Building the AuScope VLBI Array

IVS VLBI2010 Workshop on Technical Specifications

Bad Kötzting
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Katherine

Yarragadee

Hobart

2400 km

3200 km

3500 km
Assumptions

• A single site installation (complications when there are multiple sites)
• VLBI2010 specification
  – We followed as close as possible. Main concessions were antenna El drive rate, feed
• “Patriot” antenna
• Remote operation
• Australian laws, environment
They don’t make them like that anymore

Mk-I: Patriot/COBHAM

New InterTronic Antennas 12m

Many key people maintained, similar installation procedure, controller interface
Resources:
TecSpec web page, and the “Meetings” section AuScope Operations Wiki at auscope.phys.utas.edu.au/opswiki (bottom of page)

• Freely available documents:
  – These slides
  – Tender documents (antenna, maser, foundations)
  – Geotechnical survey Request for Quote (Katherine)
  – Foundation and site layout sketches
  – Summary of installed hardware
• Happy to share software on request
• Wiki also contains information on configuring hardware, operations procedures etc
Outline

• Project background
• Initial planning
• Tenders and Quotes
• Antenna tender
• Site selection and preparation
• Construction and acceptance testing
• An example site
• Operations
Project Background
How it got started…

• 2006, Federal Government announced National Collaborative Research Infrastructure Strategy (NCRIS): i.e. funding for research infrastructure

• Australian geo community put in joint proposal which included an upgrade to VLBI infrastructure

• Budget at the time was not detailed but based on an assumption of 3 sites. Knew we had to keep costs down for chance of success.

• Proposal was successful. I started work on project in May 2007 given
  – $7M budget
  – Completion and operating by 30 June 2011. Preferably operating by 30 June 2010
My Background

- PhD @ UTas, completed 1997 (AGN, VLBI, Gravitational lensing)
- Post-doc at ISAS, Japan on VSOP 1997-1999
- CSIRO ATNF 1999 – 2007: 50% research, 50% radio astronomy support at NASA DSN station at Tidbinbilla.
- Very little project management experience!
Advice Part 1: Get Organised

- You can’t keep everything in your head.
  - Google “GTD” (Getting Things Done)
  - Don’t let email take over your life
- Maintain a wiki for documentation and a blog to log changes/events. Encourage everyone in the project to use it
The start

• Most important early tasks were to define as well as possible the requirements for site, antenna and associated hardware.
Advice Part 2 : Get advice from the experts

- Formed several committees to provide guidance on key areas. Included various IVS people (thanks!):
  - VLBI Steering Committee
  - Siting
  - Antenna
  - Maser
  - Operations
- Talk to people
- Get legal advice (tenders, contracts, commercial-in-confidence, etc)
Advice Part 3: Budgeting

• Expect the unexpected. Allow a contingency, ~10%, for unexpected things
• Beware of currency fluctuations

Value of AUD in USD
Request for Quotation: Geotechnical survey at University campus, Katherine

1. Introduction

The University of Tasmania, in collaboration with the Government and Hobart City Council, is seeking quotations for a geotechnical survey at the University campus in Hobart to assess the feasibility of constructing a new facility. The survey will involve the examination of the site for potential hazards and the establishment of a design basis for the proposed construction.

2. Requirements

The survey will include the following:

- Geotechnical investigations to determine the stability of the site.
- Geophysical surveys to assess the subsurface conditions.
- Sampling and testing of soil and rock materials.
- Preparation of a report summarizing the findings.

We require the services of a qualified and experienced geotechnical engineer to undertake the survey. The quotation should include all costs associated with the survey, including travel and accommodation expenses.

3. Tendering

All interested parties are invited to submit their quotations by the deadline provided. The University reserves the right to accept or reject any quotation without obligation.

The University of Tasmania

[Signature]

Project Manager

[Address]
The Tender Process

• For all major items we needed to go out to tender, so the tender document needed to detail all desired specifications.

• Decide what is essential and what is optional. For example, we invited antenna manufacturers to quote on a S/X feed as an option.

• A Request For Tender (RFT) was issued with all our requirements. Advertised in media and on-line. Also contacted known manufacturers. RFT had to satisfy UTAS legal requirements, included reference to a contract with various terms.

• Details of the contract were negotiated with successful tenderer
Tenders (expensive items, multiple suppliers)
- Site preparation (foundations, trenching etc)
- Antennas
- Masers

Quotations (single supplier, or multiple suppliers but less expensive)
- Geotechnical survey
- Observatory buildings
- Digital back end
- Recorders, media
- Feeds

Things done in-house
- Receiver
- IF system
- Misc electronics
- Some software
Contents of a RFT: Antennas
Contents of a RFT: Antennas (part 1)

- Part B
  - Background
  - Statement of Requirements
    - Antenna size, optics, mount, limits, rates, freq range, lifetime
    - We attached an excel document with each requirement listed and requested tenderer to respond to each one. Could they comply or not?
  - Siting and Site Preparation
    - We said where the telescopes would go, said that we would prepare the sites to the manufacturers specifications prior to them starting
  - Budget
    - We said how much we had to spend ($600 - $800k). We discussed putting this in a lot before deciding to do so. We knew the budget was tight and thought the price would be hard to meet
  - Timeline
  - Frequency Coverage
  - Optics and Structure
  - Aperture Efficiency
    - We should have been more specific (e.g. 75% excluding Ohmic Losses)
  - Feed translator (option)
  - Subreflector positioning and tracking (option)
Contents of a RFT: Antennas (part 2)

• Part B (continued)
  – Cable Wrap and Pedestal
    • Number and type of cables we expected, space requirements in pedestal
  – Antenna Surface
  – Antenna mount
  – Slewing & Tracking Requirements
  – Operating conditions (wind)
  – Control and Monitoring interface
  – RFI tightness
  – Power rating
  – Design lifetime, maintenance and spares
Contents of a RFT: Antennas (part 3)

- Part D. Annexure to contract (the non-boiler-plate stuff). Was subject to some re-negotiation.
  - Delivery date
  - Completion date
  - Governing law (Tasmania, Australia)
  - Currency
    - We requested quotations in Australian Dollars (protects us, dangerous for them!)
  - Payment stages (were re-negotiated)
    - X % on signing
    - Y % on delivery
    - Z % on acceptance
  - Penalties for being late (optional)
  - Bonuses for being early (optional)
  - Acceptance tests to be made
    - Make sure that the tests cover all your specifications where possible.
    - You may not be able to test some things (e.g. aperture efficiency) until some months after construction. Consider two levels of acceptance: mechanical and RF
Site Selection
Site selection : New or established?

- New site
  - Near existing roads, power, network will reduce cost significantly
  - Penalty may be local interference
  - Site security. Even a remote site will need fencing, just for legal (public liability) reasons

- Adding to an existing site
  - Close enough to maintain time series, good local-tie to old VLBI, GNSS, gravity, SLR etc.
  - Same bedrock
Site Selection continued: Geotechnical Survey

• Advice from geologist or geotechnical engineer is essential

• Antenna manufacturer may supply plans for foundations but these may require modification to suit the local geology. This was the case at all of our sites.

• For each site, we:
  – Identified areas that would be suitable and in each area, 3 to 6 specific sites that we’d like tested.
  – Employed a local company with geotechnical/drilling capabilities to carry out drilling, sampling etc. Used this to identify best location
  – Geotechnical engineer then provided advice on foundations.
    • The engineer required information on loading and on things like maximum acceptable movement of foundations with respect to bedrock.

• Cost of these surveys varied a lot between sites ($10k to $40k)
Site Preparation

- Antenna foundations
  - Add tie-downs for damaging winds?
  - Conduit for cables, lightning conductors
- Adjacent work slab
  - Tie-downs for reflector assembly
  - Good surface for Elevated Work Platform (EWP) during construction and then ongoing maintenance
- Monuments for local-tie survey
- GNSS antenna installation (Managed by GA)
- Concrete slab for generator
- Equipment/control building with room for racks, desk space, separate maser room. Will people live on site?
- Shipping container is great for secure storage of tools, maintenance hardware
Delivery
Advice Part 4: Shipping and Insurance

• Check your local quarantine laws.
  – Any wooden packing material containing bark is prohibited into Australia. Unpack on dock, burn wood, re-pack!

• Make sure you are fully insured door-to-door with the same insurance company!

• Consider tilt / shock sensors on delicate items (e.g. masers) to establish where/when breakage occurred. Consider inspections along the way, e.g. when the item is moved from plane to truck.
Construction
Antenna construction

• Before construction started we provided
  – Foundations (to specification of Patriot and geotechnical engineer)
  – Power to site
  – Network connectivity
  – Site building/facilities
  – 2-3 local people to assist during construction
    • Kept Patriot’s costs down but also gave us valuable knowledge of the antenna construction and operation
What we should have done but didn’t

- Critical Design Review
  - Antenna was 4th generation, 3 previous customers (JPL, CSIRO, AUT) so we weren’t too concerned about design. But…
  - We still found problems that needed fixing during/after installation, some causing significant delays

- It would have been better to have end-to-end testing of system (antenna and RF/IF) at factory before delivery of first antenna (planned for the new InterTronic Antennas 12m).
Antenna acceptance testing

Occurred after construction. Covered many things but could not test anything that required a feed & receiver.

- Limit switches, emergency stop buttons
- Antenna control in maintenance and operational modes
- Slew rates, acceleration, Az and El limits
- Controller user software
- Controller features
  - Az/El and RA/Dec modes
  - Pointing model and refraction correction
  - Tracking a source or fixed Az/El
  - Settling times
  - Scanning modes
- Pointing accuracy and repeatability in calm and windy conditions
Advice Part 5: Give your antenna lots of exercise

• Make the most of the warranty period
• Acceptance testing won’t pick up on problems that might take a while to appear. It may not be possible to test on a celestial source until months after construction.
• Even without a feed/receiver, give the antenna a VLBI2010-like schedule and run it for days and days
• With a feed & receiver, tests for SEFD, aperture efficiency , RMS pointing etc can be made.
• A pointing model can be determined and tested. Look for changes in pointing accuracy over time.
• Look for changes in other key indicators (e.g. SEFD) over time
An Example Site
An example site: Katherine
Site building (Katherine)
Signal Path and equipment

[Diagram of signal path and equipment]

Feed Tube
- Feed
- Loop Coupler
- LNA

Hub
- Cross-over switch
- Band-pass filter
- Amp
- Mixer

Control Room
- Cable compensator
- Variable attenuator
- Amp

Mon DBBC Mon DBBC Mon DBBC Mon DBBC
Katherine Racks

Feed, Rx
IF Unit
DBBC
Mark 5

Antenna
Control Room
Added later...

- Redundance of network connection (3G backup at Yg, Ke)
- Ke and Yg harsher environment than Hb:
  - Dehumidifiers for feed, pedestal and hub
  - Airconditioning for drives
Operations

- All sites controlled remotely. Antennas unattended but local people available to handle modules, assist in occasional maintenance, on-call for emergencies

- Control and monitoring
  - PCFS
  - e-RemoteControl as much as possible
  - MoniCA
    (http://code.google.com/p/open-monica)
Advice Part 6: Project Management

• Keep track of things yourself.
• Good working relationships with suppliers
• Don’t lose touch with manufacturers.
  – Insist on regular meetings/telecons, especially during critical periods.
• Value enthusiastic, dedicated people
Resources

auscope.phys.utas.edu.au/opswiki
Thank you
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