support all receivers, feeds and related electronic equipment. RFI mitigation. **Some staff assigned to the JVLA site.**

Data Acquisition – *4 FTEs (3 engineers and 1 drafter/documentation specialist)*

Responsibilities: VLBA recorders, Drafting tasks, documentation management

Organization of Engineering Staff

Electronics

Digital – *6 FTEs (5 engineers, 1 technician, of which 2 engineers working on ngVLA)*

Responsibilities: Correlator and other digital electronics, electronics development

Development

At the NRAO, once a project of any size has been proposed, either by engineers or scientists, the first thing to be reviewed is who is going to do the work of the project and its impact on the maintenance/repair efforts, as well as how the implementation will affect the scientific observing. Project management assists the engineers in planning the scope, the budget, the manpower, the schedule, etc.

I like to think of both PM and engineering as toolkits, each of which has a specific set of tools to use them to successfully complete a project. It is important to lay out clearly the role each has early on. Sometimes PM takes the lead, but in most development and upgrade projects, the content knowledge and expertise of the engineers takes precedence and PM acts to support the engineers to coordinate the project. Projects can be over-managed, leading to loss of effectiveness of the process towards completion.

Maintenance and Repair vs Development

Maintenance and repair are the primary functions of the engineering staff. All technicians are required to contribute 100% of their time on maintenance and repair tasks. Engineers assist with repair, if higher level support is needed.

Development of new technology can be local to the JVLA staff, but in general, the Charlottesville-based Central Development Lab (CDL) leads the cutting edge design and development efforts.

Maintenance and Repair vs Development

Senior staff engineers are typically assigned the leads on projects, especially in the early stages of development. This does take their time away from their routine maintenance/repair obligations. If these tasks can't be covered internally, then we generally backfill with a part-time or temporary technician to support those activities., if funding allows. If not, then case-by-case decisions on whether to allow certain repair efforts to be relaxed will be decided upon.

Reliability, Maintenance and Repair

Efficiency is lost if the astronomical usefulness of the instrument is impaired. Poor quality data impacts the observatory's reputation.

A program for preventive maintenance, routine scheduled maintenance periods to perform timely repair and install upgraded equipment is developed based on experience and evidence of failure or soon-to-occur failure. JVLA assigned dedicated periods free from observing to do this. This allows management to ensure personnel are present to perform those tasks.

All problems when discovered are documented by symptoms, date, presumed component in the JIRA system. Reports and statistical analysis can be performed to assess reliability of parts and systems (such as mean time to failure, repair), that guide Preventive Maintenance.

JVLA Engineering Operations – Lessons Learned

Reliability, Maintenance and Repair

- Triage" meeting – short meeting with all group leads daily for 10-15 minutes to review new problem reports and report on completed maintenance reports
- Assign an owner to all reported problems
- Pair up experienced with inexperienced to do the repair
- Document steps taken for the diagnosis and resolution of the problem (start dates and time to conclude can be used for statistical analysis)
- Update (or create) SOPs (standard operating procedures), if needed
- Key Performance Indicators are a useful way to track performance over time, as long as you clearly understand how to obtain the measure.

Developing Design Standards for Upgrades

The biggest factor in developing design standards is to use experienced staff who are familiar with the existing equipment, who have a history of working with the scientific and senior engineering staff who thoroughly understand the goals of the upgrade and have kept up with new technologies.

We also define and use best practices when re-design efforts are needed in areas such as stakeholder engagement, peer review, and documentation.

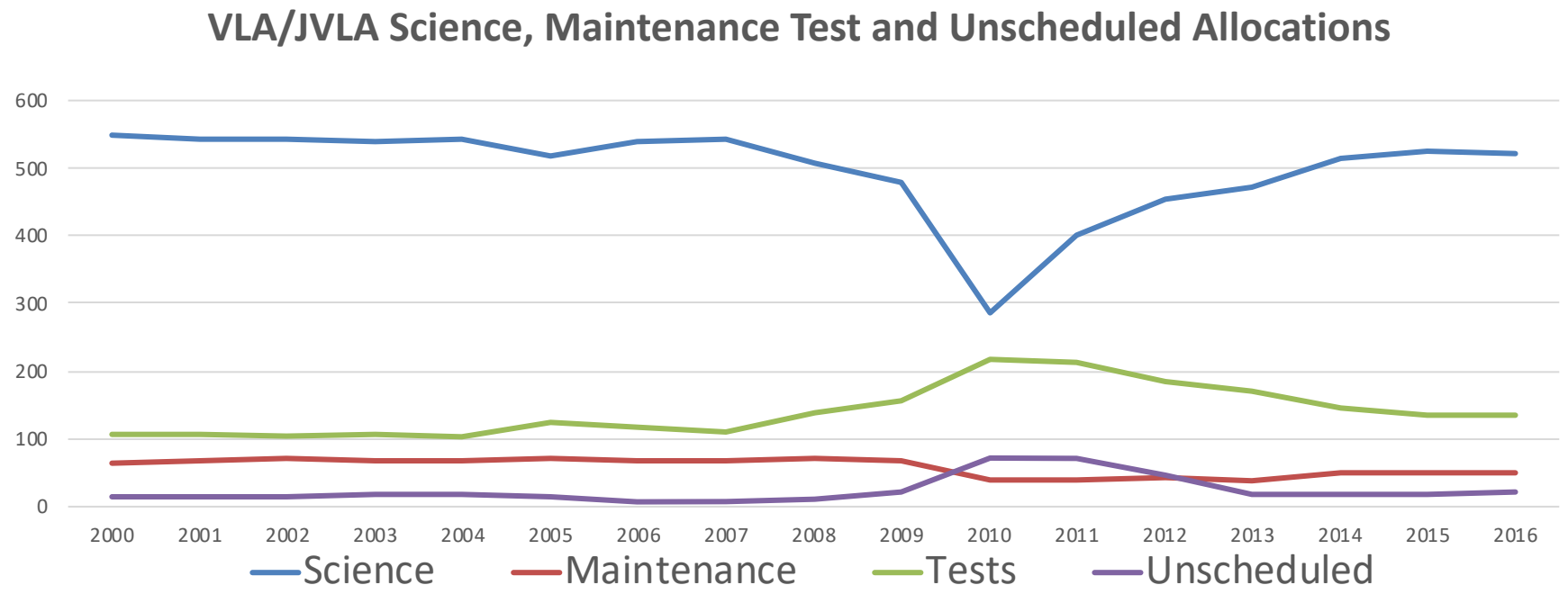
Knowledgeable, experienced staff are the key.

Telescope Time Allocation

Based on submitted proposal, a time allocation committee meets 2x a year to review and tabulate the time requested for science observations. The committee determines, based on requirements requested in the proposals for the instrument, if the science can be met and what resources are required.

In the case of the JVLA, the committee roughly schedules array reconfiguration dates in response to time pressures for a given configuration. Bryan Butler will talk more on this.

JVLA before, during and after Construction Time Allocations



Downtime is based on problems affecting data at the time of the observation, typically 3-10%

The Unexpected

- Correlator chips on some boards failed when correlator was powered down and was due to manufacturing problem that did not surface for a few years (Fix – replace chips, but chips were custom and not easy to find economical replacement. Some boards were severely damaged and repair is difficult and boards send out to commercial company (very expense and results not guaranteed).

- Bad band switches (Fix - redesign and retro-fit)

- ACU/Focus-Rotation Modules were not upgraded with the JVLA. But parts to repair became unavailable and projected failure rates caused concern – also, issues with spare parts being purged from the Warehouse exacerbated the problem. (Fix – redesign and retrofit)

The Unexpected

- Windows machine associated with operations caused the array to crash when it went into sleep mode (Fix – remove PC from Monitor and Control path)

- K-band (xxMgh receiver) installed in a way that made it difficult to perform maintenance in the field (fix is to rotate the receiver when the antenna is in the barn for overhaul)

- Water in the receiver feeds. An old problem that was fixed on the VLA, but recurred with JVLA (dry air system installed, but failures still occur).

- L-band cryo seals leaked in cold weather(-10 C and below), causing cryo units to fail. (Fix: redesign the cryo sealant system and retro-fit)

JVLA Engineering Operations – Lessons Learned

The Unexpected

- Fiber connectors and heliax cable became loose frequently (Fix – better anchoring)

- Not unexpected exactly, anywhere between 5-10 years after construction, some equipment bought and used during construction specifically to support operations began to age and needed repair and/or replacement. (CNC machine, track spiking equipment, trucks and other vehicles). Make sure these items are captured and budgeted for on risk registers and multi-year budget plans. Many components for heavy equipment are now electronic, and replacement can be costly.

- Watch for warranty expiration dates, and act on either updating or dropping appropriately

Quality Assurance

Science suffers if the telescope performance is unreliable. Ways to maintain quality control/ assurance include:

- "Triage" meeting – short meeting with group leads daily for 10-15 minutes to review new problem reports (we use JIRA) and ensure each problem has an owner who is accountable for it and reports on progress towards a fix.

- Routine testing by array operations that run system-wide checks on pointing, delays, baselines, receiver performance, check hardware changes

Quality Assurance

- Data Analysts scrutinize data samples of each observation.
- Scientific staff perform more complex quality analysis on calibration, correlator modes, etc., check new software updates, etc.
- Bench testing to QA standards prior to installation.
- The System group (Electronics Division) take the lead on investigating difficult quality issues, then ultimately pass on to the appropriate group for repair.
- Technicians following up on repairs and monitoring performance.

Documentation

- Division/Groups responsible for their documentation and writing of Standard Operating Procedures (SOP).
- Encourage the writing of memoranda on all projects and upgrades. Don't forget to document proposed solutions to problems with no funding to fix at the moment.
- Central location, with links from a web page that are clearly marked (i.e. make it easy to find the information and documentation).
- Managed –drafting/documentation specialist in the Data Acquisition group make sure that all docs are properly managed
- Once filed, most are never read again, So, keep the document short and succinct. Don't use a paragraph if a sentence will do, don't use a sentence if a phrase will do, and don't use a phrase if a word will do.

Documentation

- Worth the effort to update old formats (i.e paper schematics to digital).
- Maintain a consistent format where practical and possible to make it easy for people to write the docs/memoranda.

Training and Advancement

NRAO offers:

- New Employee Orientation
- Professional Training (wire bonding, lasers, project management, soldering, etc.)
- Offer in-house training when practical
- Budget for external experts to come in for training
- Budget for individuals to go to training seminars

Training and Advancement

- Reimbursement for tuition for degree programs
- Management training
- Current employees given first consideration for open positions
- Promotions and Salary Review annually for all employees, and whenever an internal transfer occurs
- Salary schedules and job descriptions available to all employees

Safety

The importance of safety cannot be overstated. The cost to the Observatory in both human and financial resources is great if safety is not prioritized by the institution. A facility that does not do so risks not just loss of productivity, but employee morale will suffer if it is perceived that management doesn't care, and may affect retention and performance.

Safety

Two safety officers split time at the DSOC, the VLBA stations (3-4x a year), but mostly at the JVLA site. Their responsibilities are to provide safety training, perform inspections and provide documentation.

Main Responsibilities:

- Document and Investigate any accident/incidents
- Maintain an Observatory Safety Manual containing all policies
- Provide or contract for specialized training as needed

  e.g. High space work, CPR, AED, Maintain/replace PPE

Safety

- The most common safety issue and the one that causes the most employee absentee-ism at the JVLA is back injury, usually due to improper technique in lifting, often exacerbated by a sedentary life-style.

- The next common by trips and falls, caused by uneven surface, loose carpeting, electrical cords in pathways.

- Third is misuse of or failure to use safety equipment such as eye protection, safety shoes, harnesses, lockout/tagout.

- Inattention when using equipment.

Summary/Last Thoughts

- **Plan for efficiency** – cannot rely on budgets to be continually increased to cover the needs of the observatory.
- **Development** needs to be an on-going aspect of engineering operations – much of the technology from the construction phase will be heading towards obsolescence by completion.
- **Enable engineers to stay current in their area of expertise** to increase their value to the observatory, to keep them engaged and better able to provide in-house help with development activities.
- **Watch for expectations that software can fix all fix data problems**, rather than address the root engineering issues. Stay knowledgeable about the state of the science data to better advise on this score.
- **Don't sacrifice safety** to expediency.
- **Experience** is your most valuable asset. Work on providing a rewarding, creative environment.
- **Avoid management creep** – don't create management positions as a reward, too often effective engineers, technicians end up less productive because the company rewards management positions financially over great content work.

People Management

An Observatory can have the most well-planned organization, tremendous technology, and first-class facilities providing cutting edge science, but it will not achieve its potential without the support of its personnel.

A poorly managed staff can cause loss of productivity, as more effort needs to be devoted to addressing personnel issues. If employees feel that management is the enemy, or even worse, incompetent, morale will plummet and people will not be motivated to put their best effort into their work and eventually, turn-over rates will increase.

As noted earlier, long-term employee expertise is extremely valuable to the organization and once it is gone, it takes a long time to recover. That does NOT mean poor employees should be retained, but management needs to provide a working environment conducive to creating successful employees.

10 Tips for Managers and Supervisors

1. **Make it easy for people to do the right thing** (or make it hard to do the wrong thing). One way to do this is to set clear expectations for performance and review this with employees frequently.

2. **Communicate effectively**. Have **SHORT** daily/weekly/monthly meetings, as needed and make sure you start them on time. Send reminders, pass on useful information, but keep it simple – don't use a paragraph if a sentence will do, don't use a sentence if a word will do and don't use a word if a look or a gesture will do. Walk around the work areas for a short period every day.

3. **Learn all company policies and follow them**. Make sure your employees know and understand them. Review at monthly meetings, especially policies regarding attendance, safety.

JVLA Engineering Operations – Lessons Learned

4. **Document all work-related conversations**, even if it is just an email to yourself. It is too easy to forget conversations with an employee and the words and phrases used. In some cases you may want to forward copy to the employee.

5. **Make expectations clear.** Goals, deadlines, work quality and other work-related should be transparent to both supervisor and employee. Set up a method to review progress periodically (hint – once a year is not enough).

6. **Maintain professionalism** – don't lie, don't over-promise, don't cover-up, admit mistakes.

JVLA Engineering Operations – Lessons Learned

7. **The job of a supervisor boils down to two things:** reduce distractions and find the resources that your team needs to do its job. It is not to be your employees' best friend, or to be the best engineer.

8. **Never hoard knowledge**. Share what you learn about new techniques, solutions to problems and encourage your employees to do so. Encourage cooperation and collaboration, not competition. Be a mentor.

9. **Reward success**, even if it is just a verbal recognition. Poll your team for ways to acknowledge contributions.

10. **Listen** more than you talk.

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