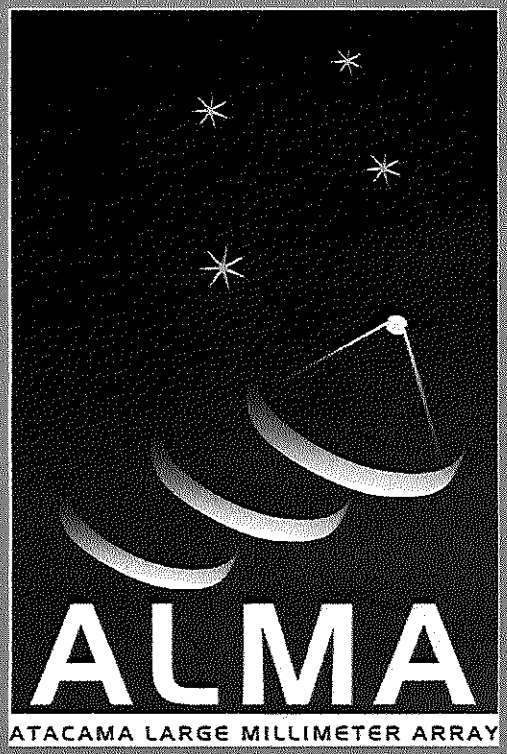
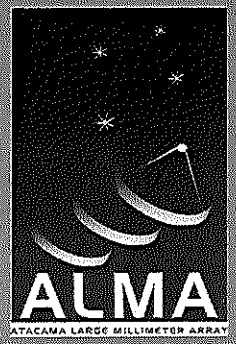
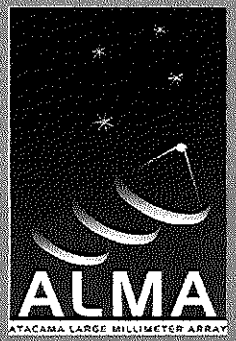


ALMA Antenna Meeting
Dulles Nov 29-30 2004



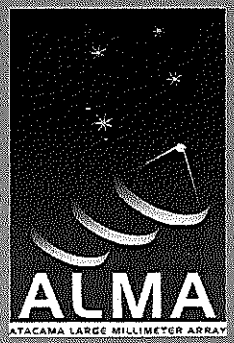
Agenda

- Monday PM – preview, complete data
- Tuesday
  - (brief review)
  - Examine options



Antenna History

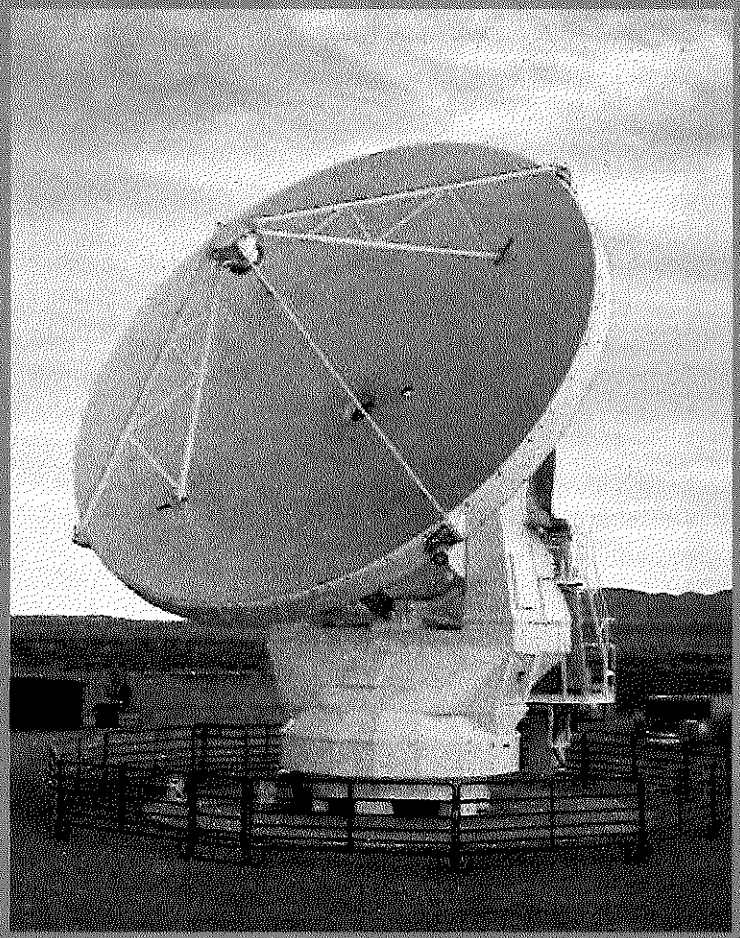
- Science/tech specs evolved 97-99
  (MMA 12 ↔ LSA 15m, ASAC-style inputs, antenna company inputs…)
- ~Jun 1999 → Prototype call for tender
- Feb-Mar 2000 → Prototype contracts signed (18-21 months delivery, i.e. late 2001)
  US VertexRSI, Eu EIE/Costamasnaga
- Dec 2001 → Alcatel joins EC → AEC
- Mar 2002 → Project antenna budget
- Oct 2002 → Antenna budget revised
- Feb 2003 → Bilateral Agreement signed
- Mar 2003 → VRSI prototype in AEG hands
- Dec 15th 2003 → Production Call for tender

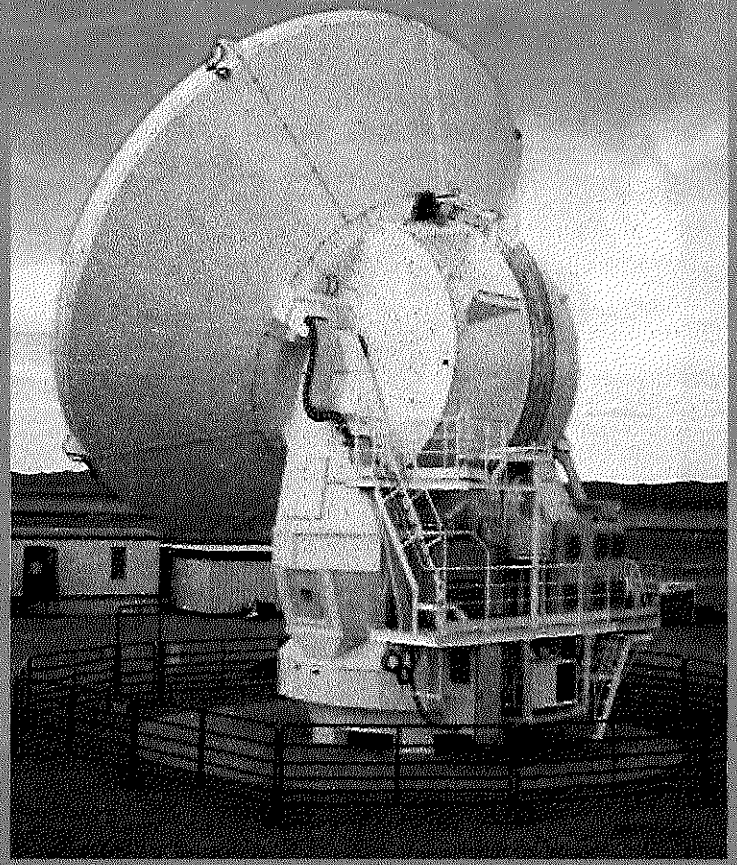


2004

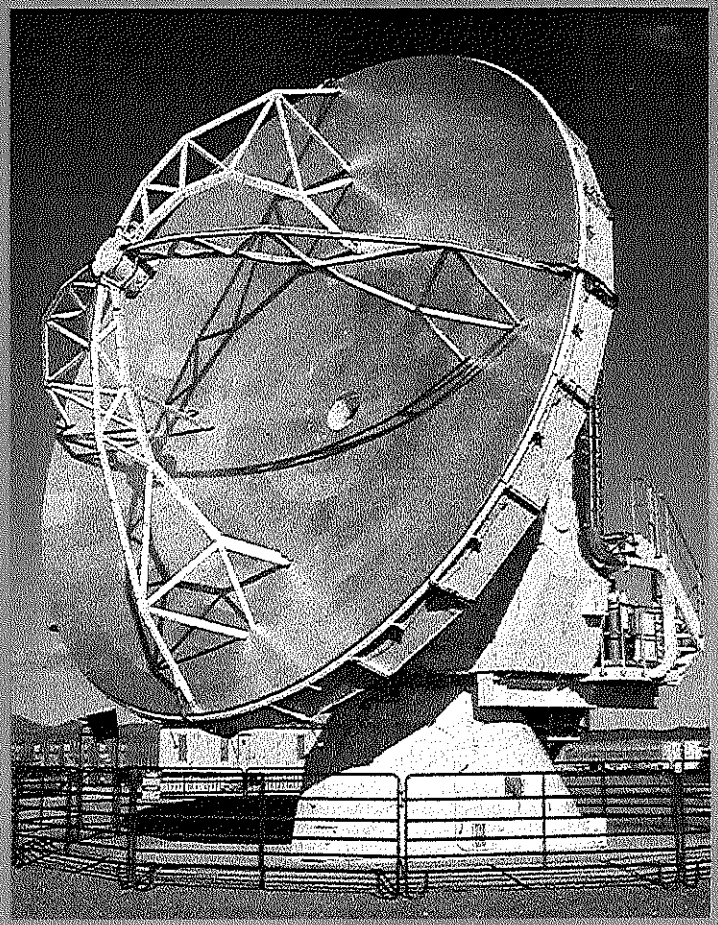
- Jan 2004 → AEC antenna in AEG hands
- Bids received Apr 2004…
  - US: Vertex/RSI, AEC,
  - EU: VA, Alcatel, Alenia
- AEG late 2001 → May 28th 2004
  - NRAO/ESO technical evaluation of prototypes
  - Full report due Dec 1st 2004 (originally Sep 2004)

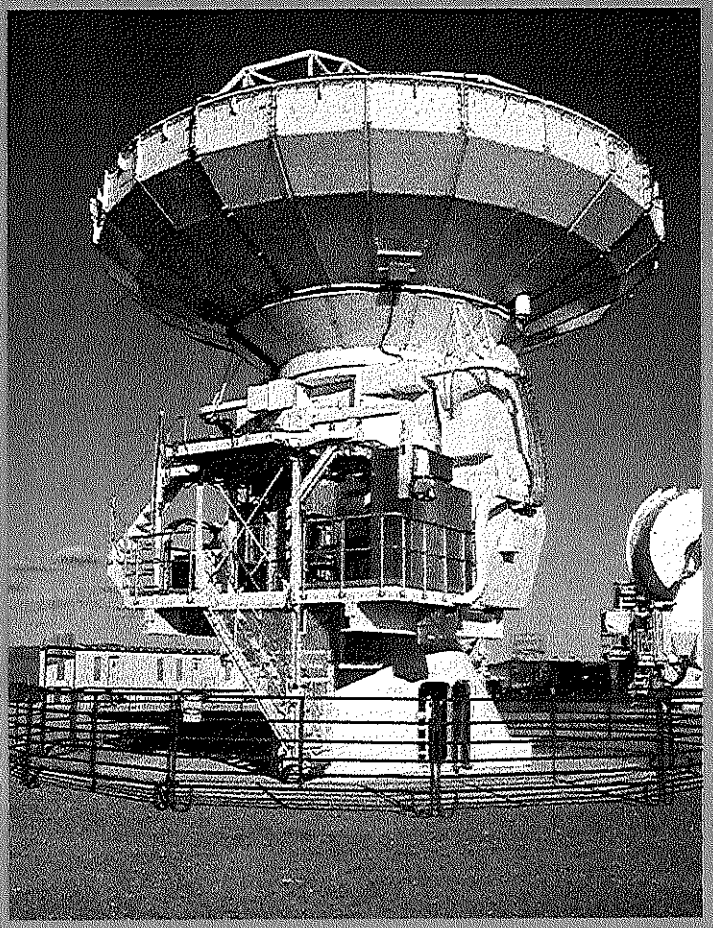
AEC prototype





Vertex Prototype





Prototypes Design Characteristics

VERTEX RSI/VA

- 264 Panels, 8 rings, **machined Al**, open back
- 7 adjusters / panel
- 24 CFRP BUS sectors, **open back**
- Feed legs & Apex in CFRP
- Hexapod secondary positioner
- **Invar support cone I/F Bus-cabin**
- **Cylindrical Invar/steel Rx. Cabin**
- **Pinion drive**
- Absolute Encoders
- 3 Point support base

ALCATEL/EIE

- 120 Panels, 5 rings, **Replicated Nickel, Rhodium coated**, closed back
- 5 adjusters / panel
- BUS in CFRP, 16 sectors, **close back**
- Feed legs and Apex in CFRP
- Three axes Apex mechanism
- **Direct connection Cabin BUS**
- **Cabin in CFRP**
- **Direct drives on both axes**
- Incremental encoders
- 6 Point support base

AEG Results

Parameter	Vertex RSI	AEC
Surface	M	M
Pointing (All-sky)	PM	PF
Pointing (Offset)	PM	PM
Fast switching	PM	M
On-the-fly	M	M
Path Length	M	M

EU: full release to bidders; US: relevant tech info only to Vertex

AEG Issues

- Insufficient time for testing (prototypes delivered 15-24 months late..)
- VLA conditions not representative of ALMA site (9 m/s wind?)
- VLA site poor optical seeing
- Critical (unique?) problems in integration, delivery for both vendors
- Management issues (AEG vs AIPT; vendor bias competition from beginning)

2004

- JTET → May-Jun 2004
  - Technical & management analysis of bids received
    No AEG information
  - Alenia scored highly; Vertex, Alcatel: technical & management issues identified

- JTET+ → Jun 17th 2004 (JTET+AEG report)
  Core JTET - add AEG information – Similar scores

- Late June - financial proposals opened; CSC/CAC begin evaluations, interactions with vendors
- June 30th – NA sidelines Alcatel, focus on Vertex
- NA places Alcatel on hold, requests Vertex BAFO (~Aug 31).
- Sep 14th – NA letter to NSF requesting to proceed to contract

- ATWG → Sep 29th 2004

ATWG Charge

- For each of the specific technical issues raised by the two Executives the group shall provide the following advice to the committees:
  - Based on an analysis of all available data, determine the level of remaining technical risk
  - Determine if any specific modification to the proposed design are required to mitigate any remaining technical risk.

- Specific Technical Issues:
  - Will the proposed antenna designs maintain surface accuracy specifications over all elevation ranges?
  - To what extent can the proposed metrology systems reliably improve the pointing performance of the proposed antenna designs in order to meet the required ALMA pointing specifications?
  - Comment on the maintainability of the two proposed designs and establish a first estimate of lifecycle costs for the operational lifetime of the telescope.
  - Other issues resulting from interaction with the antenna vendors.

SHOULD ACCESS ALL DATA + INTERACTIONS

ATWG Results(29th Sept)

Vertex

- Photogrammetry – focal length change with elevation differs by 50% from FEM prediction
- QD data – large, complex deviation data↔FEM
- If: scale (gravity + wind)*1.5, surface rms still meets spec (24 microns)
- But… BUS deformations may be non-homologous… residuals could scale by a larger (unknown) factor.
- Temperature gradients in cabin walls could deform dish?
- Metrology – untested, but should work

Alenia

- Metrology system not satisfactory; questions about use of tiltmeters on yoke arms.

ATWG Issues:

- Short timescale to operate
- Data access problems (AEG had relevant data)
- External influences
- 30-yr lifetime issue – not addressed

ATWGII + JTETII

- In Florence – decision to pursue testing plan to examine technical risks associated with Vertex antenna identified by ATWG + reconvene core JTET to examine management revisions
- Data ⟶Antenna IPT, coordinated by JAO; JTETII ⟶ ESO (JTETII not part of NA CSC process, though all info considered)
- Data were successfully obtained (including existing AEG information, but no APEX)

ATWGII:

- Evaluate new technical data, reflect on risks identified in ATWGI
  (primarily Vertex; also new Alenia info)

ATWGII results(17th Nov)

- Revised QD setup significantly improves measurement errors; systematic discrepancy still seen, with estimates between 8-38%; ongoing complex polite discussion.
- Photogrammetry: Non-homologous deformation detected (astigmatism + spherical aberration, EU + NA analysis Hill/Schwab); surface appears to have changed with time (although these measurements are at the sensitivity limit for this technique); ATWGII suspects bolt tightening significant, Vertex does not.
- Conclusion: BUS/FEM predictions still differ by ~10-30% (multiple analyses). Even with pessimistic assumptions this could ~leave surface rms below 25 microns, but non-homologous deformations may be important.
- Unresolved: differences in FEM vs measured 1st eigenfrequency.

ATWGII Results

- Revised Alenia metrology plans satisfactory.

Ongoing:

- QD debate (8-38%, more data?)
- Photogrammetry (More work required. NHD?)

Issues:

- No unified charge/schedule to ATWGII remains…
- Separate JTETII/CSC management review processes – allows different conclusions
- Overstressed volunteers…
- Heavy politics…

JTETII (Europe only; Nov 22nd)

- Requested to examine revised managerial proposal from VA using JTET methodology

- "In conclusion it appears that VA together with VRSI, have the industrial capability to produce the antennas. The level of confidence in the ability of the presented industrial setup to produce them within the time requirement of the project is still questionable on the basis of the material provided."

- TB note: CSC addressed same issue; item 45: revised information + "face-to-face meeting information have given CSC confidence"; information has been distributed.

Comments

- Parallel procurement & review – CSC & CAC – can cause problems, inconsistent conclusions
- Prototypes: Further testing required in all scenarios to understanding their designs, performance (Vertex+Alcatel)
- US budget. Unquantifiable urgent concerns about NA failing to sign contract before Q1-2005, unused money soaked up by Congress?
- Rebaselining. Can we confidently commit ~1/3 our budget before we have a rebaselined project? Can we buy antennas before we know the results of rebaselining?
  (Only OK if antenna budget firewalled from project?)

ALMA Antenna Specifications

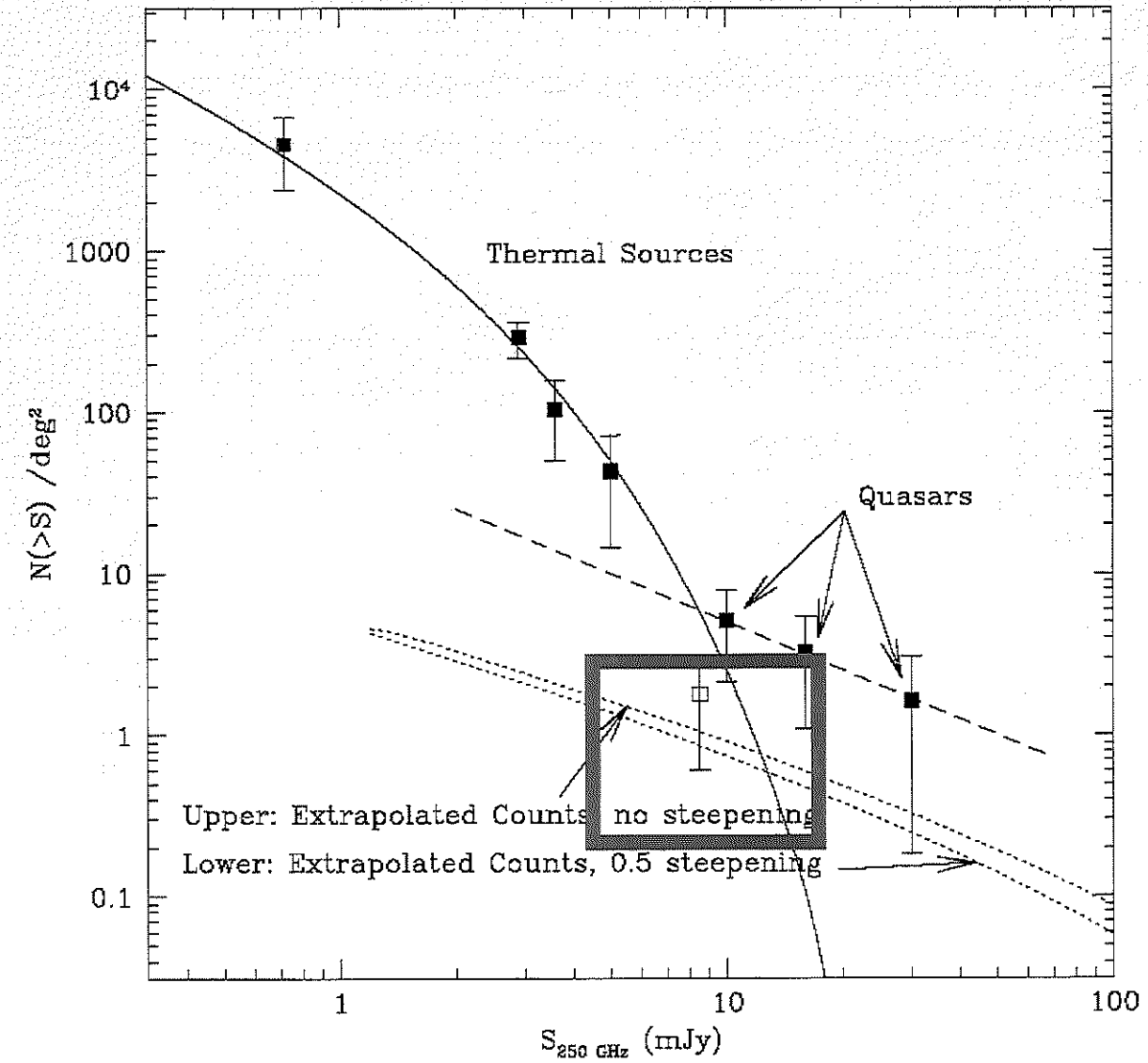
Parameter	Value	Reference
Number of antennas	64	SCI-90.00.00.00-0100-00 + BL
Diameter	12 m	SCI-90.00.00.00-0100-00 + BL
Surface Accuracy	25 microns (goal 20um)	SCI-90.00.00.00-0110-00 + BL
Forward efficiency	0.95	SCI-90.00.00.00-0120-00
Aperture Efficiency at 30 GHz	75%	SCI-90.00.00.00-0140-00
Aperture Efficiency at 675 GHz	45%	Tech Req. 130
Geometric Blockage	<3%	SCI-90.00.00.00-0150-00
Offset pointing	0.6" RSS over 2° radius	SCI-90.00.00.00-0260-00 + Antenna Bid TS
Fast switching	1.5 deg/1.5 s, settle to peak pointing err <3"	Antenna Bid TS + BL
Non-repeatable absolute pointing	2" RSS	Antenna Bid TS
Solar Observing	All frequencies	SCI-90.00.00.00-0360-00
Delay Error from Structure	(a) rms, non-repeatable, drift, over 300sec <13 fsec. (b) rms deviation from 10 sec average, short term <38 fsec	Tech Req. 151/152

Parameter	Value	Reference
Subreflector Stability	<2mm (two axes)	Antenna Bid TS
Repeatable pointing error (measured, corrected)	1.5 arcmin	Antenna Bid TS
Nonrepeatable errors (wind, temperature diff/changes, servo & drive errors, others…)	minimize	Antenna Bid TS
Calibration of pointing model	Once/month	Antenna Bid TS
On the fly requirements TP	0.5 deg/s, turn around 1', settle 0.8s, cont, 2" accuracy	Antenna Bid TS
Wind spectrum		Antenna Bid TS
Max/min Angular Velocity		Antenna Bid TS
Total weight	105 tonnes	Antenna Bid TS
Max/min Angular Acceleration		Antenna Bid TS

Pointing

- 0.6" RSS over 2°
  - Origin: Interferometric mosaic images with dynamic range > 1000:1 and high fidelity require 1/16th primary-beam pointing (Cornwell, Uson, Holdaway 1993 + recent others)
  - 1/16th PB at 535 GHz
  - 1/10th primary beam at 950 GHz (6")
  - ALMA DR: 50,000:1 (was 1e4:1, 1e6:1)
  - Metrology will be needed at high site
  - This spec evolved (ALMA, community, contractors)
- 2°
  - Holdaway, Owen & Rupen (1994): ~20,000 sources at 90 GHz > 20mJy (~one per 1.8°) (inconsistencies…)
  - Origin of offset pointing + fast switching specs: 1.5°…
  - Estimated from cm counts, some v. small-area surveys…

LAMA 805 – Holdaway, Carilli & Bertoldi



Pointing

- 2” Absolute over the sky
  - Origin: Desire to step directly to (2) below when adjacent calibrator known.

ALMA Pointing in practice (mosaic or target):

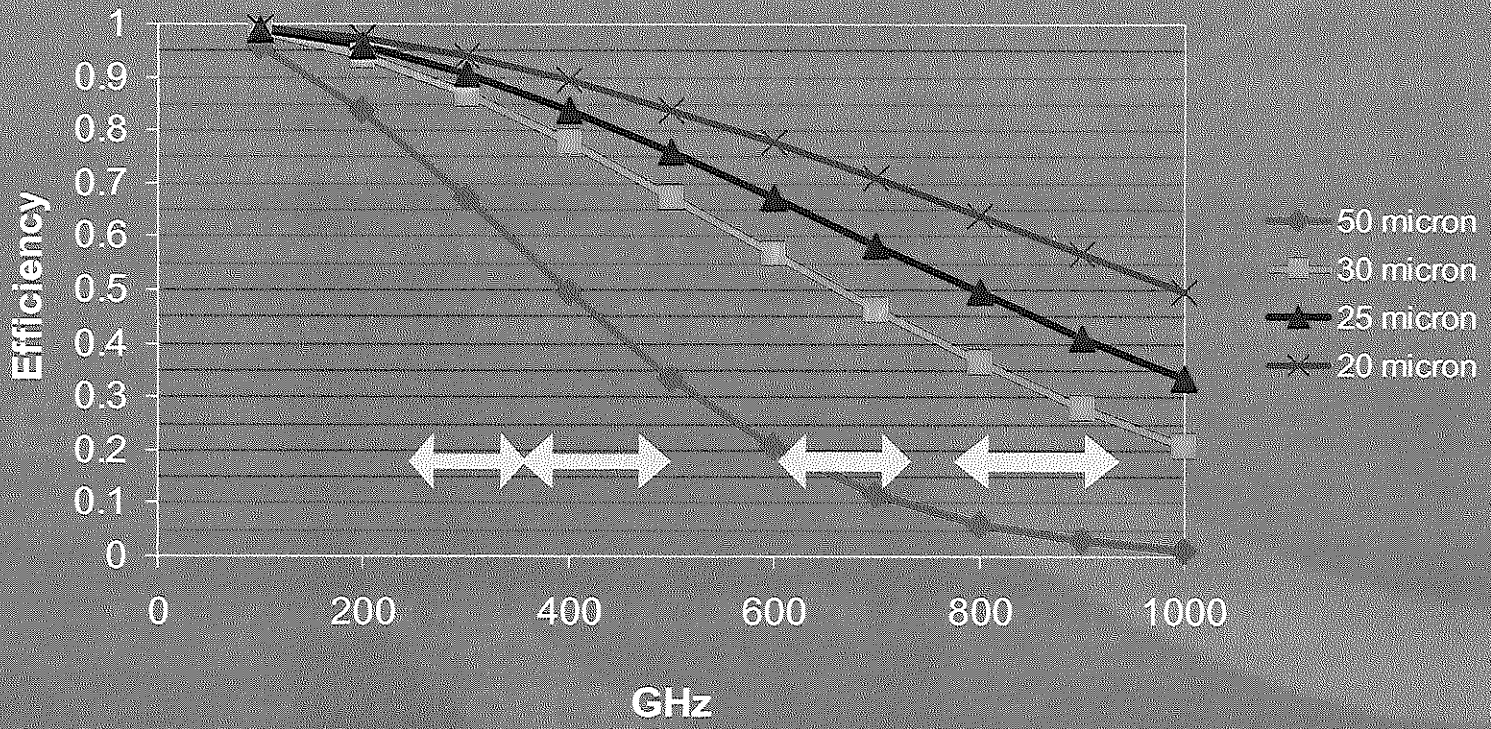
1. Slew to region of interest, reference point to known bright source within 10-15°.
2. Slew to region of target, find or know extragalactic calibrators within a few degrees, observe/solve its position, tweak pointing.
3. Slew to target & observe; reference point to nearby cal as needed.

- Step (1) required for bandpass calibration in many cases
- If problem: low ⟶ high frequency bootstrapping

Surface

- 25 microns RMS (20 microns goal) – Ruze
- Panels – set surface initially at OSF at 5-10°, including FEM tweak so best surface at 45°. Long-term – holography at AOS.
- Need good (few percent) FEM model; gives confidence in design.
- Beyond random (Ruze) deformations, important surface shows no systematic distortion (e.g. astigmatism, spherical aberration = non-homologous deformation)
- Vertex concerns….

Ruze equation



Importance of trade-offs in efficiency vs number of antennas – at 1 THz surface improvement of 30→25 microns is equivalent to having 50% more antennas.

Status with Contractors

NA

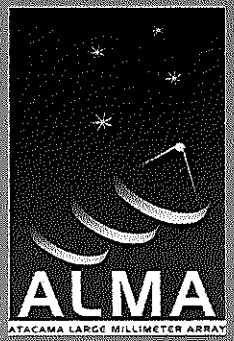
- Alcatel – on hold since ~Aug 30th; bid expired Oct 31st.
- Vertex – No exchange yet re: Dec 15th

EU

- Prelim Letter to all vendors – possible delay coming (end Q1 2005); final letter late this week.
- Full menu of options from all three bidders
- No FFP from Alcatel

Budgets

Budget	NA Plan	NA funds	Cont.	NA total	Eu Plan	Eu Funds	Cont.	Eu total	ALMA Total
March 2002	31 x $2,900 +$500	$90,557		$90,557	32 x $2,900	$92,963		$92,963	$211,048 (incl. $27,528 15% cont.)
October 2002	31 x $2,900 +$1,000	$91,055	$6,262 (6.8%)	$97,317	32 x $2,900	$92,960	$10,353 (11.1%)	$103,313	$200,630
November 2004	31 x $2,900 +$1,000	$91,055	$5,746 (6.3%)	$96,801	32 x $2,900	$92,960	$7,283 (7.8%)	$100,243	$197,044
BAFOs	25+25 VRSI	$136,862 (2004+ Then-yr)			25+25 VA	€ 140,000 (€ 130,000) (2004)	€ 116,000 to € 135,000	Equivalent bids, bank guarantee, no penalties	
					25+25 AEC	€ 141,308 (€ 135,761) (2004)	€ 141,800		
					25+25 Alenia	€ 155,000 (€ 147,850) + € 5M osf (2004)	€ 147,800 + 5M osf		



Options

Build-to-spec

- Current bids

Build-to-cost

- Current specs
- "N antennas"

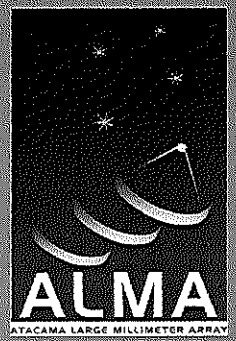
Other Options

Build-to-spec

- Use the current bids

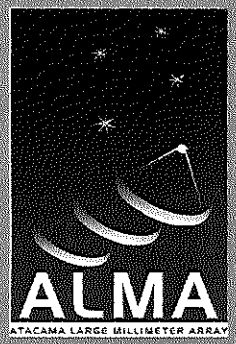
Alenia

- Meets spec & Eu process constraints
- Expensive (short term), long term?
- No US bid : would need to reopen call for tender in US
- NA: AUI would need to rule Vertex non-compliant
- NA: NSF: no use of prototype effort awkward (?)
- Cost – 30% higher than lowest bid
- Time – 12 months (US cycle)



Alcatel

- More testing required at AEG level
- EU: process issues (AEG, JTET, ATWG); need JTETII
- US: on hold; bid expired; need to resuscitate
- Cost: Middle price 20-30% higher than low bid
- AEG work – 2 months?
- JTET-like review – 1-3 months?

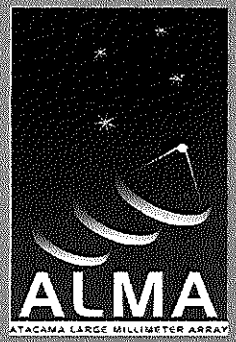


Vertex

- ALMA: At present unable to prove conclusively the antenna meets current specs; further analysis + observations (3 months?) may confirm/deny.
- Delay ⟶ cost increase
- BUS – design issue?
- US: NRAO/AUI ready to go (with working assumptions)
- EU: Management issues with VRSI/VA are improved, but concerns remain
- EU: various process issues make proceeding with Vertex difficult at this point

Build-to-cost

- Declare current call for tender dead
- Develop new joint call for tender indicating budget available, request bids analyzing three options
  - Current specs – How many antennas?
  - "N antennas" – for N, what specs possible?
  - ???
- Time: 1-2 months to develop call (terms & conditions), 3 month call, 2 months evaluate – 7-9-12 months total
- Cost: capped.
- Number of antennas, what specs?
- US process: funding peril, credibility, use of prototypes?
- EU process: ?



Option A

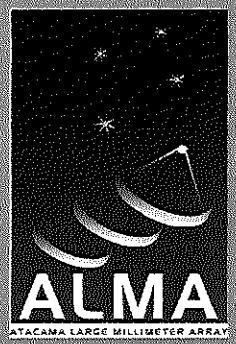
- Build to cost
- Assemble #1 in factory + test; remainder delivered/assembled by ALMA.

Option B

- Separate the procurements

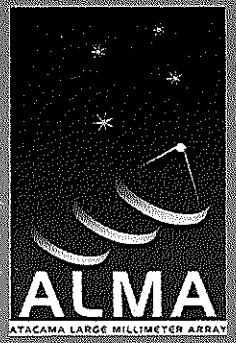
1. Two types of antennas (up front, ops cost)

1. Shift distribution of purchasing, project internals (NA buys 2/3rds antennas)
2. NA proceeds with Vertex contract; Eu follows later
3. E.g.; Eu assumes all site, computing
4. NA assumes antenna risks and responsibility ; Eu follow-on contract more expensive?
5. Does not solve Eu acceptance issues.



Option C

- Drop current procurement
- Call again with existing TS, open possibility on price revision etc.
- (continue testing...)
- Turn around 3 months?
- Review with "proper" AEG information



- Plan A - End of February – Working Notes
  - Need: Apex gain curve, drift in focal point with elevation, out of focus beam patterns
  - Further holography?
  - Fast switching?
  - Meet jointly with Vertex + Alcatel??? Goals??
  - Further photogrammetry - NHD
  - Need: Converged ATWGII report
  - Need: Alcatel information – continue testing…
  - Need: Management side: careful upgrade of JTETII Vertex information? (issues at FC: 25 vs 32, contractual terms different, price revision, contractor history)
  - Evaluation late February??
  - Can we guarantee an outcome?
  - Two outcomes: Vertex or Alcatel?
  - Does this resolve the 3*marginal issue for FC?