EVLA Phase II :
Science Goals, Technical Specifications, and Proposal Status

Rick Perley

EVLA Goals

- EVLA Project goals are to improve by factor 10 or more all capabilities of the VLA => a new telescope, the EVLA.
- Major technical capabilities of the EVLA:

1) Spatial resolution of 10 milliarcseconds (at 23 GHz).
2) Sensitivity of < 1 microJy. (1 to 40 GHz)
3) Frequency resolution from 0.1 Hz to 1 MHz.
4) Number of spectral channels at full bandwidth > 16384.
5) Capability of images with 10^9 pixels, covering the entire primary beam, containing all spatial frequency information.
6) Complete frequency coverage from 1 to 50 GHz.

EVLA Science Capabilities

- 10 milliarcseconds resolution provides:
  - 5 AU at Orion (High mass star formation site)
  - 100 AU at Galactic center (Nearest Super massive black hole)
  - 1 pc at distance of 20 Mpc (Resolve SNR in Virgo cluster)
  - 100 pc or better anywhere in the universe(High z galaxy formation)
- The spatial resolution and sensitivity combine to provide a brightness temperature sensitivity of 10s of Kelvin (3 to 35 GHz)
- This capability is unequalled by any telescope (at any waveband) currently in existence.

EVLA and ALMA

- Equalled only by ALMA amongst telescopes under construction or planned for the next 10 years or more.
- The EVLA does not duplicate ALMA's capabilities.
- The EVLA provides similar sensitivity and resolution as ALMA, but at centimeter wavelengths, where the physical processes are different.
  - Nonthermal processes (synchrotron emission, pulsars, BH, etc.)
  - Optically thin thermal emission (HII regions).
  - High-redshift thermal emission.
  - Long-wavelength (low opacity side) of nearby thermal emission.
- These are complementary instruments.

EVLA New Science

(Theme: Resolving Cosmic Evolution)

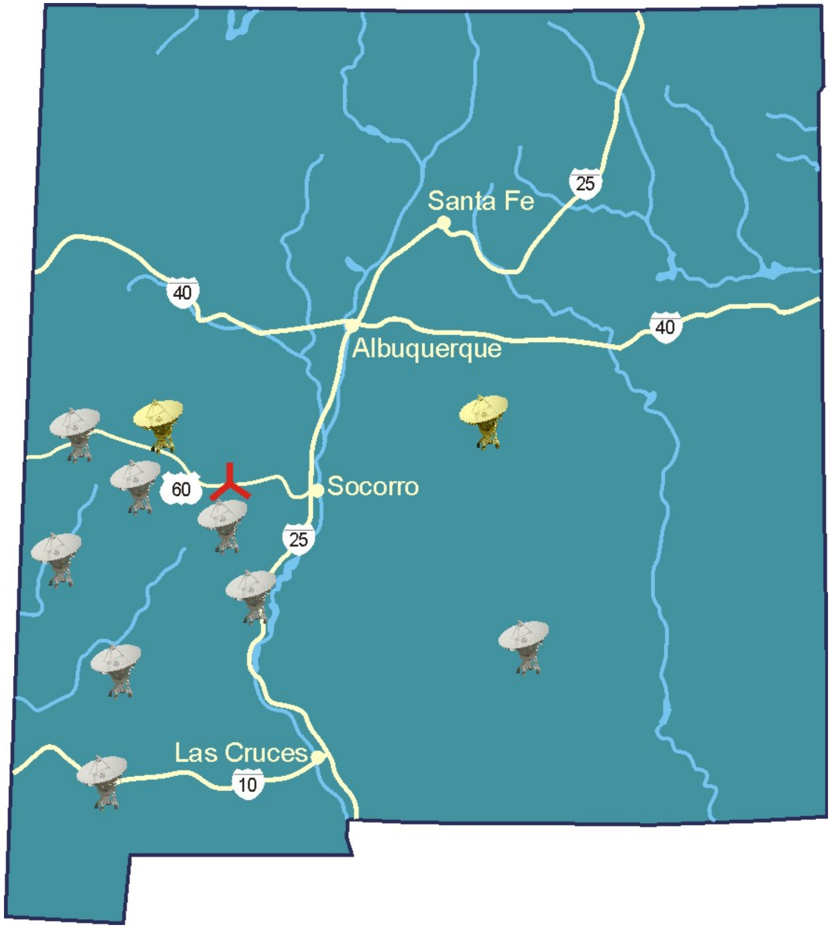
- Highest resolution in any waveband of the earliest galaxies – even back to z~30, should such galaxies exist
- Resolve central regions of galaxies and quasars, to understand the environments of relativistic jets at all cosmic epochs.
- Measure density structures in clusters of galaxies on scales of 50 kpc at any redshift.
- Resolve the dusty cores of galaxies, to distinguish star formation from black hole accretion, and provide an unbiased census of both processes over most of the age of the Universe.
- Resolve the expansion of all galactic novae from one week after explosion, to provide three-dimensional estimates of mass, temperature, and density throughout the expansion phase.
- Provide AU-scale images of massive star formation, to probe the intimate connections between accretion and outflow.

EVLA Phase II Plan

- Phase I (begun 2001, progressing well) provides all the new capabilities **except** the factor of ten resolution improvement.
- Phase II adds new antennas at distances to 250 km from the VLA site to provide the resolution.
  - Eight new antennas, connected by rented optical fiber.
  - Two converted VLBA antennas.
  - Full 16 GHz bandwidth, full-time operation.
  - Same sensitivity and frequency coverage as Phase I (VLA) antennas.
- Phase II also will define a new compact (`E') configuration, to provide low brightness wide-field mosaicing capability.

Location of the Phase II Antennas

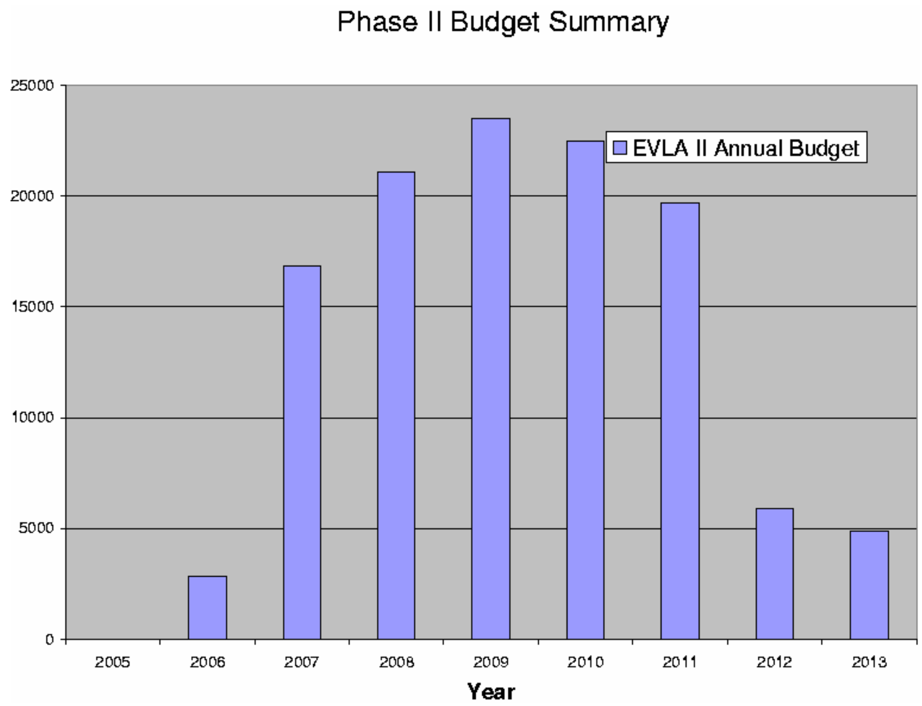
- The Phase II antennas are indicated in white.
- All have nearby access to existing fiber, road, power, on land we believe we can acquire.
- Converted VLBA antennas are in yellow.
- One of these (LA) is shown at its proposed new location.



Phase II Proposal Status

- Proposal was submitted to the NSF on April 15, 2004.
- Total request is for $117M.
- Optimum timescale is 2006 – 2013.

Yearly spending profile is shown in the figure.

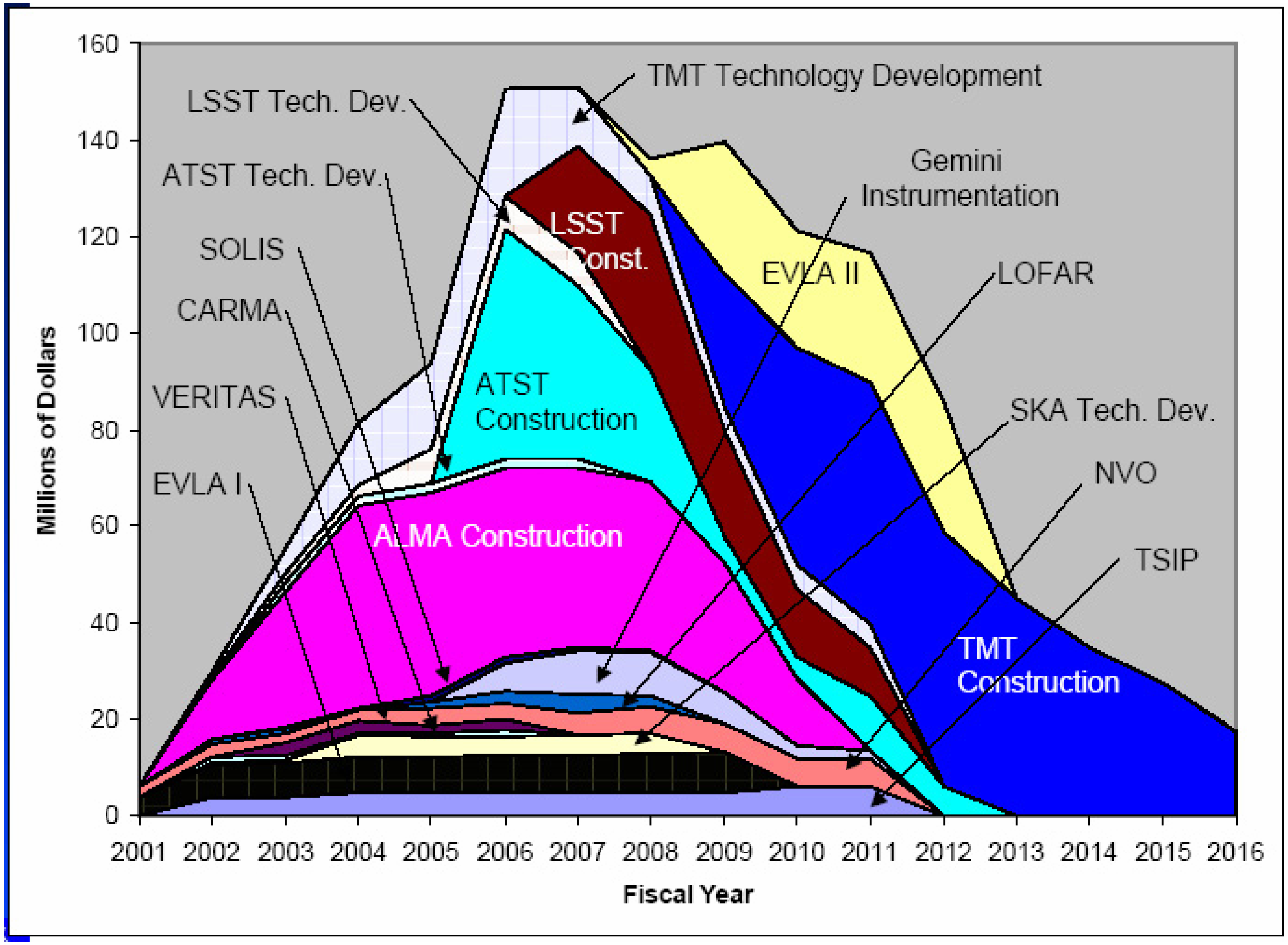


Proposal Status, cont.

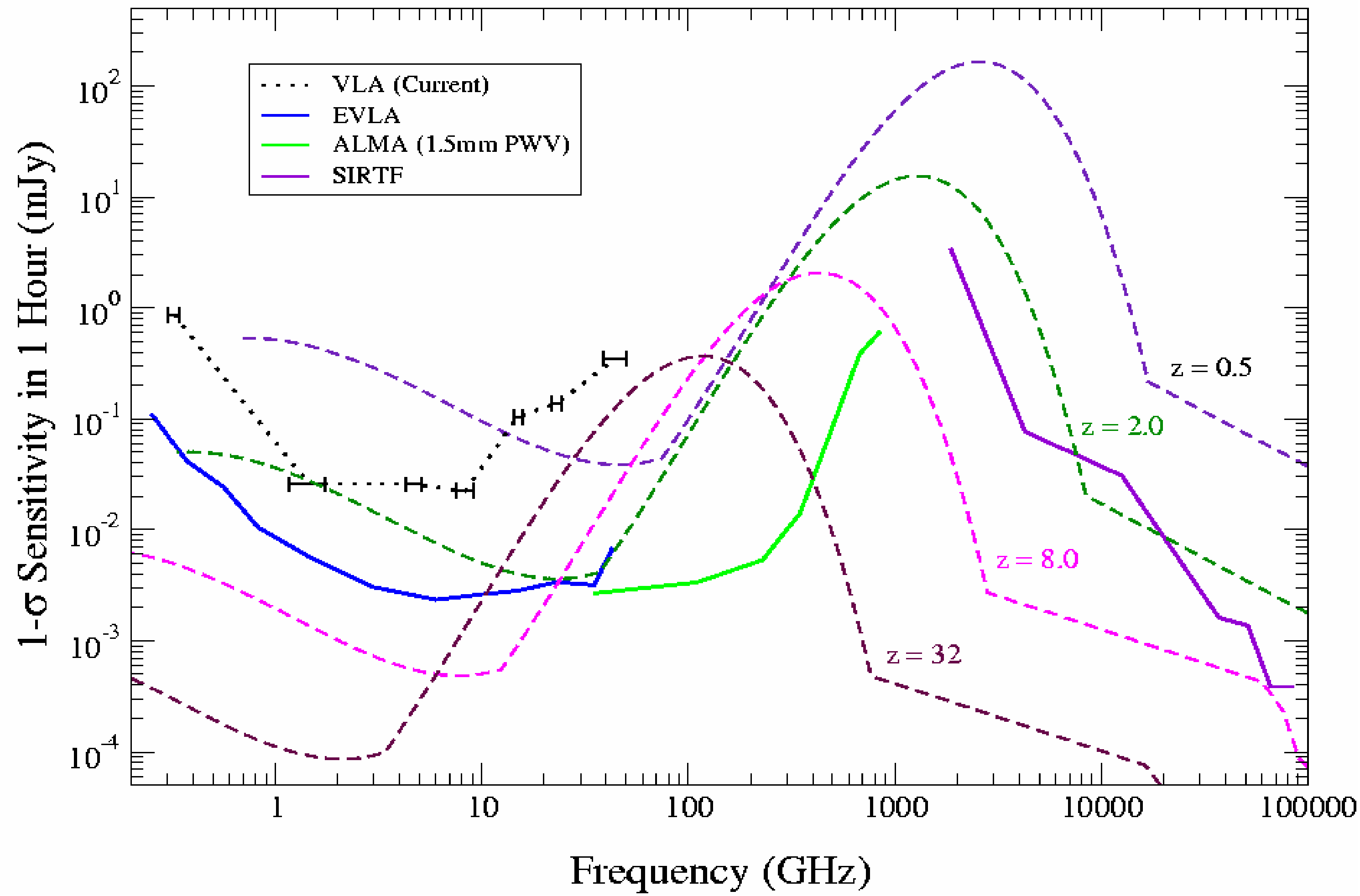
- The NSF sent the proposal out for review in October (6 months after receiving it).
- We were told the reviews would be due in November (but this seems a little short. Probably it's later).
- The next step is a 'site review'. We were told this would be scheduled for Dec. or Jan., but this is clearly not going to happen. We hope for the spring.
- Information from the NSF is very hard to obtain!
- After the site review, (presuming all goes well), we wait for the good news …
- How to best encourage success?
- The good news – Phase II does appear on the NSF's official project list.

The NSF Funding Plan

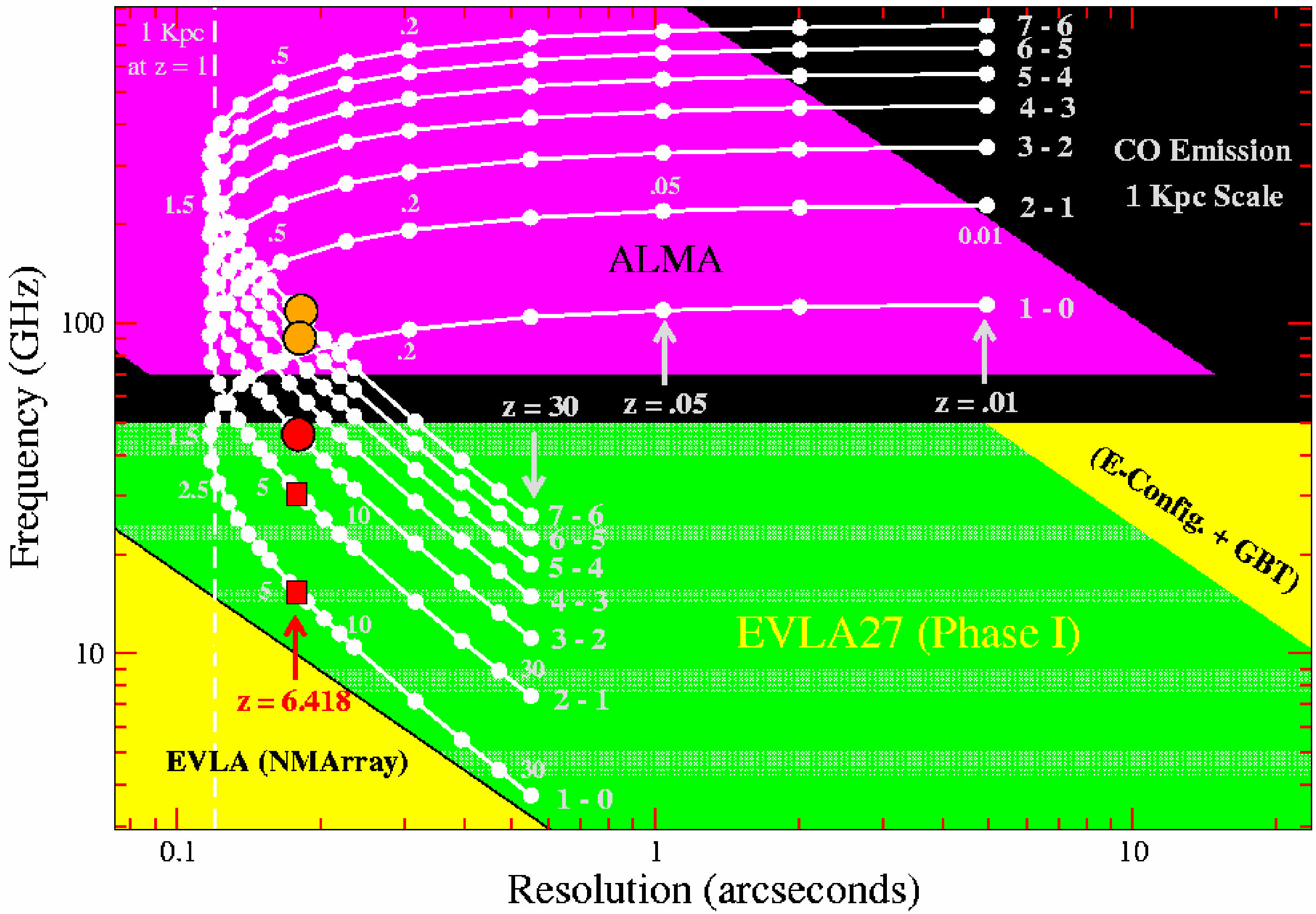
- This shows the published NSF plan for funding major construction projects.
- Phase II shown from 2008 to 2013.



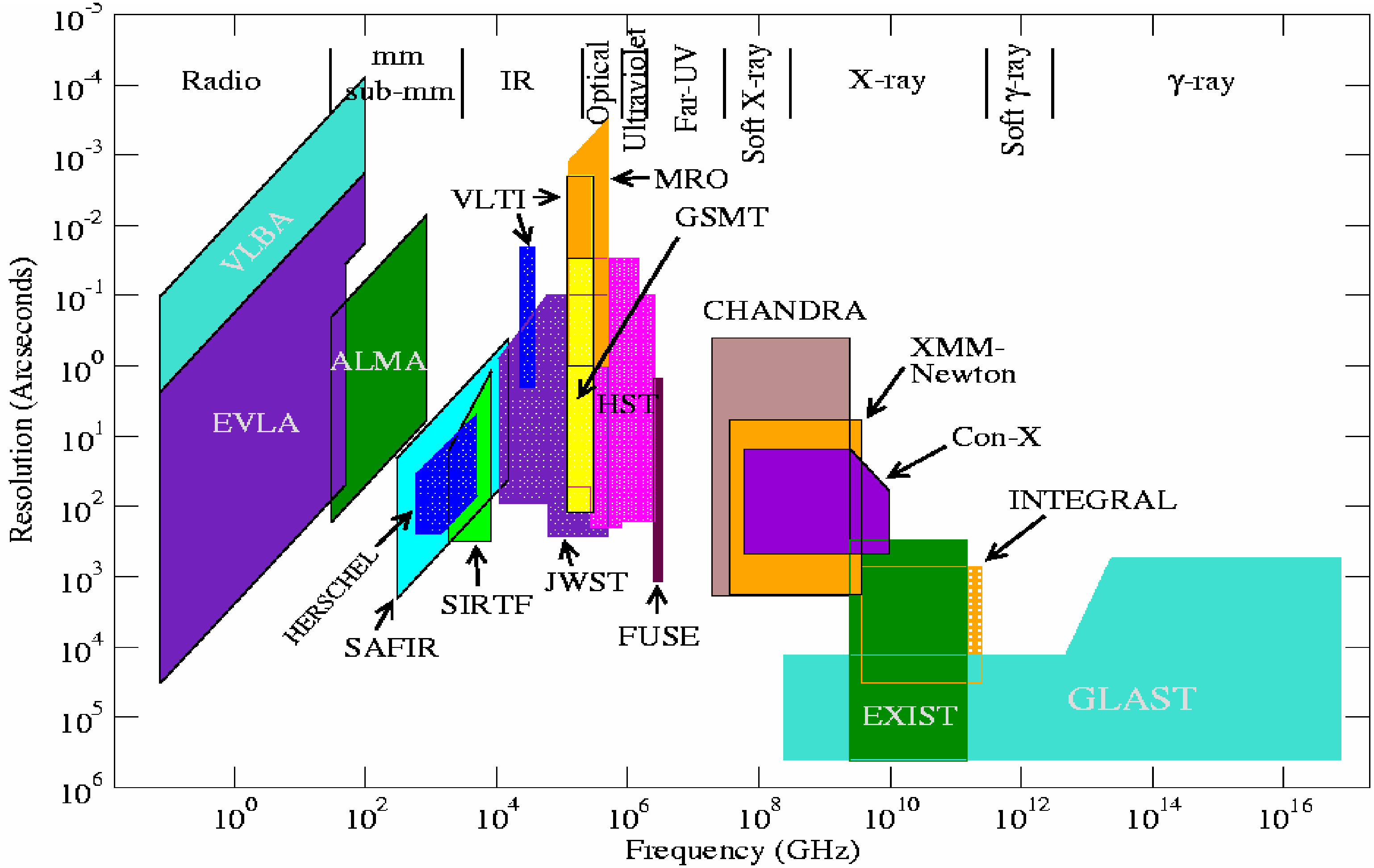
ALMA-EVLA Complementarity



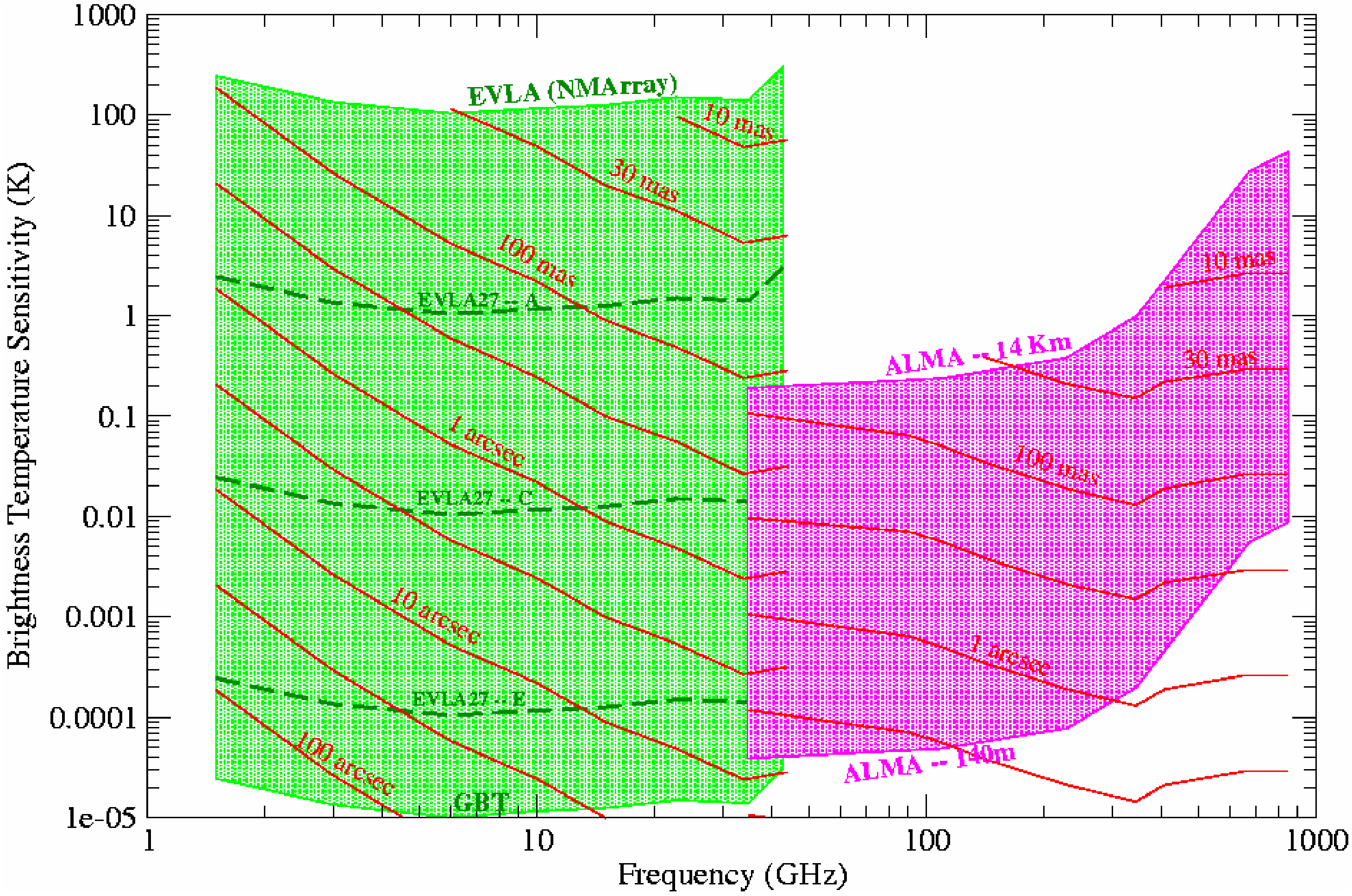
ALMA-EVLA Complementarity (II)



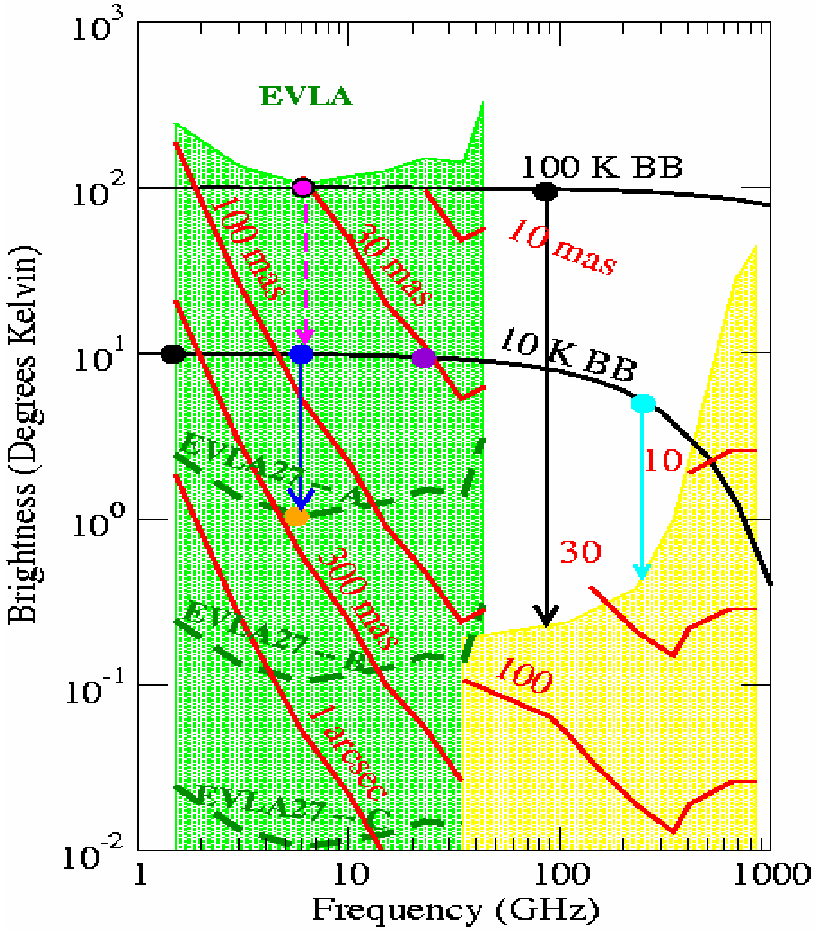
Astronomical Discovery Space

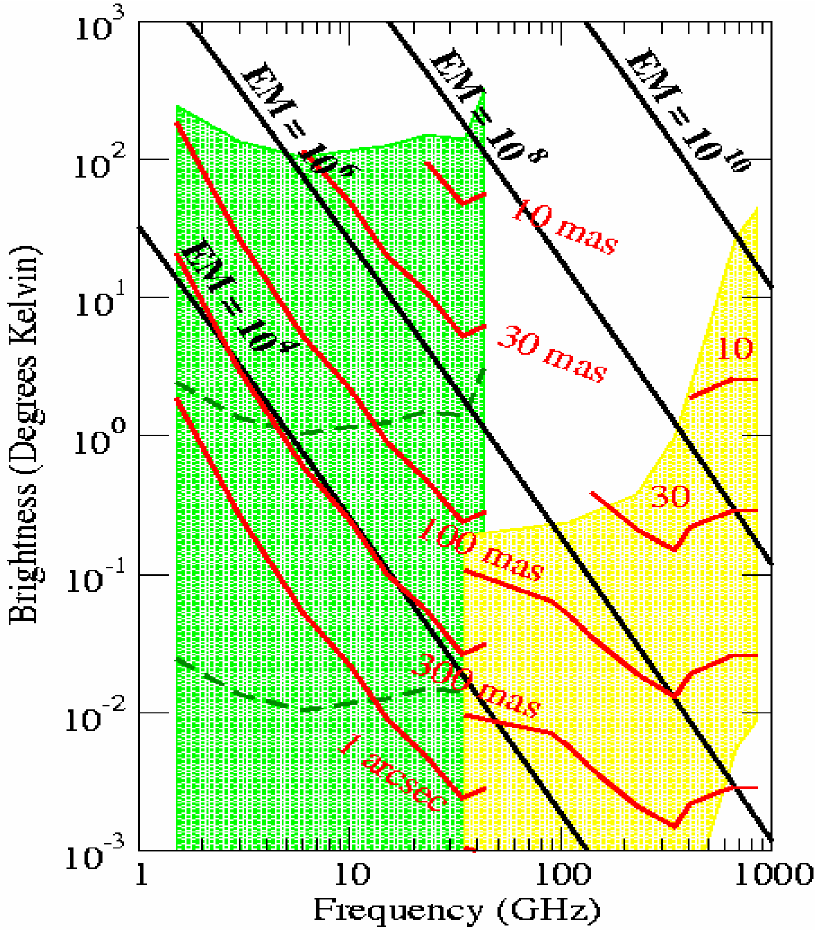


EVLA and ALMA
Surface Brightness Sensitivity



EVLA and ALMA Brightness Sensitivity II





EVLA – Current Status

What’s here now

What’s to come

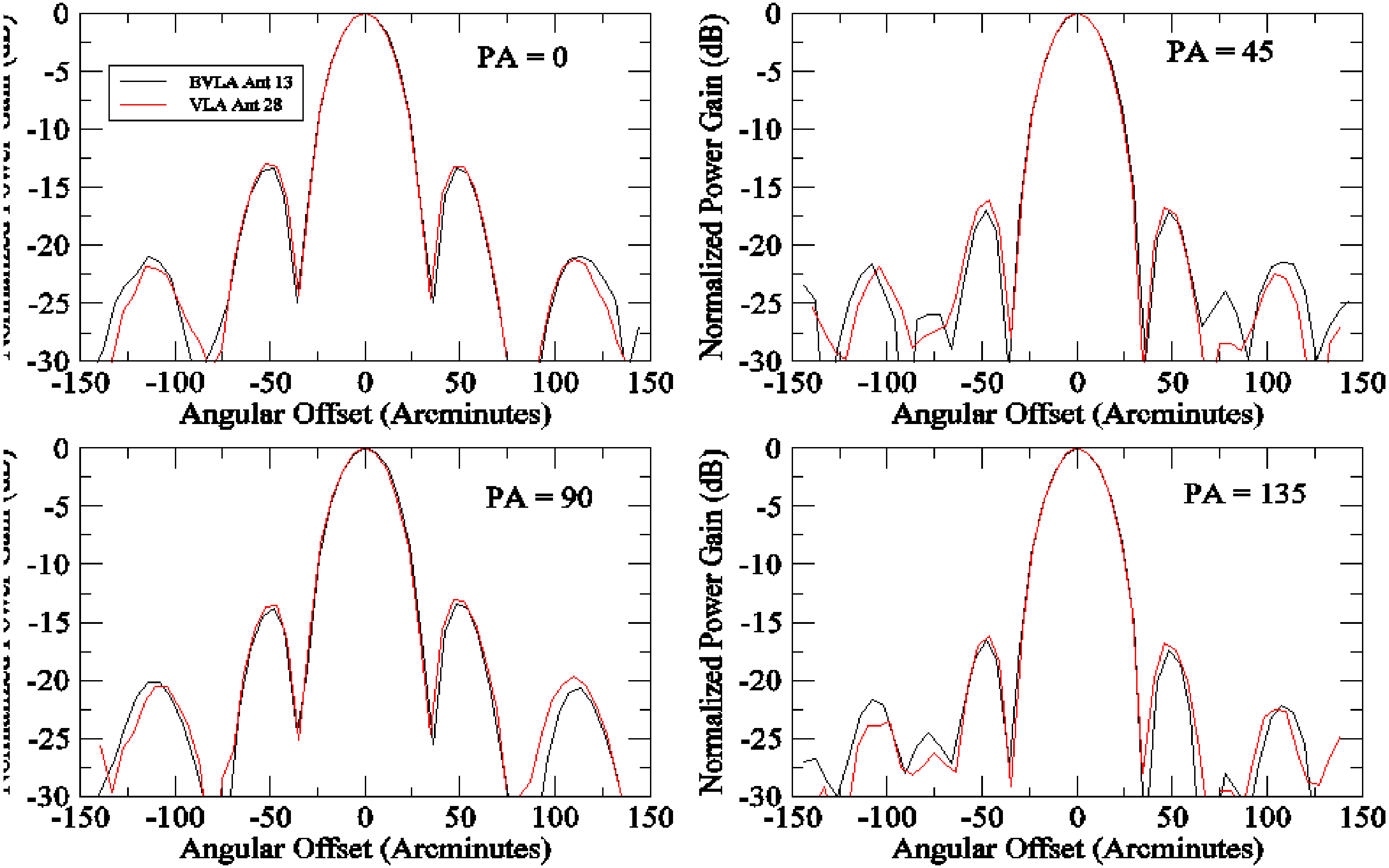
The EVLA L Band System

First L Band feed

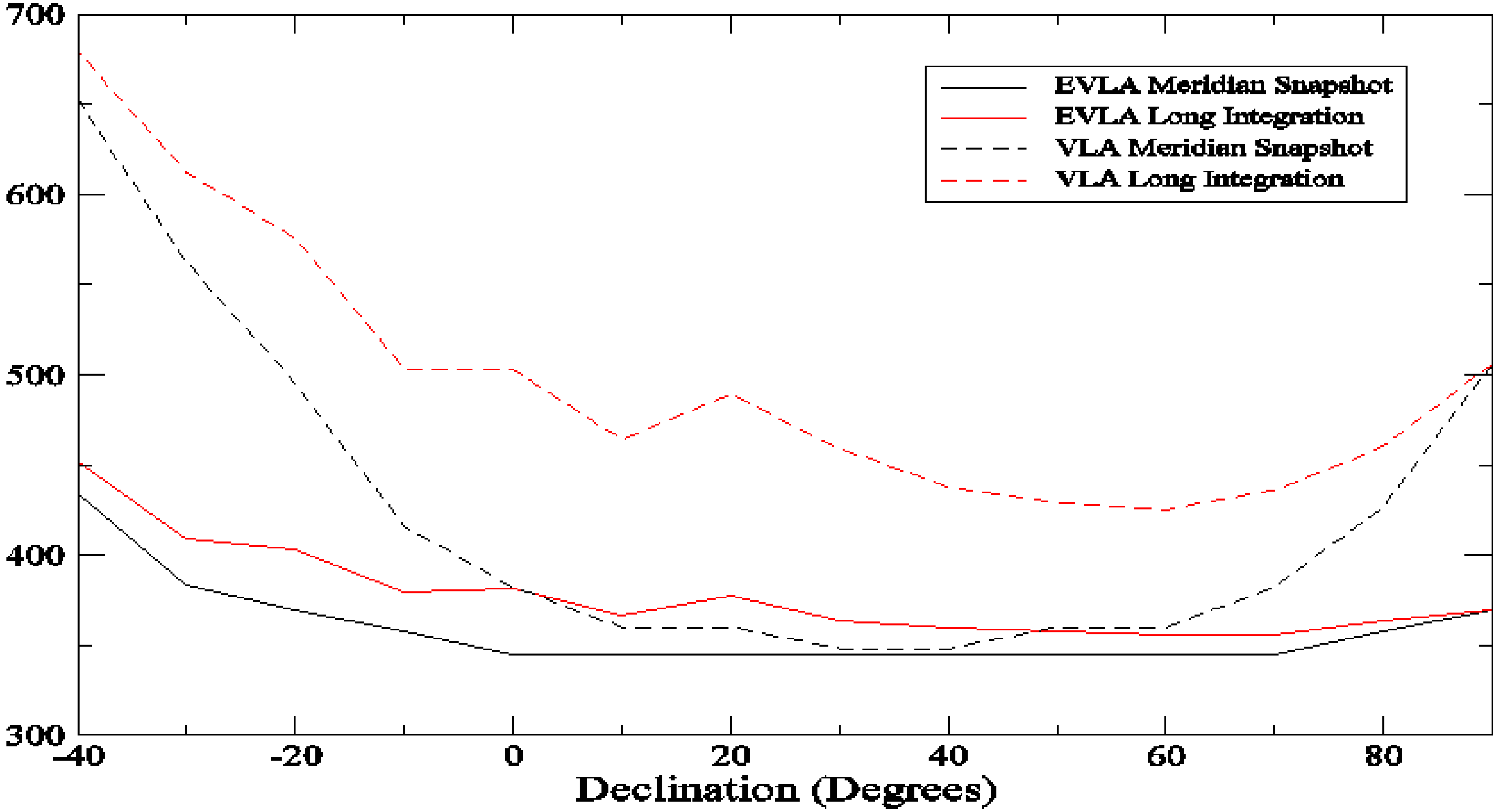
In the shop.

Antenna 13 Showing feeds

Vertex Room

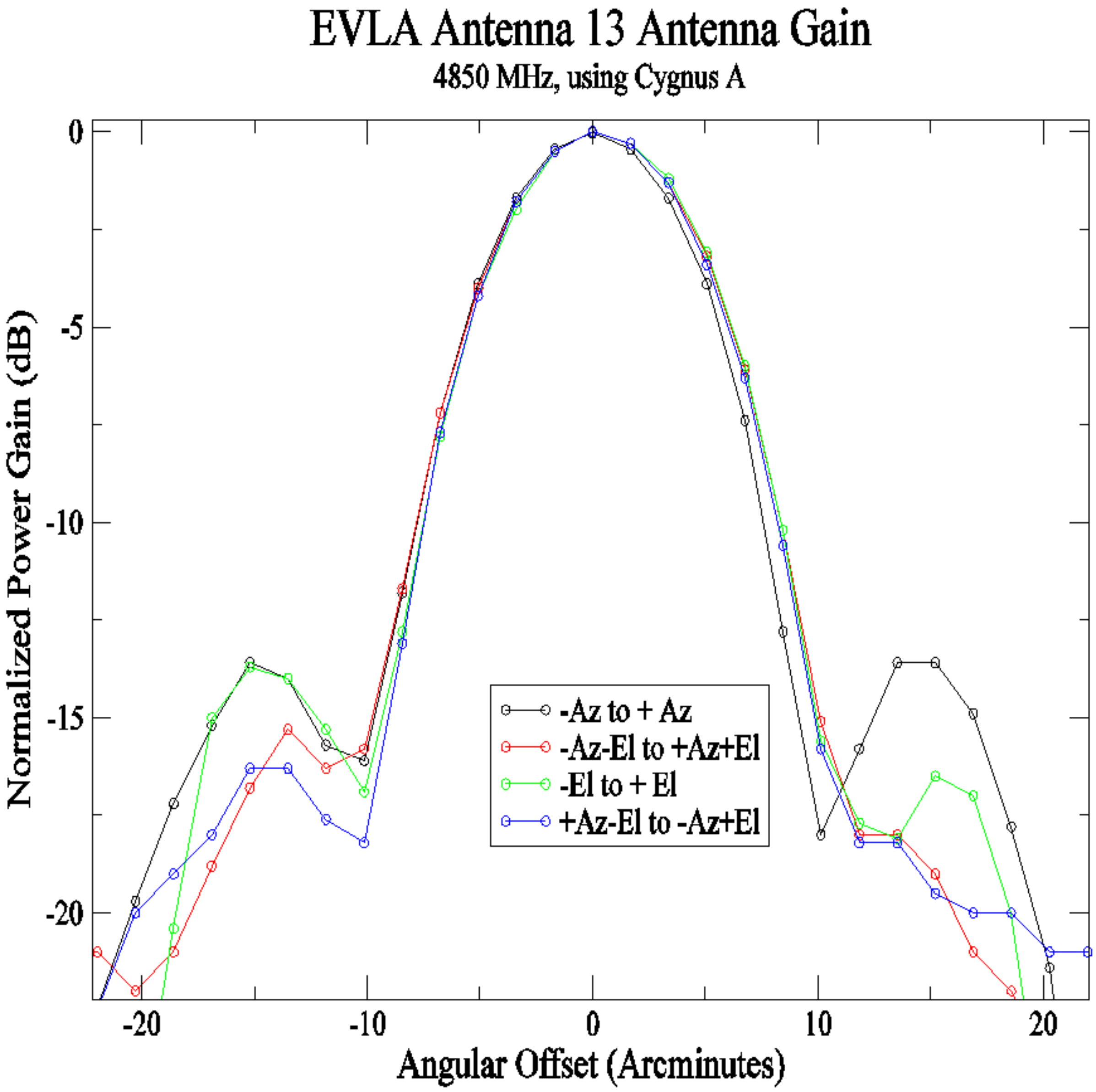


L Band Feed Pattern

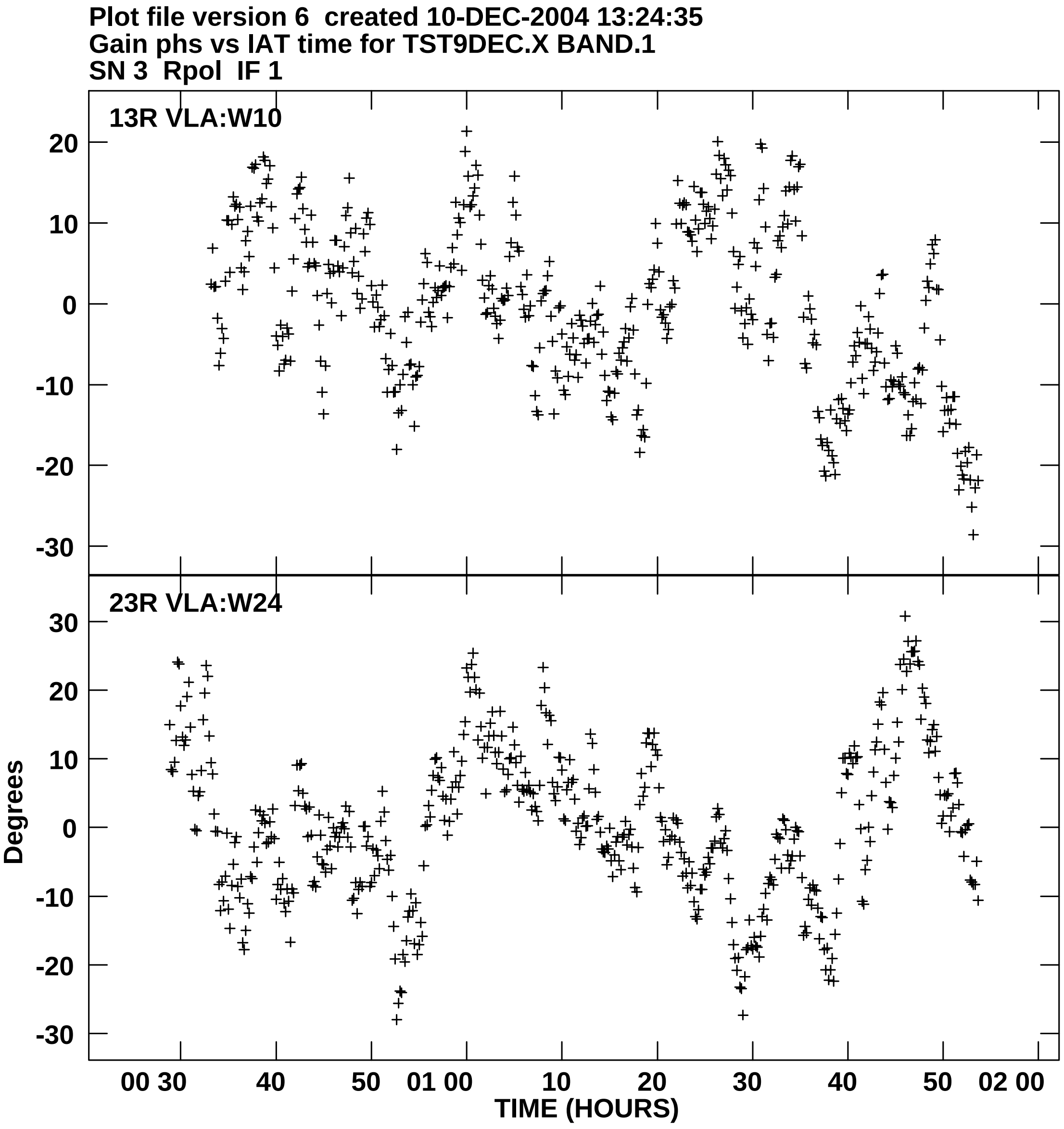


Sensitivity at L band, EVLA feed compared to VLA feed

C Band
feed pattern



Fringe phases at X band, compared to a VLA antenna



EVLA – The WIDAR correlator

- Lots of bandwidth
- Lots of channels
- Lots of flexibility

WIDAR has lots of bandwidth

- At the high bands (X band and higher) 16GHz are correlated (8GHz in each polarization).
- This is 80 times the bandwidth processed by the current VLA correlator.
- At this bandwidth, in full polarization mode, there are up to 4096 full stokes frequency channels with bandwidths as small as 2 MHz.

WIDAR has lots of channels for continuum

- To map the full beam at 15 GHz, you need channel width of 6MHz. WIDAR offers 2MHz
- At 6 GHz, you need channel width of 2.5MHz. WIDAR offers 1MHz.
- At 3 GHz, you need 1.2MHz, WIDAR gives 0.5MHz
- At 1.5 GHz, you need 600kHz, WIDAR gives 125 kHz

WIDAR has lots of channels for HI

- For external galaxies, channel widths of 3km/s (16kHz) are appropriate. In stokes I WIDAR will cover 3000 km/s.
- For absorption lines, channel widths of 0.2km/s (1kHz) are appropriate. In full polarization, WIDAR will cover 150 km/s.
- For HI searches with 25km/s channels, WIDAR will cover 24000 km/s.

For redshifted CO, WIDAR has reasonable coverage.

- In stokes I at 43 GHz, WIDAR offers 7km/s channel widths covering 50,000km/s.

WIDAR is flexible

- It supports easy swapping of spectral resolution for bandwidth.
- It supports full polarization processing, and also stokes I processing (for additional channels).
- It supports pulsar phase binning.
- It supports very narrow channels for special processing (radar mode).
- It support different combinations of resolution and bandwidth for different parts of the spectrum

WIDAR is coming

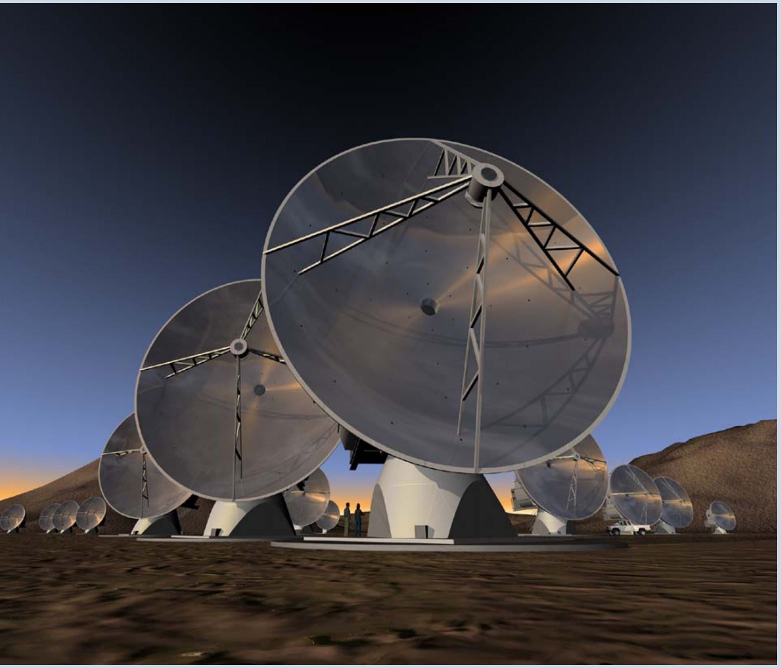
- Prototype device for test, May 2006
- Partial installation, scientific usefulness, July 2008
- Commissioning complete, May 2009

ALMA

ALMA = Atacama Large Millimeter Array

North America/Europe/Japan

Operational 2012 (Early Science in 2007)



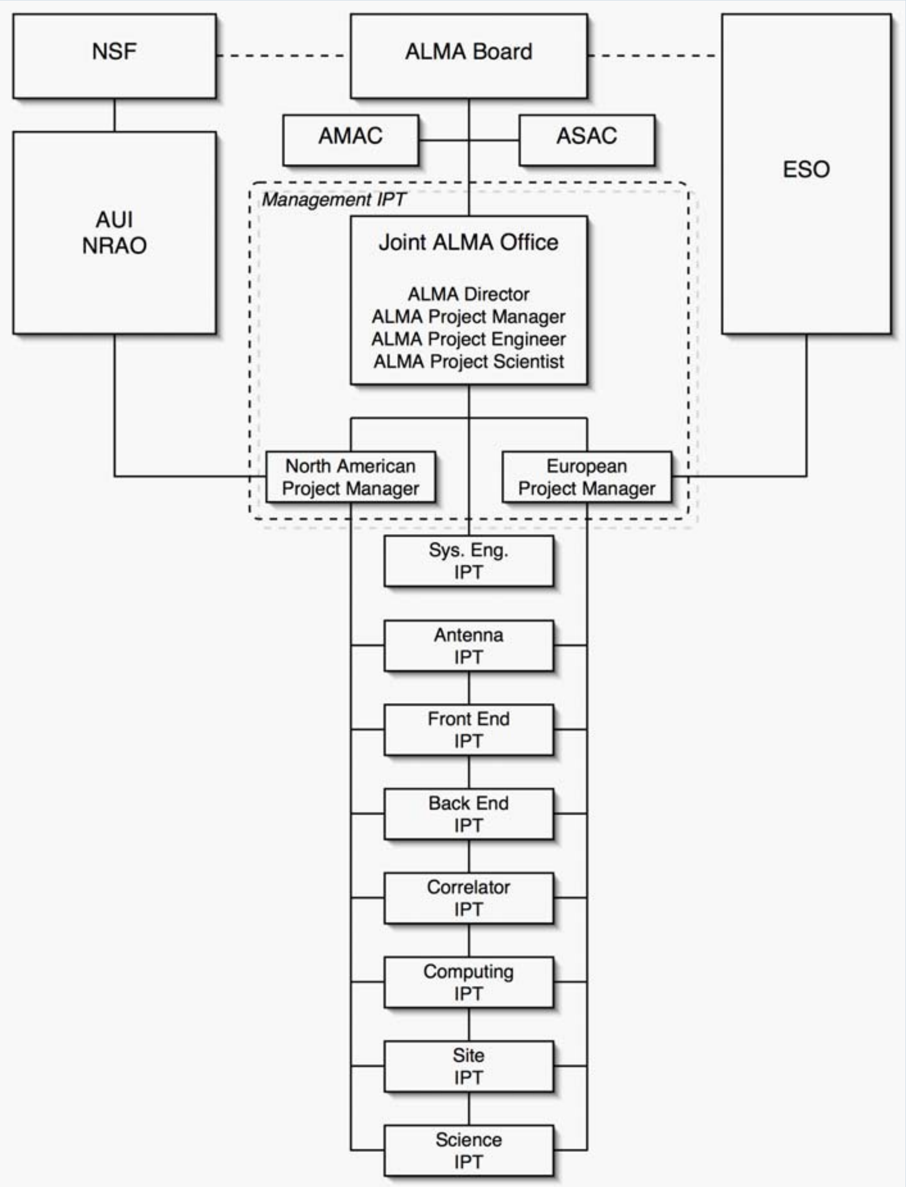
64 × 12-m telescopes at 5000m

+ ACA: 12 × 7-m + 4 × 12-m + 3 additional frequency bands

Level 1 Science Goals

- Image Milky Way-like galaxies out to z ~ 3 in 24 hours
- Image and resolve proto-planetary disks
- Provide 0.1” images in mm/submm wavelength range

ALMA Project Organization



ALMA Board

(Meets face-to face 3 times a year, telecons monthly)

- Bob Dickman (NSF)
- Jim Hesser (NRC)
- K. Y. Lo (NRAO)
- A. Sargent (Caltech)
- Piet van der Kruit (ESO)
- Catherine Cesarsky (ESO)
- Richard Wade (PPARC, UK)
- Roy Booth (Onsala)

ASAC

5 (NA) + 5 (EU) + 3 (J) + 1(C) + 2 (PS)

Meets 3 times a year + telecons

Chris Carilli	(NRAO)
Pierre Cox	(IRAM)
Yasuo Fukui	(Nagoya)
Diego Mardones	(U Chile)
Munetake Momose	(Ibaraki)
Lee Mundy	(Maryland)
Phil Myers	(CfA)
John Richer	(Cambridge)
Peter Schilke, Chair	(MPIfR)
Leonardo Testi	(Arcetri)
Jean Turner, Vice Chair	(UCLA)
Ewine van Dishoeck	(Leiden)
Christine Wilson	(McMaster)
Thomas L. Wilson , *ex officio*	(ESO)
Al Wootten, *ex officio*	(NRAO)
Satoshi Yamamoto	(Tokyo)

$\Rightarrow$ ANASAC

ALMA Management Advisory Committee

(Meets 3 times a year)

• Gary Sanders, Chair	(TMT)
• Gordon Chin	(Goddard)
• Janet Fender	(Langley)
• *Dominick Tenerilli*	*(Lockheed Martin)*
• Robert Wilson	(CfA)
• Robert Aymar	(CERN)
• Sergio Bertini	(INTEMA, Italy)
• Jesus Sanchez Minana	(ETS, Spain)
• Joachim Truemper (MPE)	
• Arnold can Ardenne	(ASTRON)

Joint ALMA Office
Based in Chile

• Director:	Massimo Tarenghi
• Project Manager:	Tony Beasley
• Project Engineer:	Rick Murowinski
• Project Scientist:	*Vacant*
• Project Controller:	Richard Simon (interim)
• Logistics Officer:	Charlotte Hermant

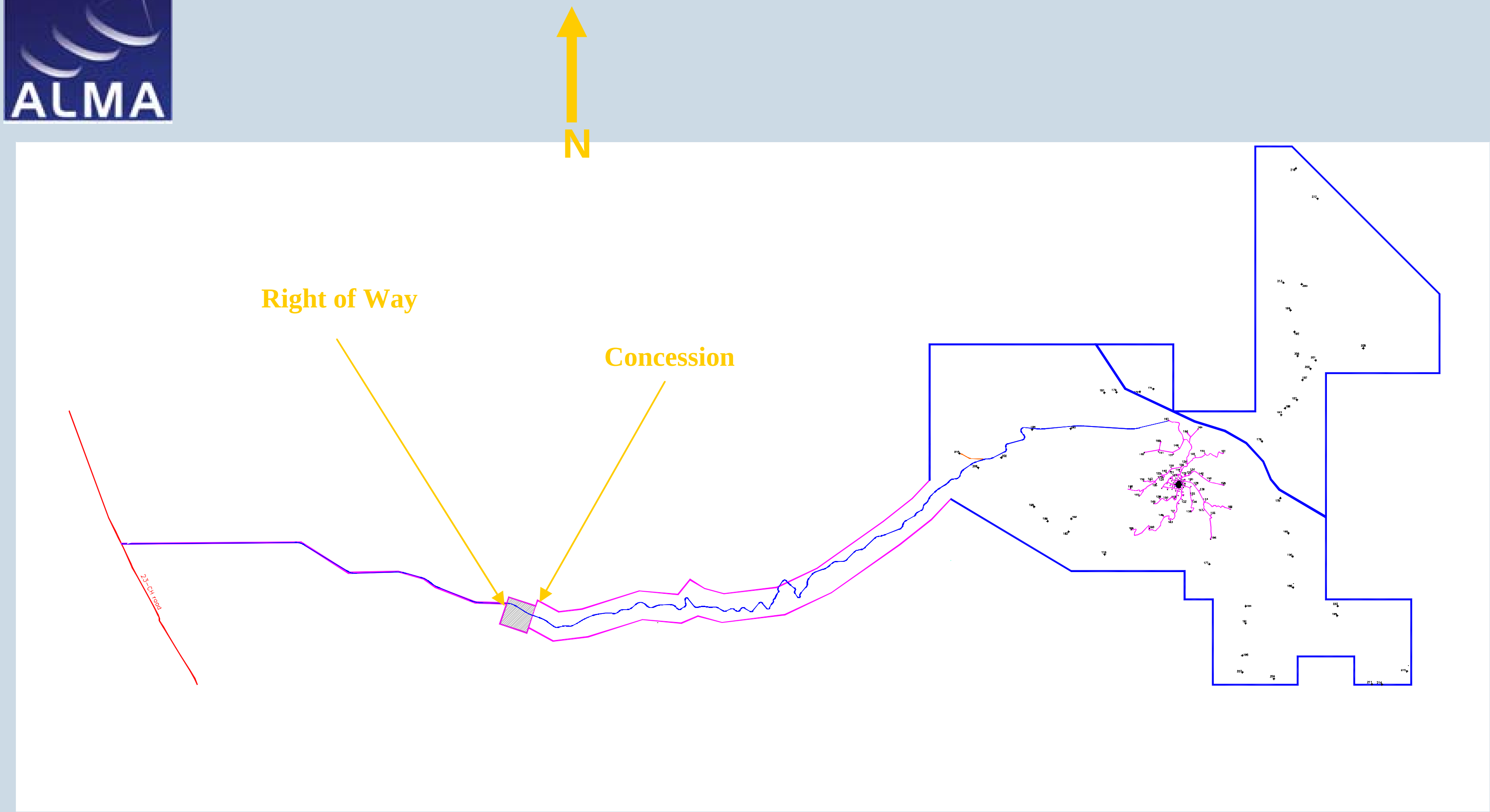
NA ALMA Project Office

- Project Manager: Lo (Interim), Adrian Russell (6Jan05)
- Deputy PM: Marc Rafal
- Business Manager: Bill Porter
- Controller: David Hubbard (Interim)
- Accountant: Janet Lychock
- Scheduler: Vacant
- Administrative Assistant: Jennifer Neighbours

NA IPT Leads

- Science: A. Wootten
- SE/SI: Dick Sramek
- Site: Eduardo Donoso
- Antenna: Victor Gasho
- Front End: John Webber
- Back End: Clint Janes
- Correlator: John Webber
- Computing: Brian Glendenning
- *AUI/NRAO Chilean Operations: Eduardo Hardy*

ALMA Site



View from Highway CH23

View from 18km

42 km of road: CH23-OSF-AOS

View West

View East

ALMA Camp

Inner Court

ALMA Camp – General View

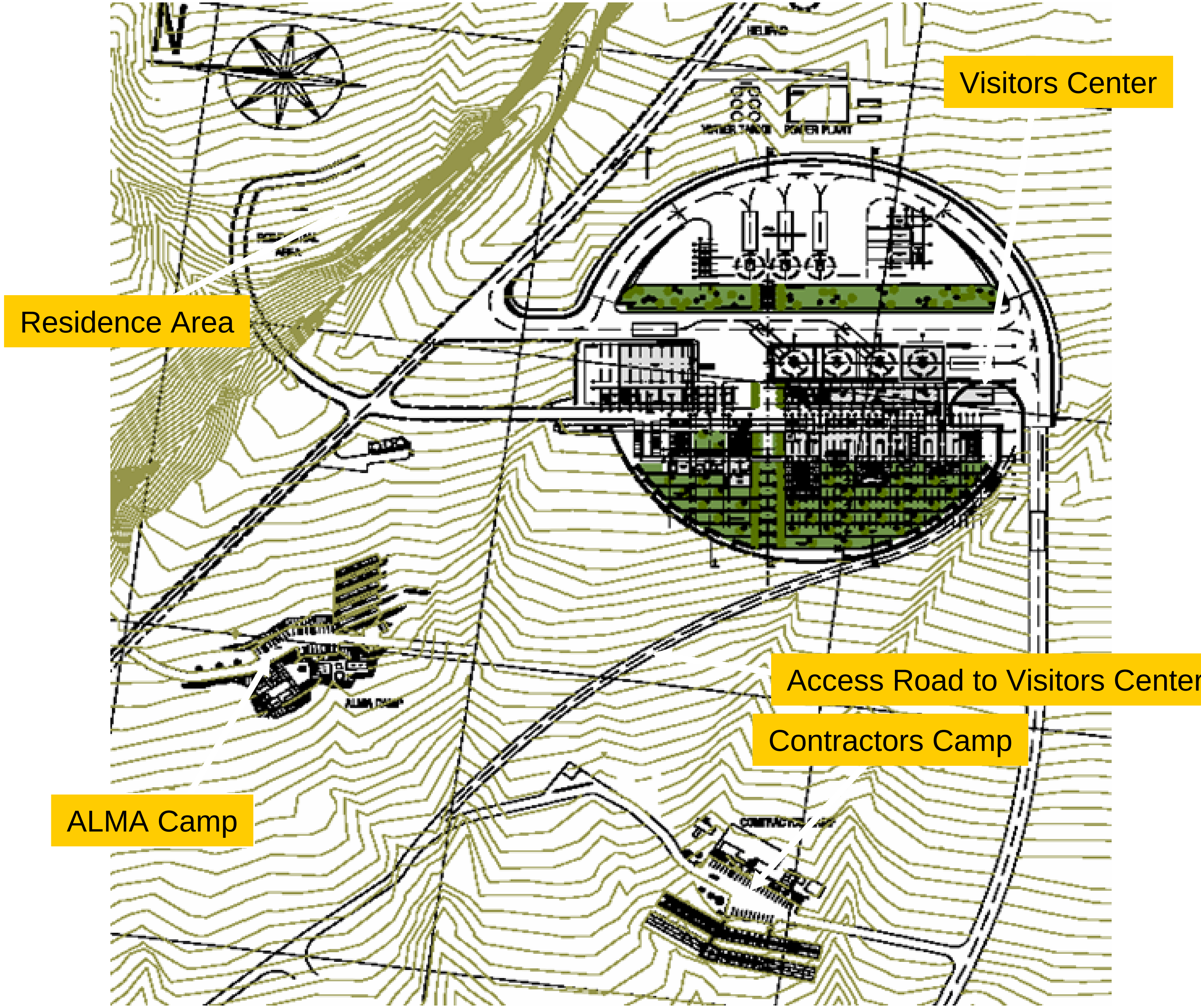
Typical Office

ALMA Board Meeting

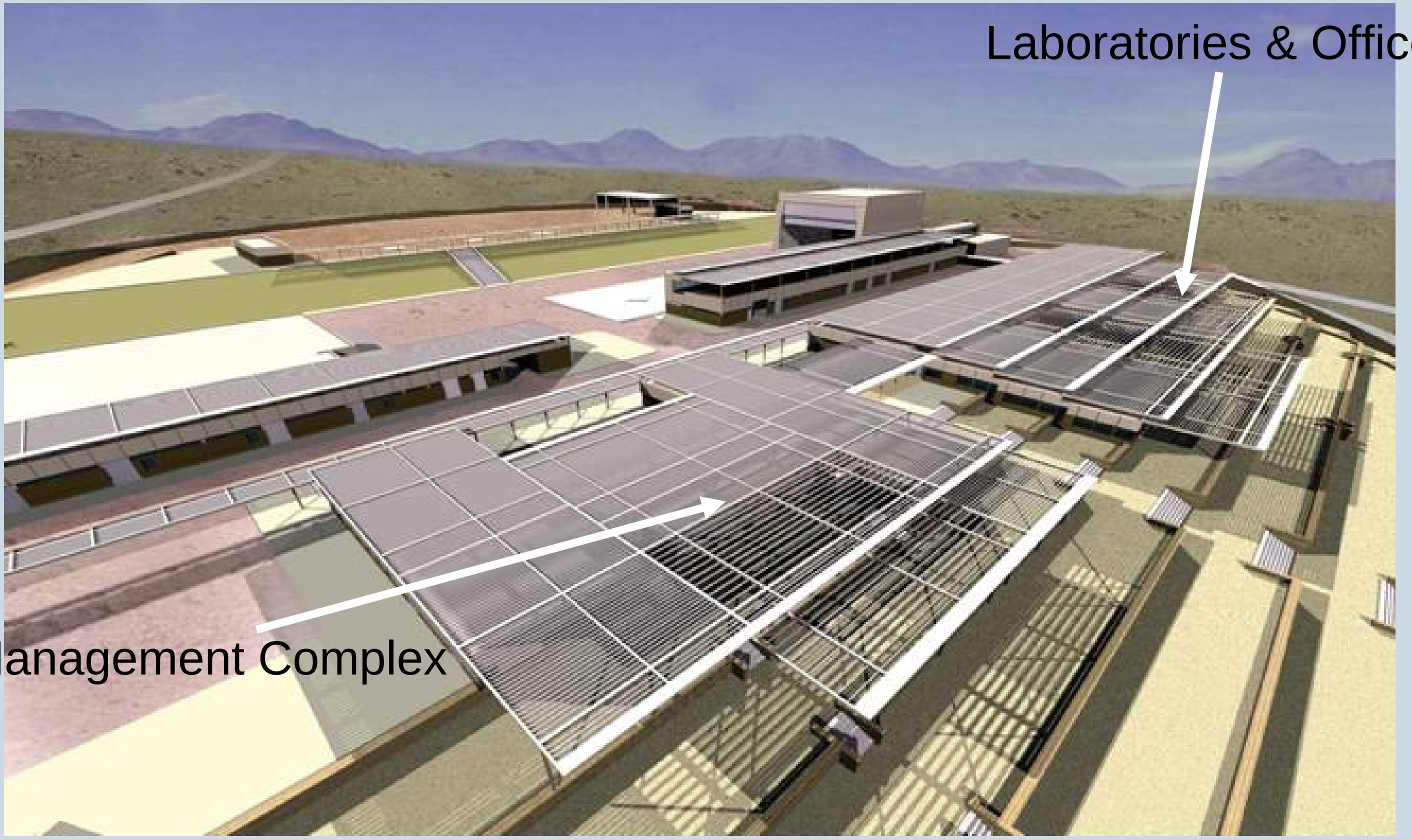
2-3 November 2004

Dining Room

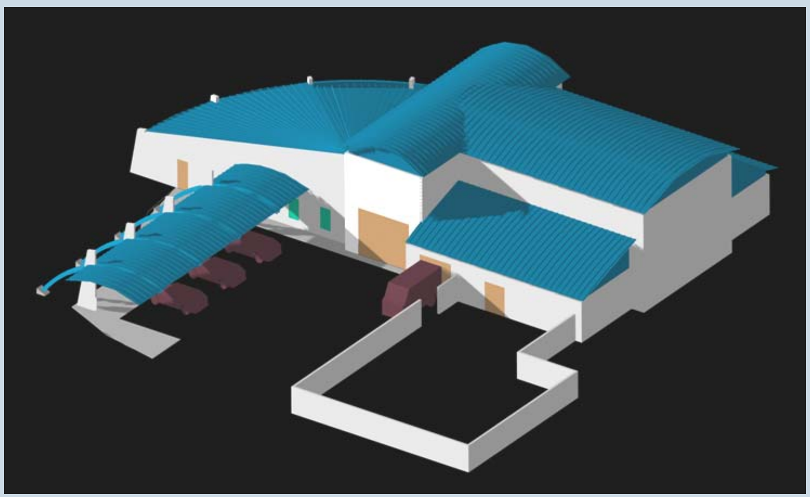
OSF Camps and Technical Facilities

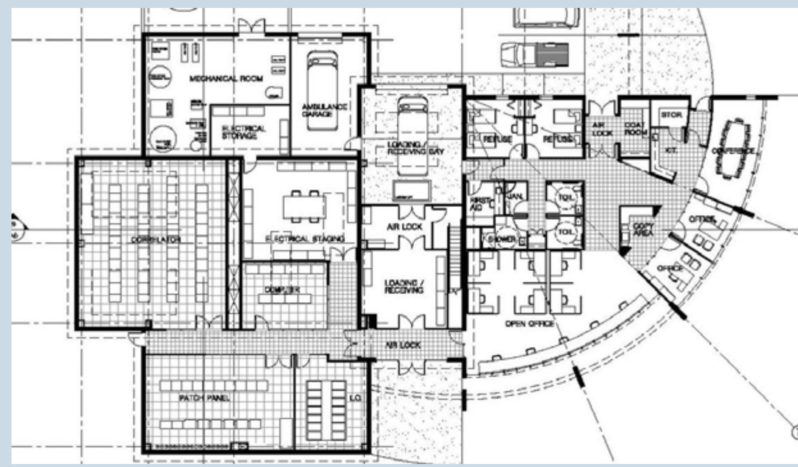


OSF Technical Facilities



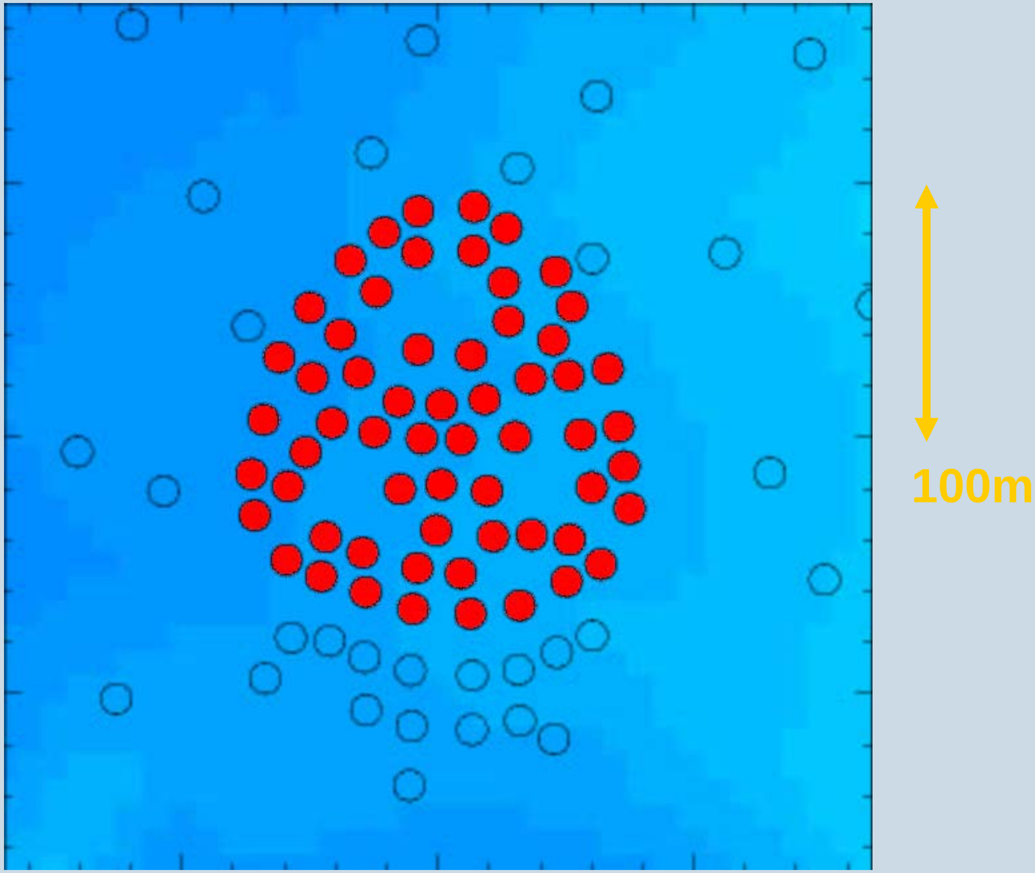
AOS Technical Building

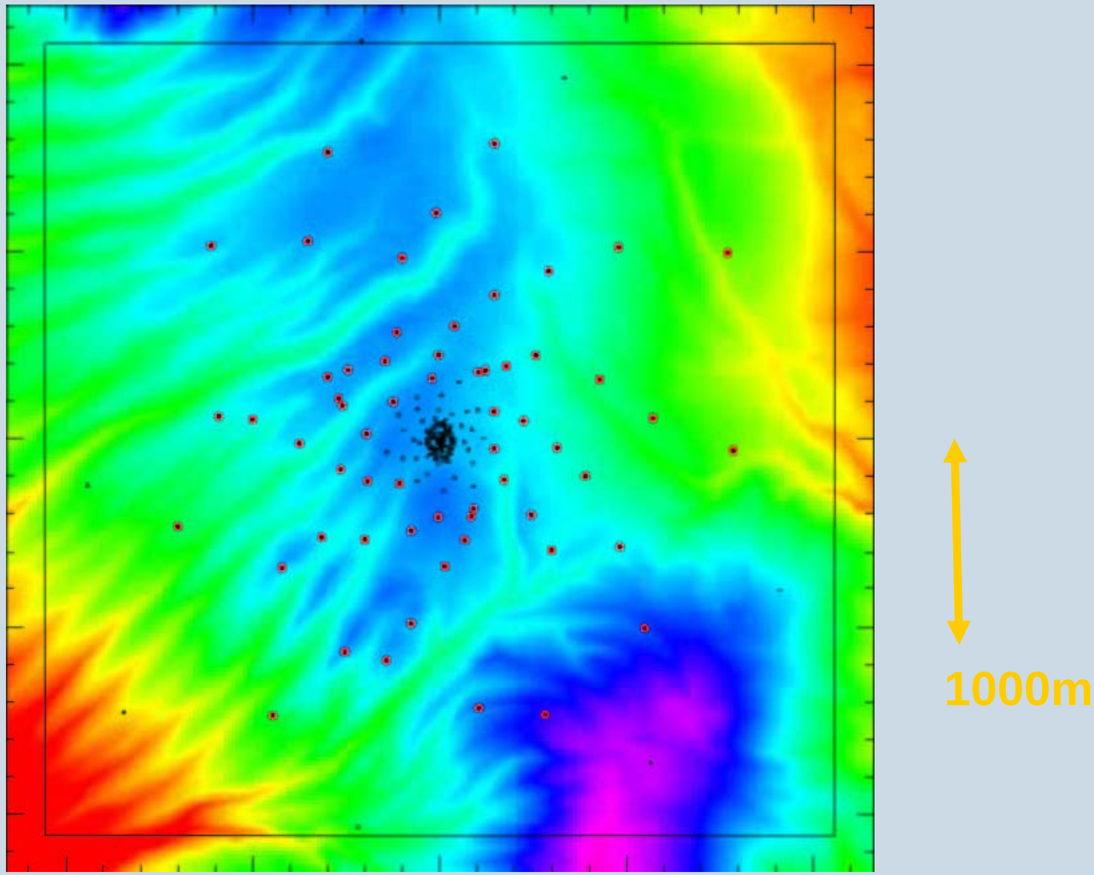


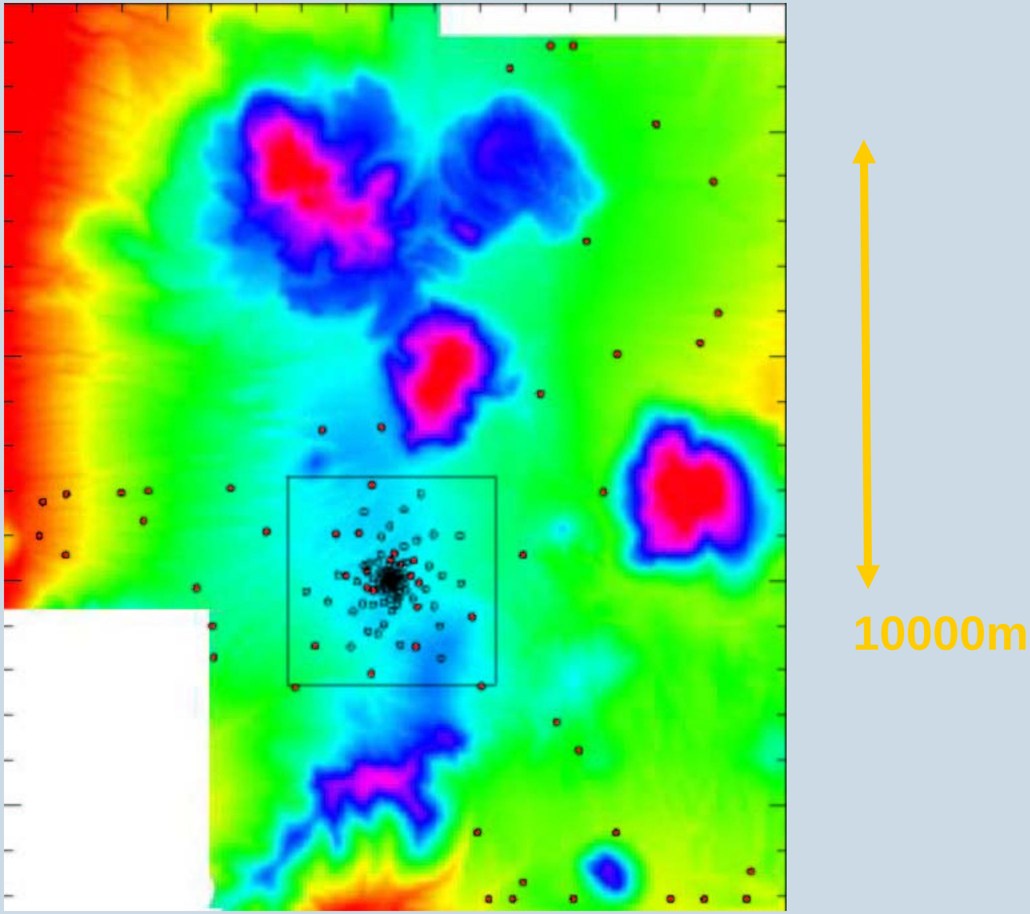


Configurations

The compact array: as densely packed as possible, with minimal shadowing and still allowing all antennas to be accessed by the transporter.




1000m


10000m

Antennas

Mitsubishi **Vertex** **AEC**

Prototypes Design Characteristics

VertexRSI

- 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

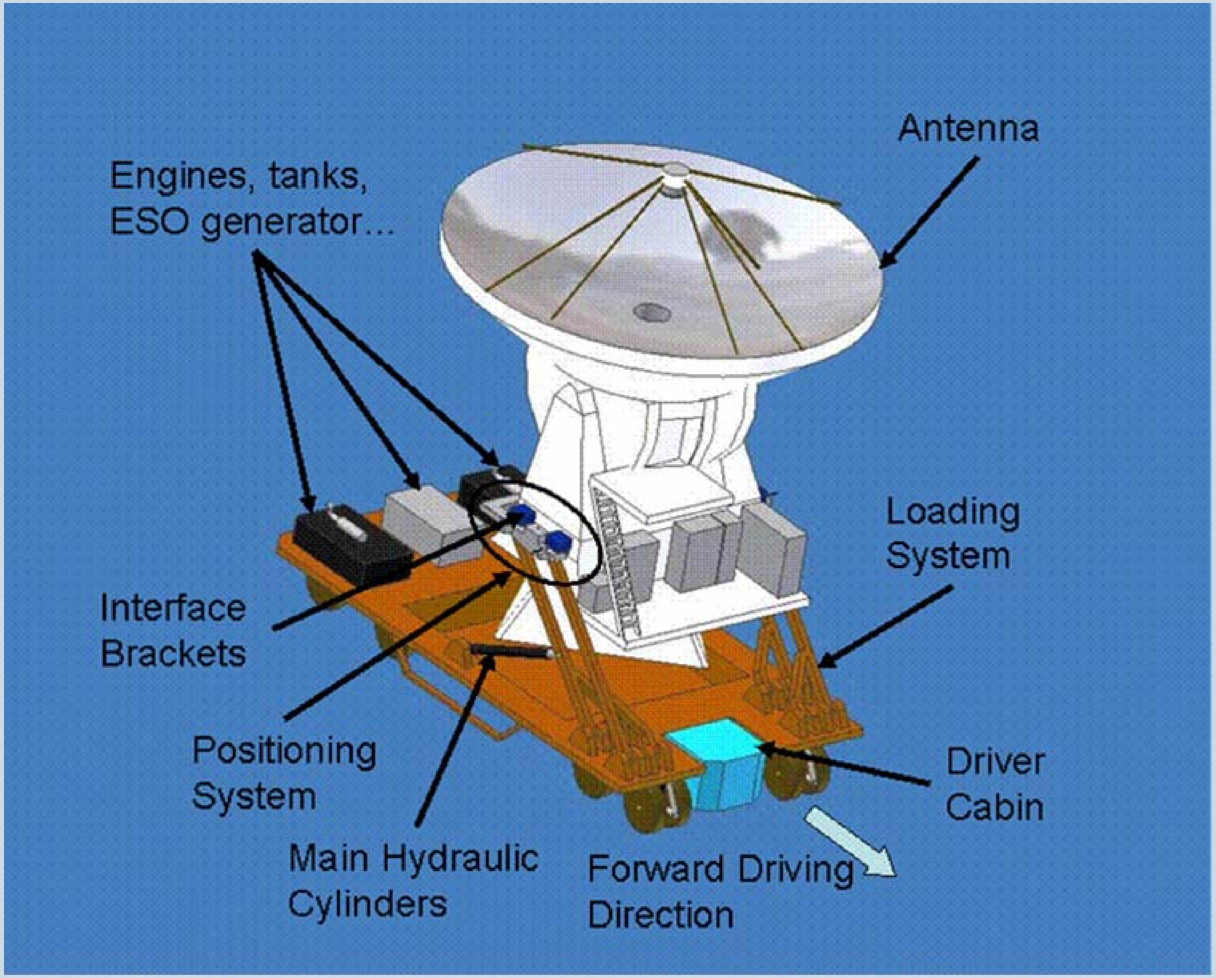
ALCATEL/EIE

- 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

AEG "Core" members		***AEG other contributors***	
Jeff Mangum (leader)	**NRAO**	**José Lopez-Perez**	**OAN,**
		Alcala de Henares	**ES**
Jaap Baars (deputy)	**ESO**	**Henry Matthews**	**HIA**
Albert Greve	**IRAM**	**Angel Otárola**	**ESO**
Robert Lucas	**IRAM**	**David Smith**	**MERLAB**
Ralph Snel	**Univ. of Lund**	**Michael Bremer**	**IRAM**
Pat Wallace	**RAL (UK)**	**Mark Holdaway**	**NRAO**

- Delays in the delivery of the two prototypes plus limitations of the site, affected the work of the AEG. Nevertheless, the AEG managed to collect a reasonable set of data for the evaluation program.
- The test results of the two prototypes indicate the feasibility of the specification for the production antenna.
- Further evaluation underway.


Antenna
Engines, tanks,
ESO generator…
Loading
System
Interface
Brackets
Positioning
System
Driver
Cabin
Main Hydraulic
Cylinders
Forward Driving
Direction

Front Ends

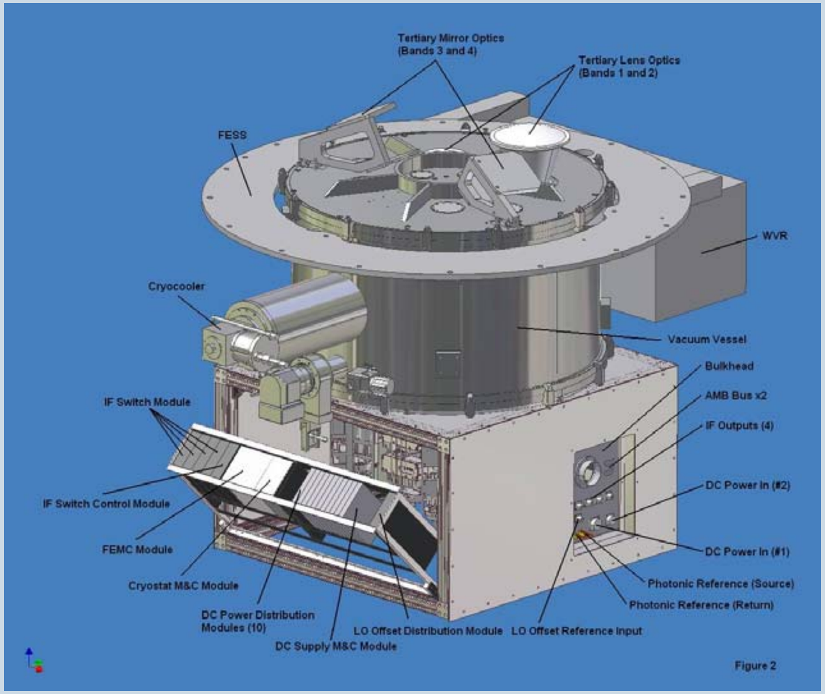
ALMA Band	Frequency Range	Receiver noise temperature T_{Rx} over 80% of the RF band	 T_{Rx} at any RF frequency	Mixing scheme	Receiver technology
1	31.3 – 45 GHz	17 K	28 K	USB	HEMT
2	67 – 90 GHz	30 K	50 K	LSB	HEMT
3	84 – 116 GHz	37 K	62 K	2SB	SIS
4	125 – 169 GHz	51 K	85 K	2SB	SIS
5	163 - 211 GHz	65 K	108 K	2SB	SIS
6	211 – 275 GHz	83 K	138 K	2SB	SIS
7	275 – 373 GHz*	147 K	221 K	2SB	SIS
8	385 – 500 GHz	98 K	147 K	DSB	SIS
9	602 – 720 GHz	175 K	263 K	DSB	SIS
10	787 – 950 GHz	230 K	345 K	DSB	SIS

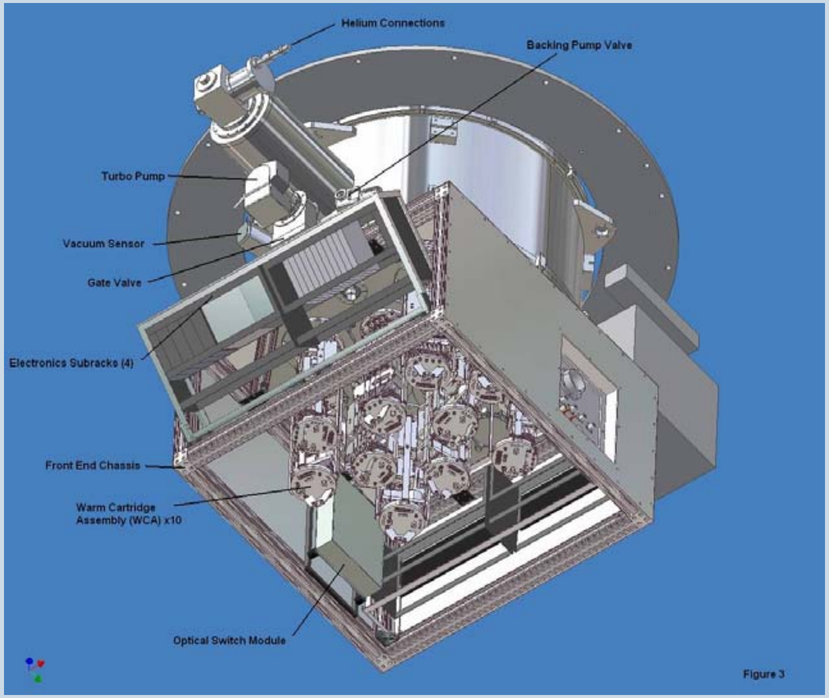
- Dual, linear polarization channels:
  - •Increased sensitivity
  - •Measurement of 4 Stokes parameters

•183 GHz water vapour radiometer:
- •Used for atmospheric path length correction

* - between 370 – 373 GHz T_{rx} is less then 300 K

Front End assembly

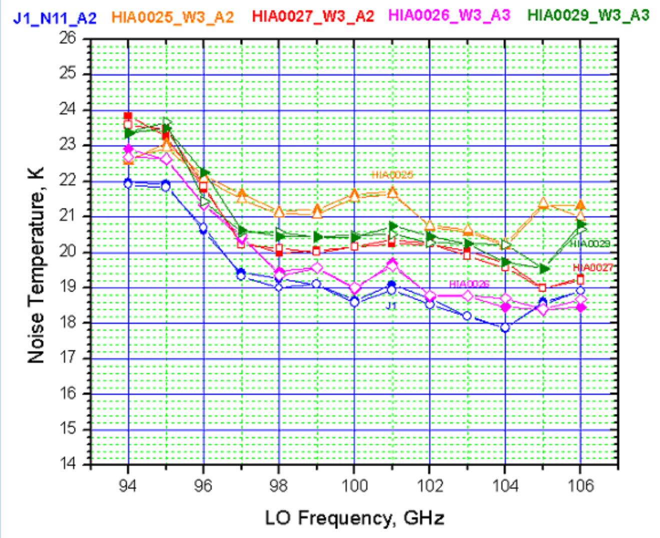




Cryostat - RAL

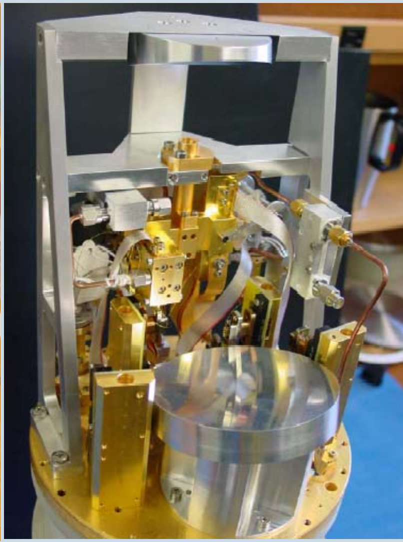
Band 3 Cartridge
84 – 116 GHz

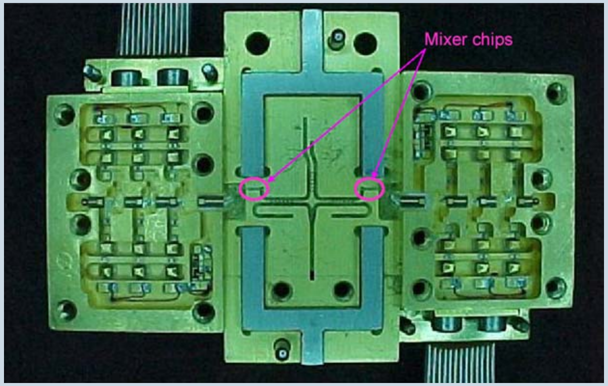
- Mixer development
  - Focus on a 2SB, 4 – 8 GHz IF bandwidth, mixer solution
- Cartridge PDR held March ‘04
- Current status:
  - Complete the construction of the cartridge test set in semi-automatic mode
  - Finalize integration of cartridge #1 with two fully characterized 2SB mixer units and four LNAs.

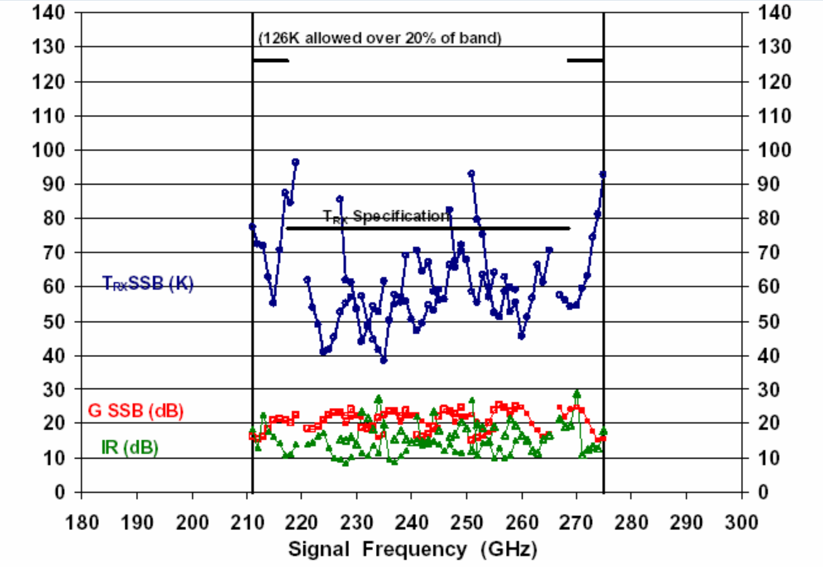


Band 6 Cartridge 211 – 275 GHz

- Mixer development
  - Focus on a 2SB, 4 – 12 GHz IF bandwidth, mixer solution without isolator
- Cartridge PDR held April ‘04
- Current status:
  - Finalize integration of cartridge #1
  - Prepare automated test set up for production

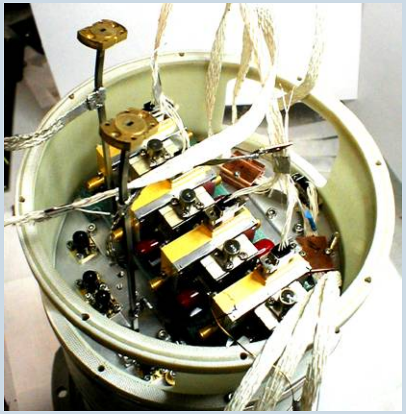


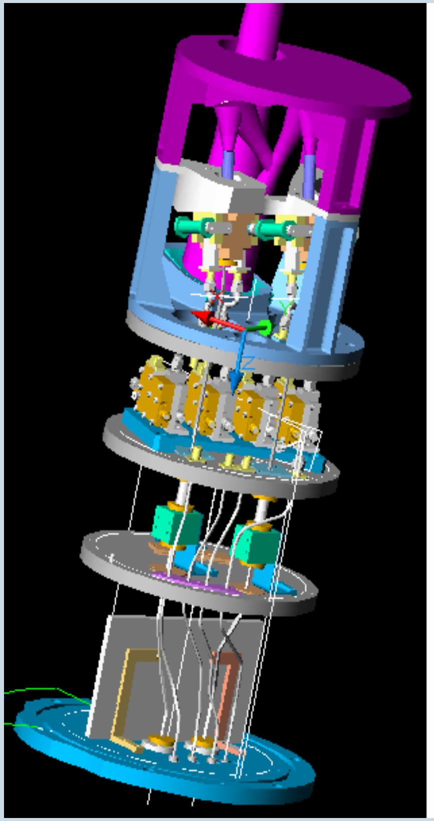


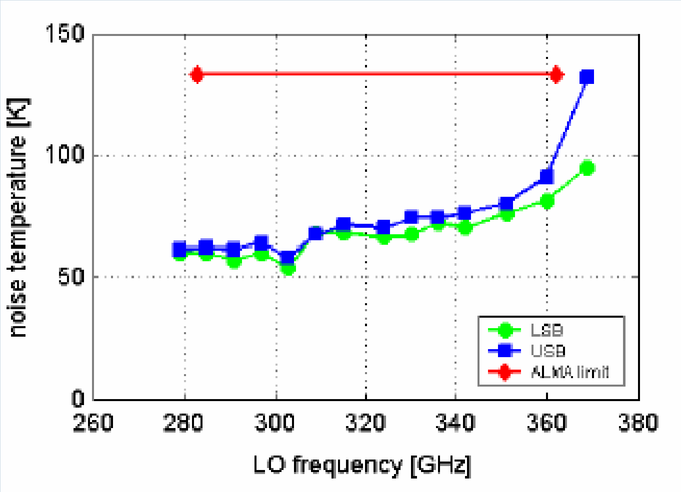


Band 7 Cartridge 275 – 373 GHz

- Mixer development
  - Focus on a 2SB, 4 – 8 GHz IF bandwidth, mixer solution
- Cartridge PDR held June ‘04
- Current status:
  - Finalize integration of cartridge #1 with two fully characterized 2SB mixer units and four LNAs





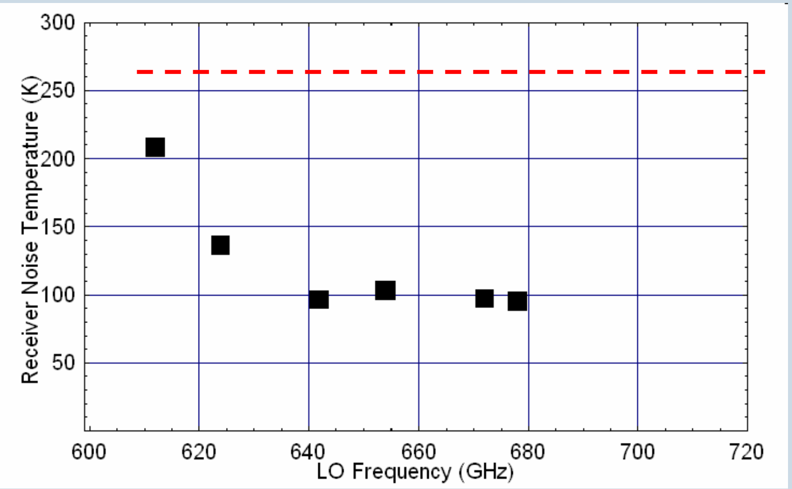


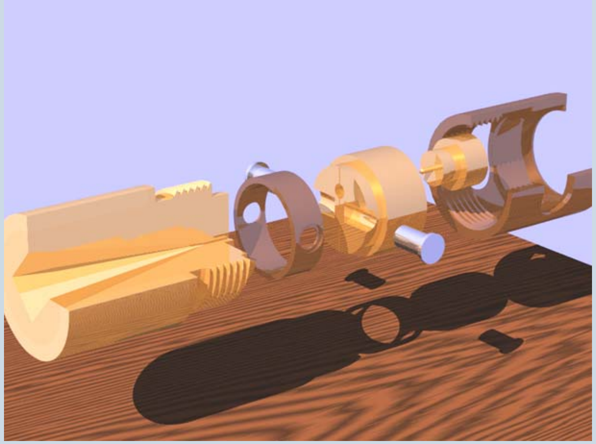
Band 9 Cartridge 602 – 720 GHz

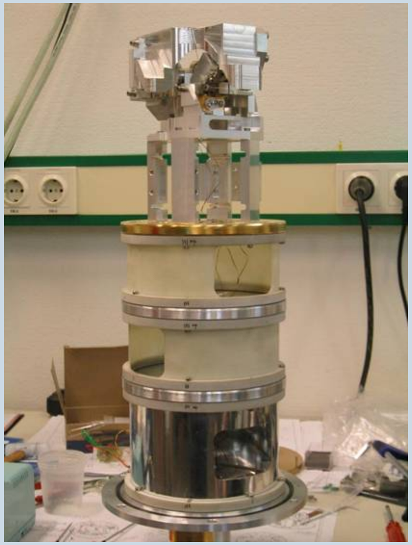
- Mixer development
  - Focus on a DSB, 4 – 12 GHz IF bandwidth, mixer solution
- Cartridge PDR held March ’04
- Final design is in progress that should fulfill ALMA requirements:

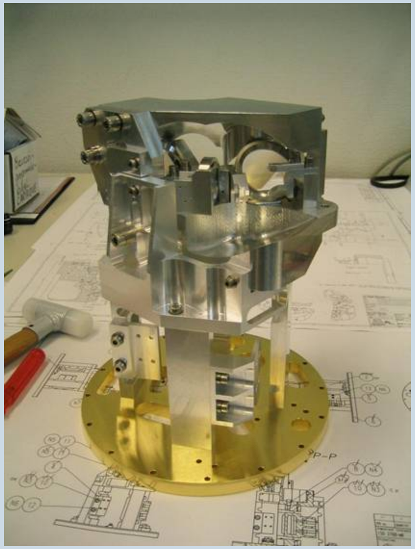
< 175 K (80 % of full RF band)

< 263 K (20 % of full RF band)

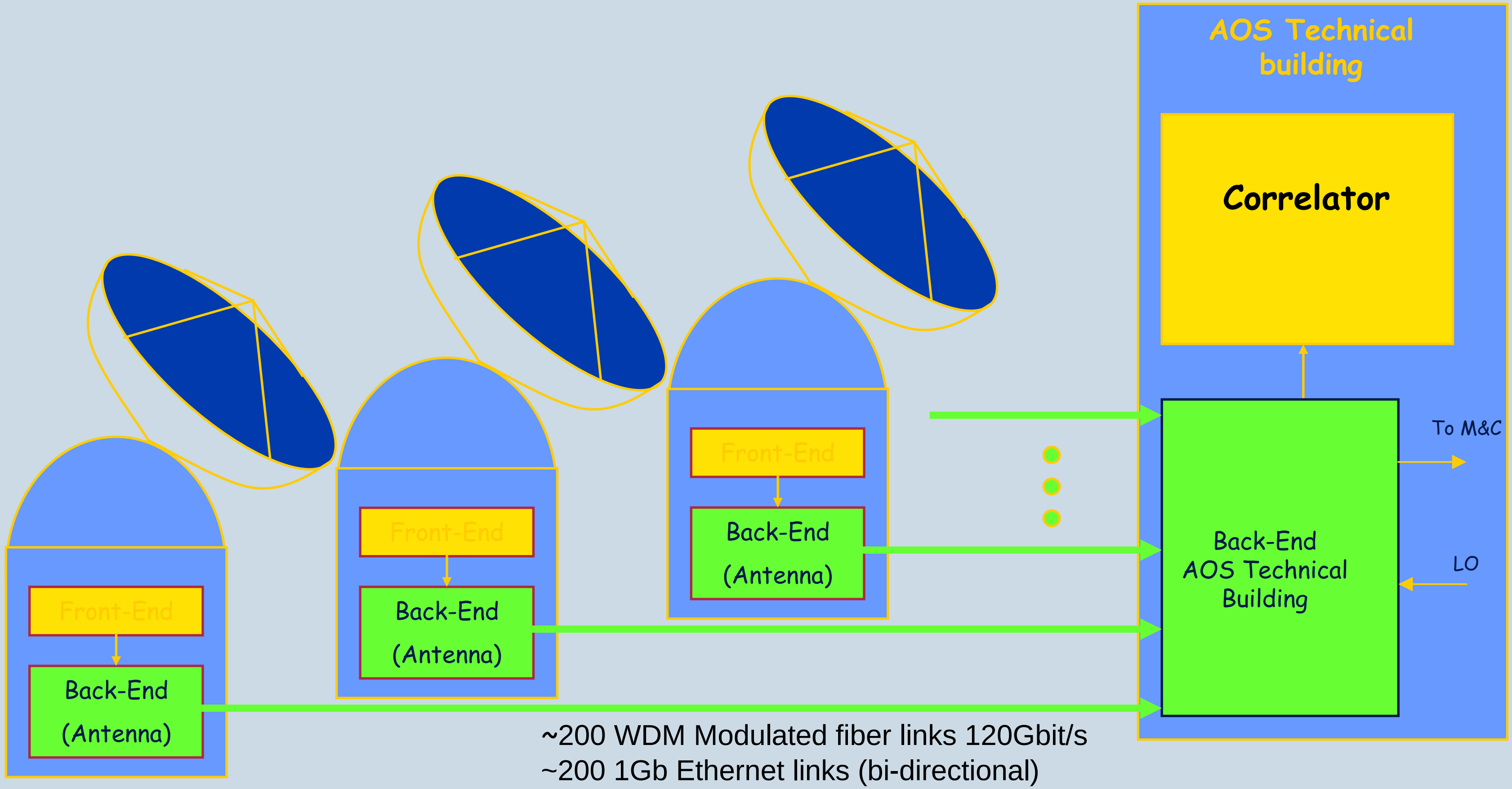






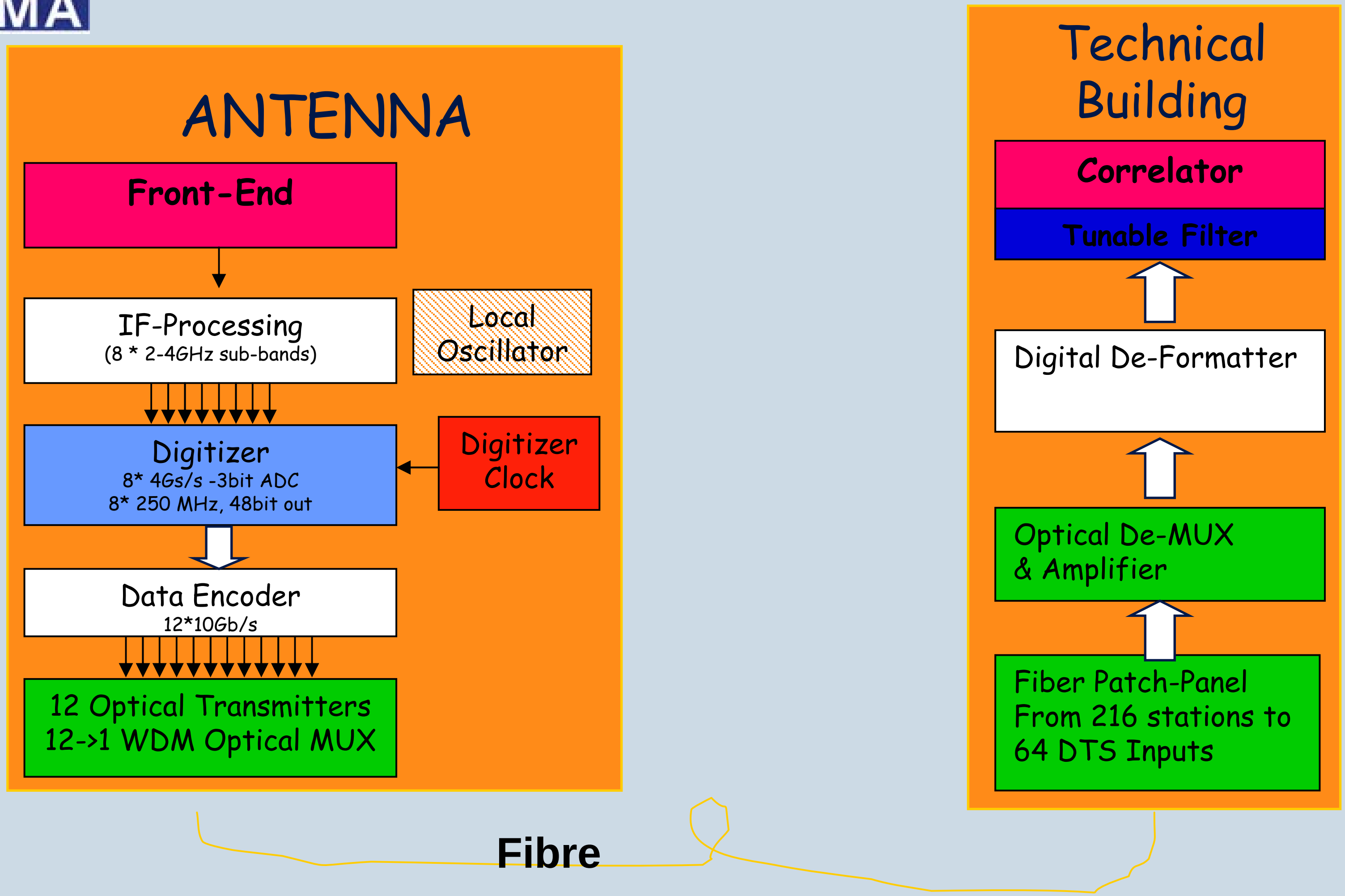


Back End & Correlator



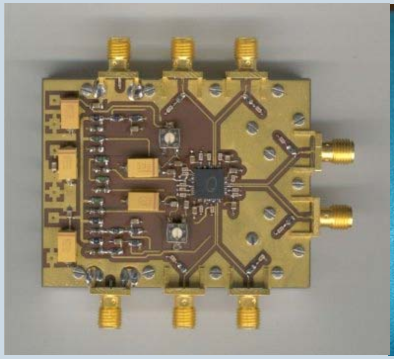
~200 WDM Modulated fiber links 120Gbit/s
~200 1Gb Ethernet links (bi-directional)
~200 Phase accurate LO reference
(64 Active at once)

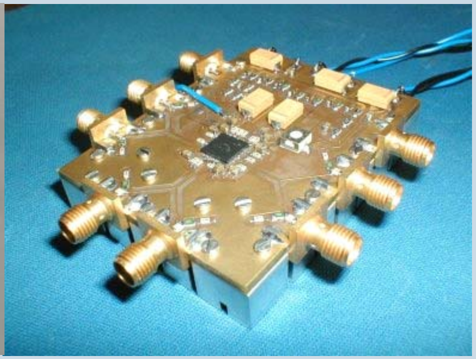
Back End & Correlator



Digitizer & Clock

Prototype Digitiser >
Sub-assembly

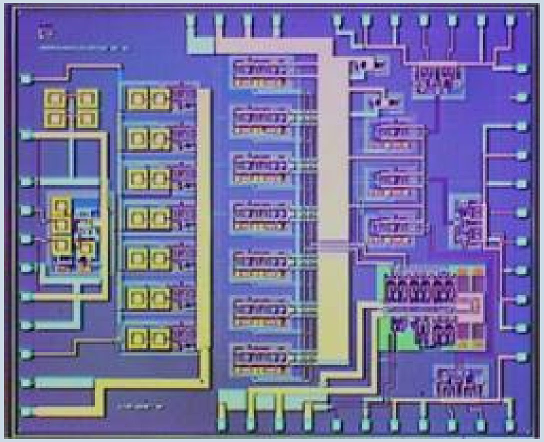




< Digitiser Clock

DGS Chip microphoto >

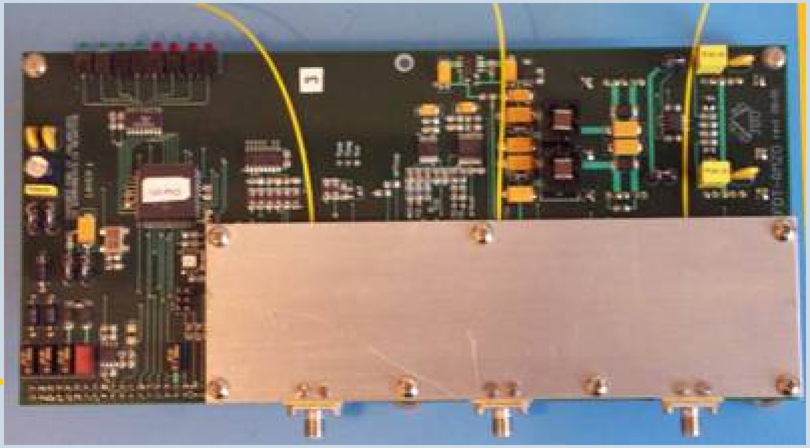
Die size 3 x 3 mm



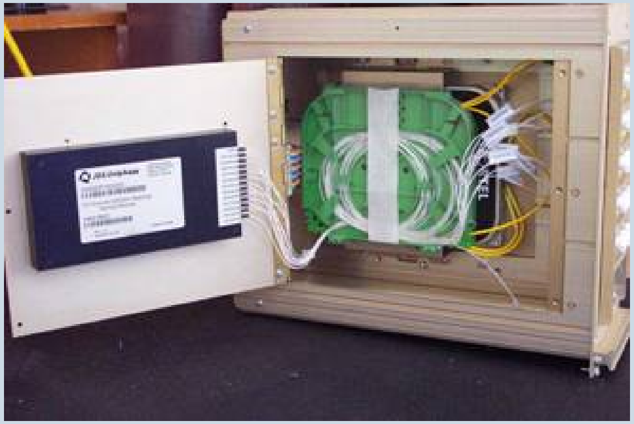
Back End – Optical DTS

Optical Transmitter

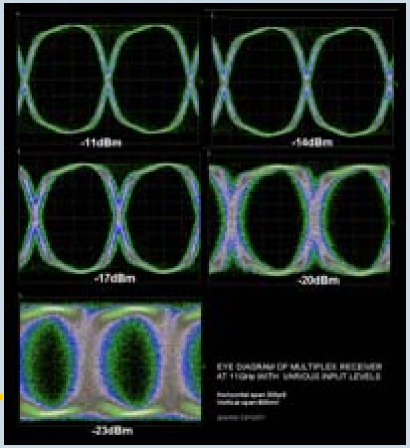
Optical Receiver >



< Optical Amplifier Demux



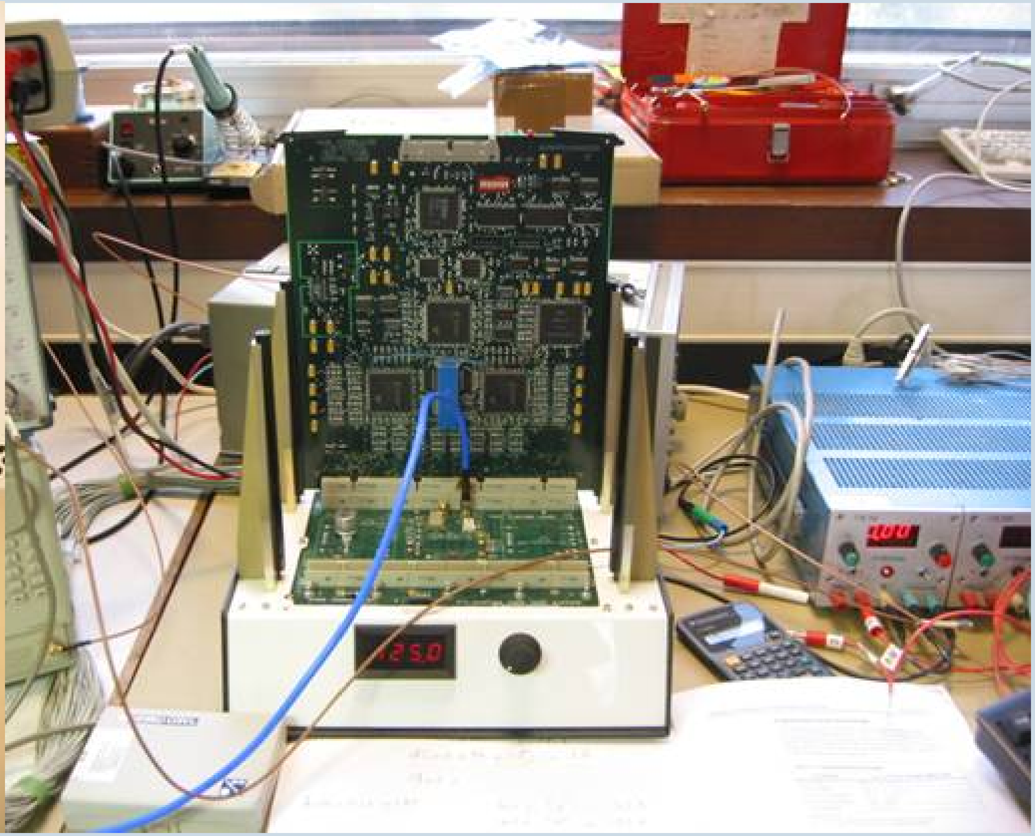
Eye Diagram >



Correlator Integration Facility

Correlator Boards

Correlator – Tunable Filter Bank



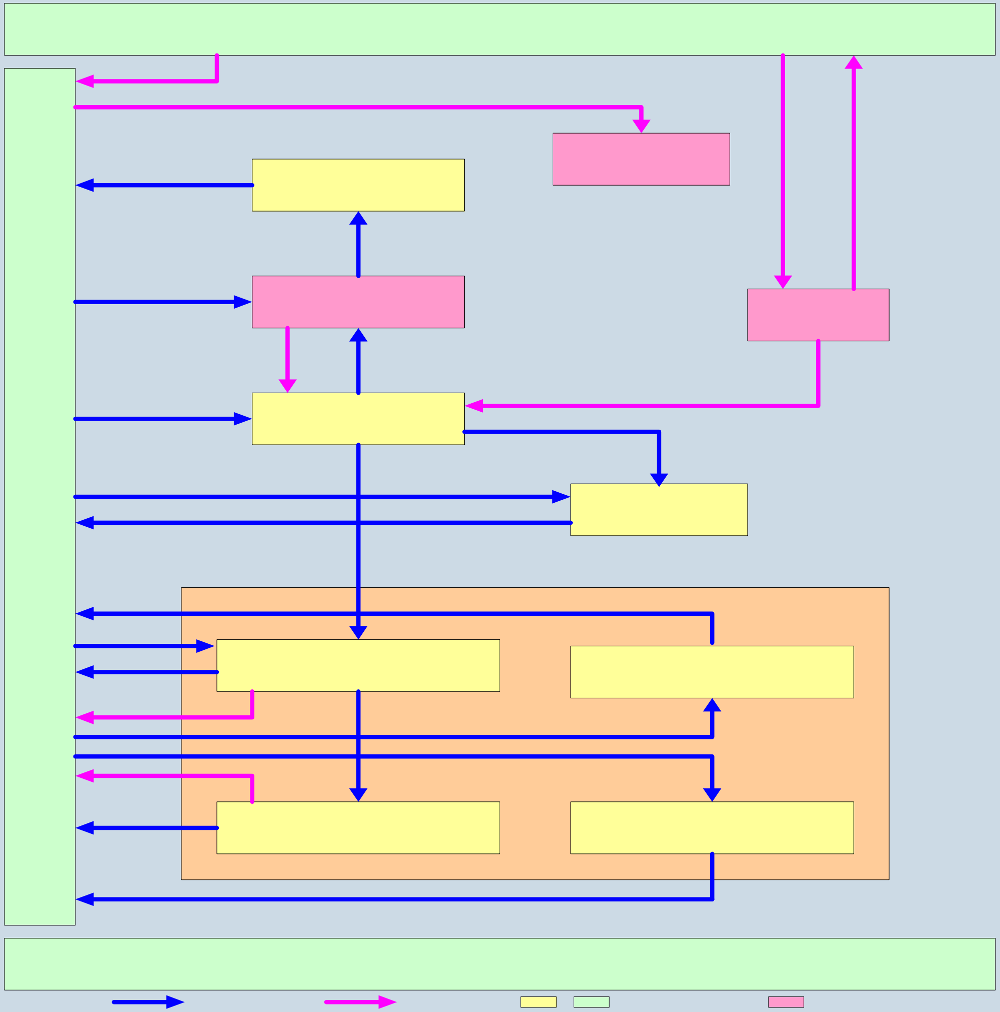
SE & I - IPT Tasks and Organisation

SE & I IPT

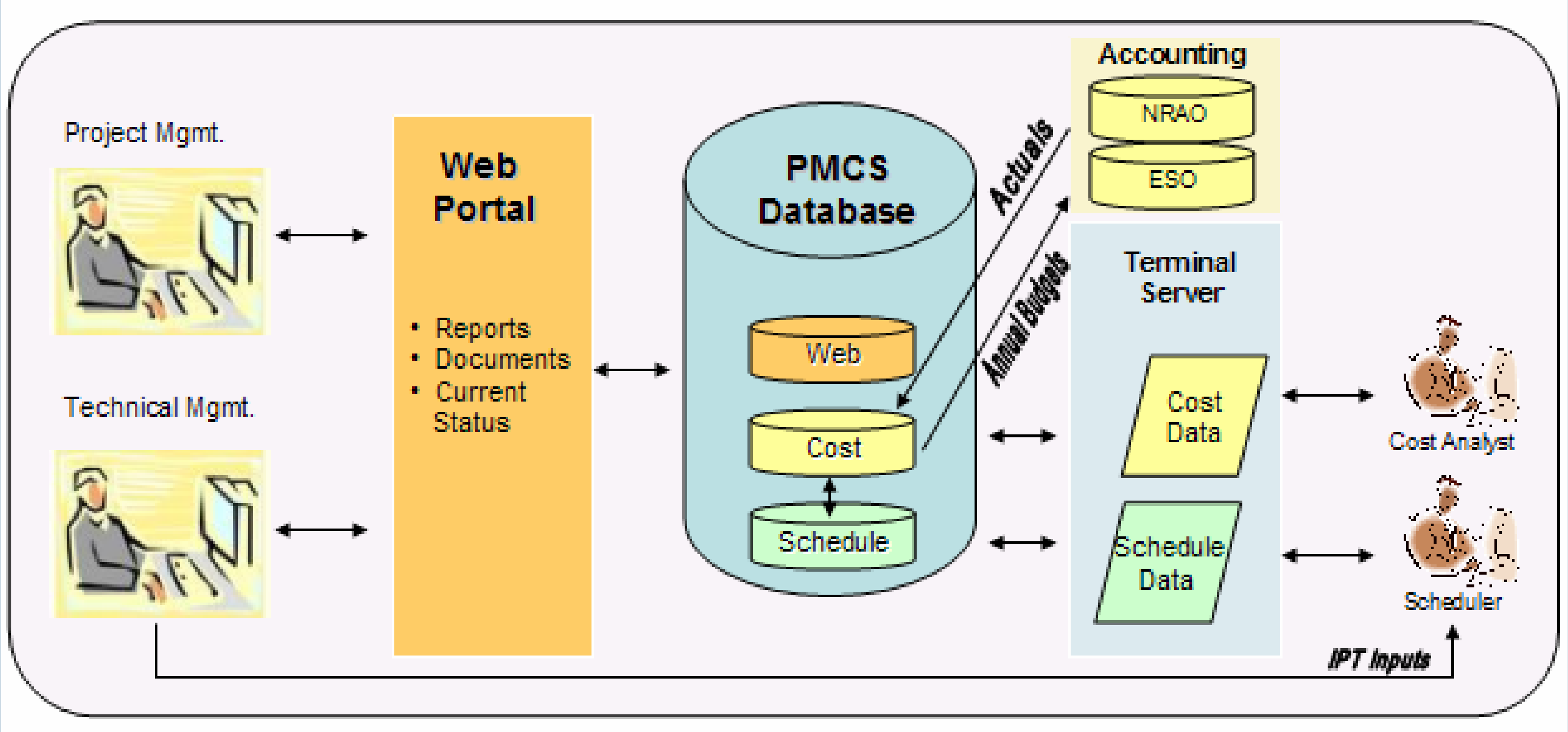
- Manage-ment
- System Engineering
- Product Assurance
- Prototype Integration
- System Integration

- 50 / 50 activity between North America and Europe
- Lead: Richard Sramek NRAO; Deputy: Christoph Haupt ESO
- SE & I IPT reports directly to ALMA Project Engineer, member of JAO
- Configuration control, product tree maintenance and documentation management

Computing - Architecture



ALMA PMCS Concept



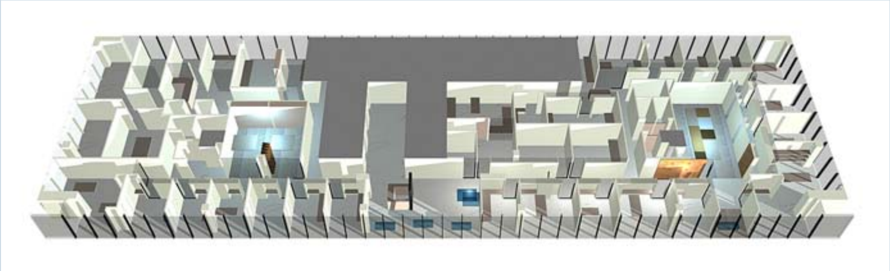
Current Issues

- Antenna Procurement
  - Goal to procure 64 antennas of same desing
  - Parallel ESO and AUI/NRAO procurement of 32 antennas each
  - Coordination extremely complex and cumbersome
  - Cost more than budgeted amount
    - Commodity price at historic high: oil, steel and nickel
    - Descope options
  - Some remaining technical issues: Built-to-spec contracts
  - Urgency in committing NA antenna budget!
- Baseline Review (to be completed 15 May 2005)
  - Cost and schedule review $\Rightarrow$ update definition of scope

Operations Planning

- **Operations Plan: Version I2 under review**
  - Chilean Operation: Joint ALMA Obsrevatory
  - ALMA Regional Centers
    - Define scope of North American ALMA Science Center
    - Require more Scientific Staff participation across NRAO
- **Areas of concern**:
  - Staffing
  - Funding profiles
  - Schedule coordination
  - Operations vs. SE/SI

JAO: Santiago Office (temp)



Enhanced ALMA in 2012!