The ALMA Project

Lars-Åke Nyman

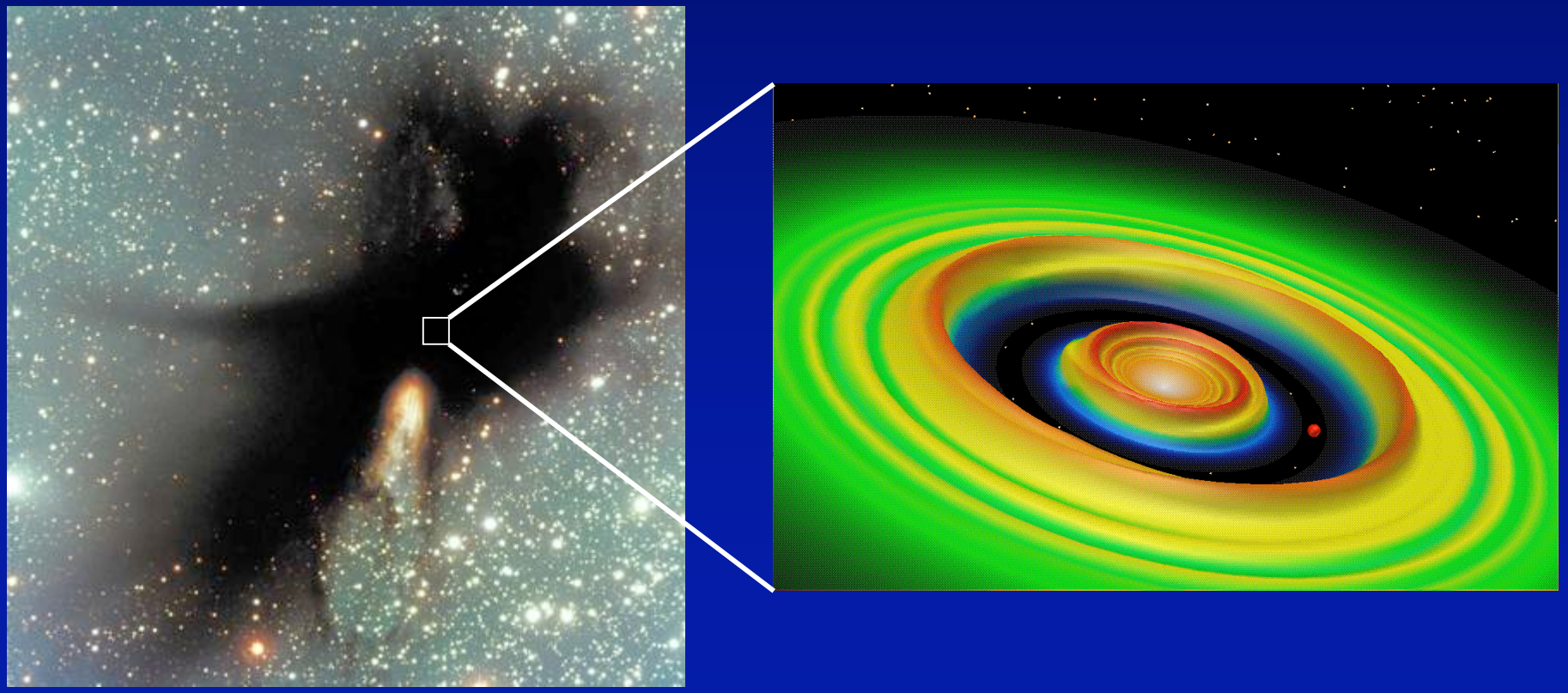
Head of Science Operations

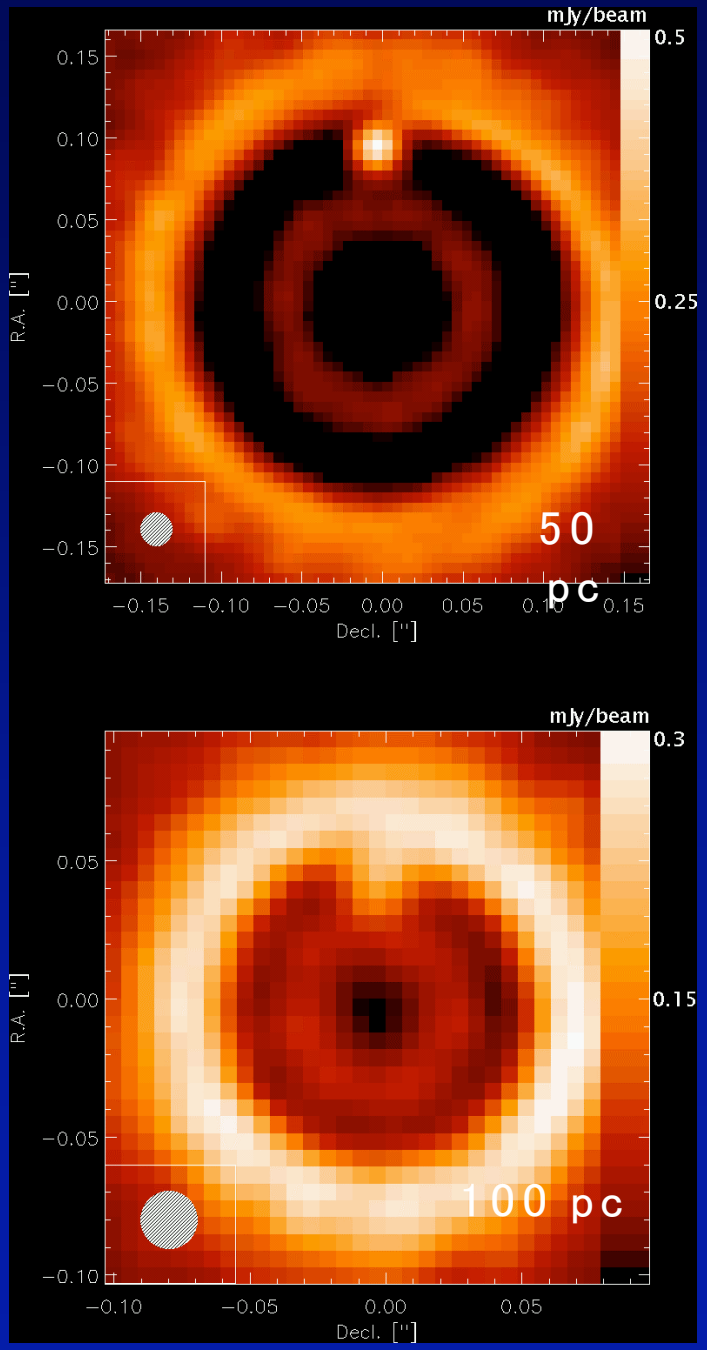
ALMA: Atacama Large Millimeter/submillimeter Array

- International project to build & operate a large (66-antenna) millimeter/submm (λ ~0.3-3mm) array at high altitude site (5000m) in northern Chile.
- Partners at East Asia, Europe and North America, in collaboration with Chile.
- 66 antennas, 10 receivers in each antenna.
- Commissioning starts 2009.
- Early Science Operations in 2011.
- Full Operations in 2013.

Scientific Goals (1)

Make images of new stars being formed, with planets emerging from the disks around them.





Planet formation in nearby disks

$M_{planet} / M_{star} = 0.5\ M_{Jup} / 1\ M_{sun}$

Orbital radius: 5 AU

Disk mass as in the circumstellar disk around the Butterfly Star in Taurus

(ALMA: 10km, t_{int}=8h, 30º phase noise)
Wolf & D'Angelo (2005)
astro-ph / 0410064

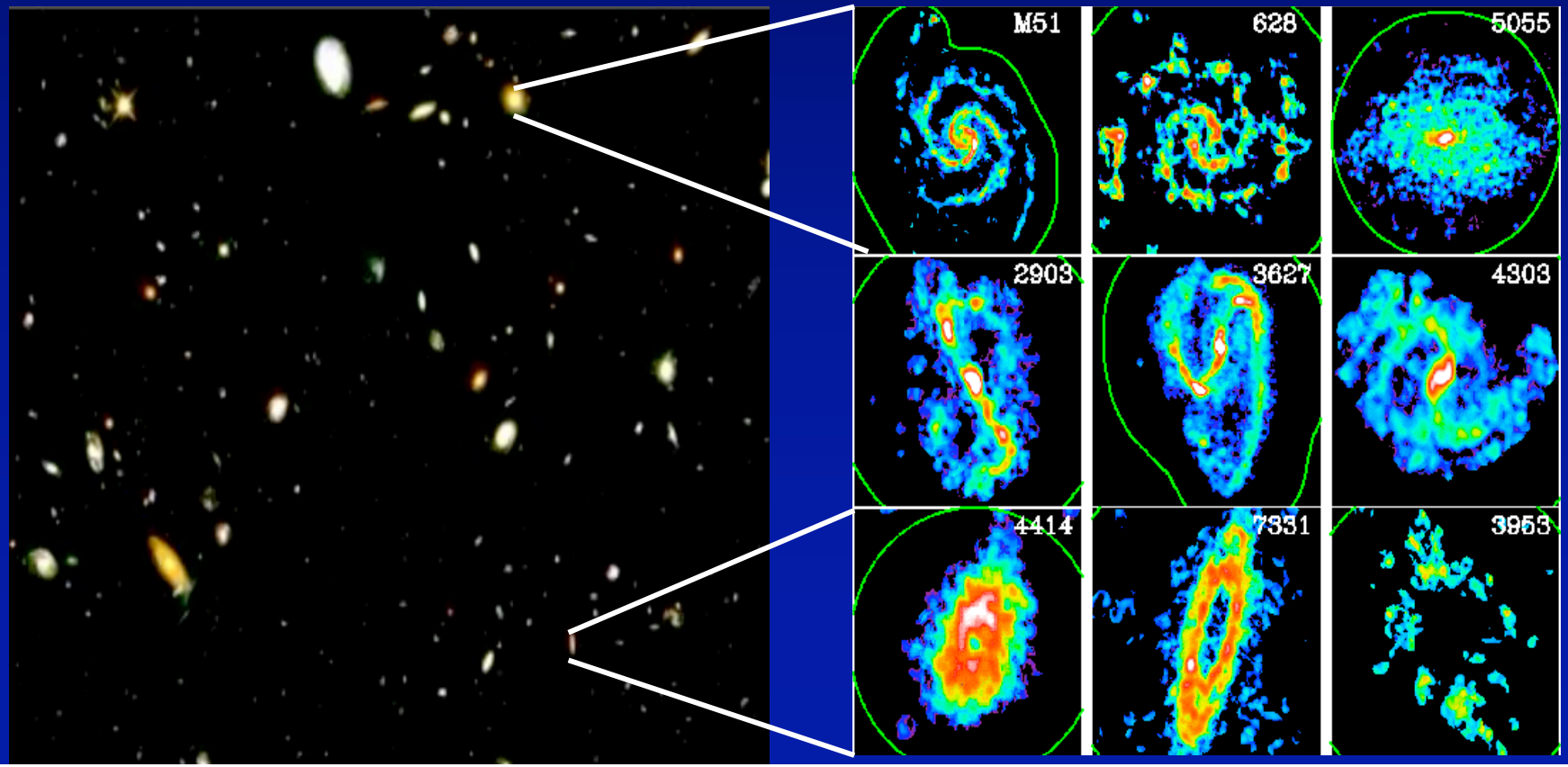
Goal for angular resolution is 0.005 arcsec at 950 GHz

Scientific Goals (2)

Map distant galaxies

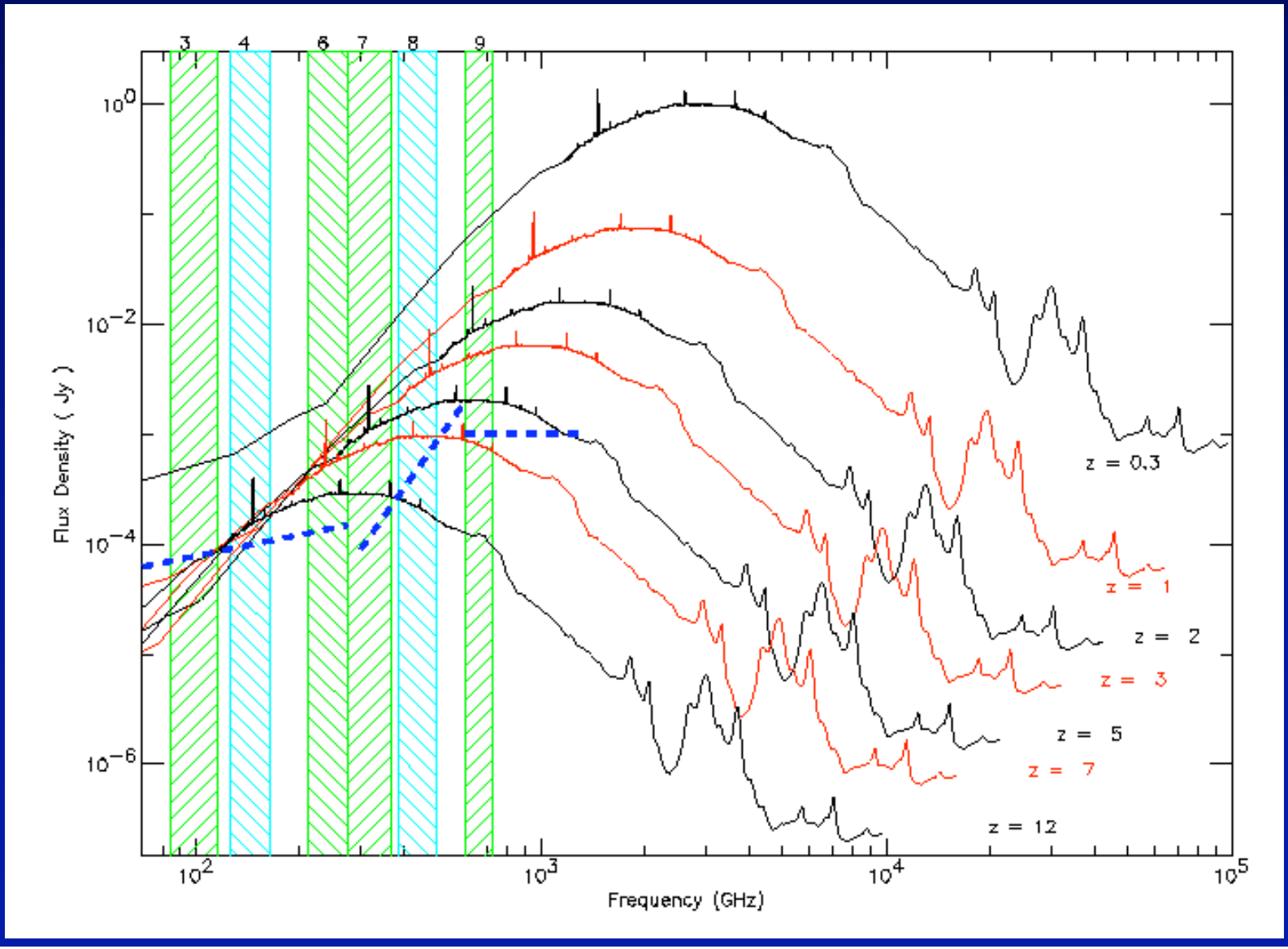
Left: Hubble image of distant galaxies

Right: Mm-wave images of nearby galaxies



Red-shifted far-IR peak

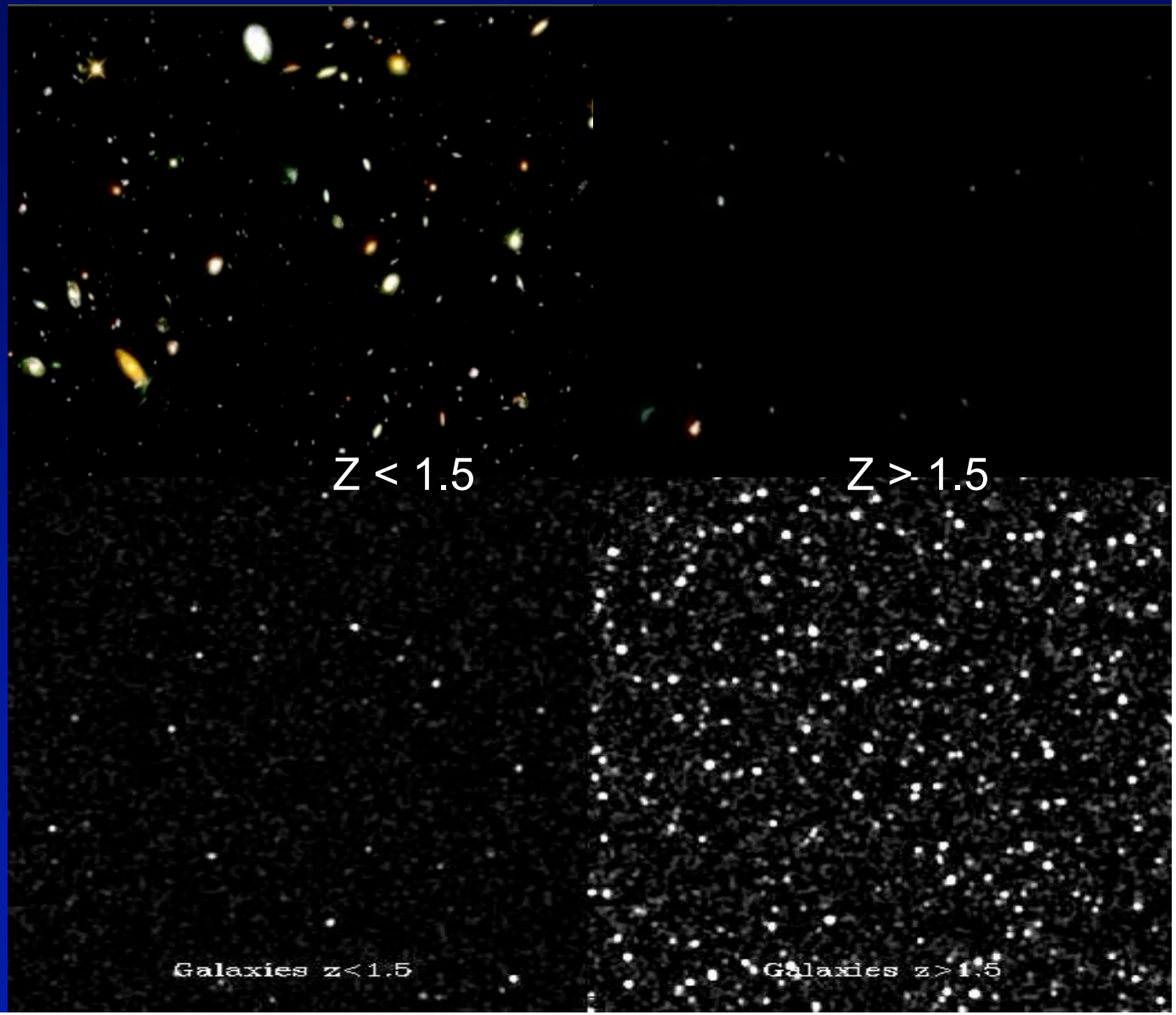
M82 shifted to z = 1,2…12



Goal for sensitivity at 1.3 mm wavelength (continuum) is 10 microJy in 1hour

Hubble:

ALMA:



Scientific Goals

With 100 times more sensitivity and angular resolution than existing submm/mm arrays ALMA will extend our understanding of the nature of almost every type of astronomical object – from our own sun and planets to the most distant quasars.

In addition to these key properties we have high specifications on accuracy (i.e. calibration), time resolution and polarization, which is critical for determination of magnetic fields.

We are also aiming to achieve great flexibility in observing – e.g. spectral line setup, scheduling

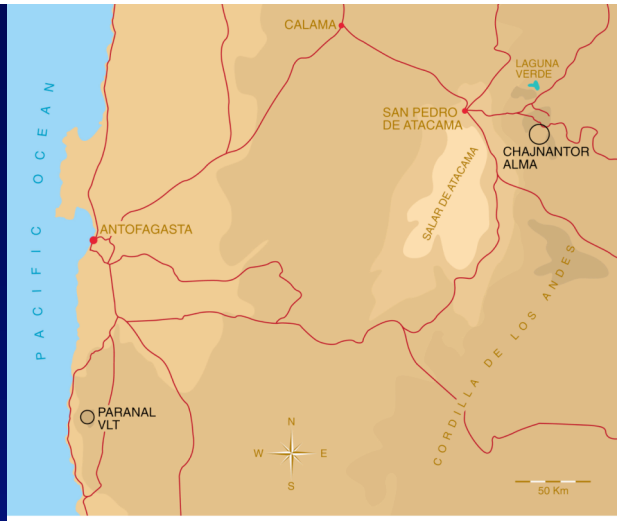
Additional Requirements

- Total power ("zero spacing") and short spacings provided by the ACA (ALMA Compact Array) – four 12m antennas plus twelve 7m antennas
- Ability to observe the Sun. Time resolution 16ms
- Track comets and other relatively nearby objects
- Polarization measurements – goal is 0.1% accuracy in Stokes parameters

Key Components

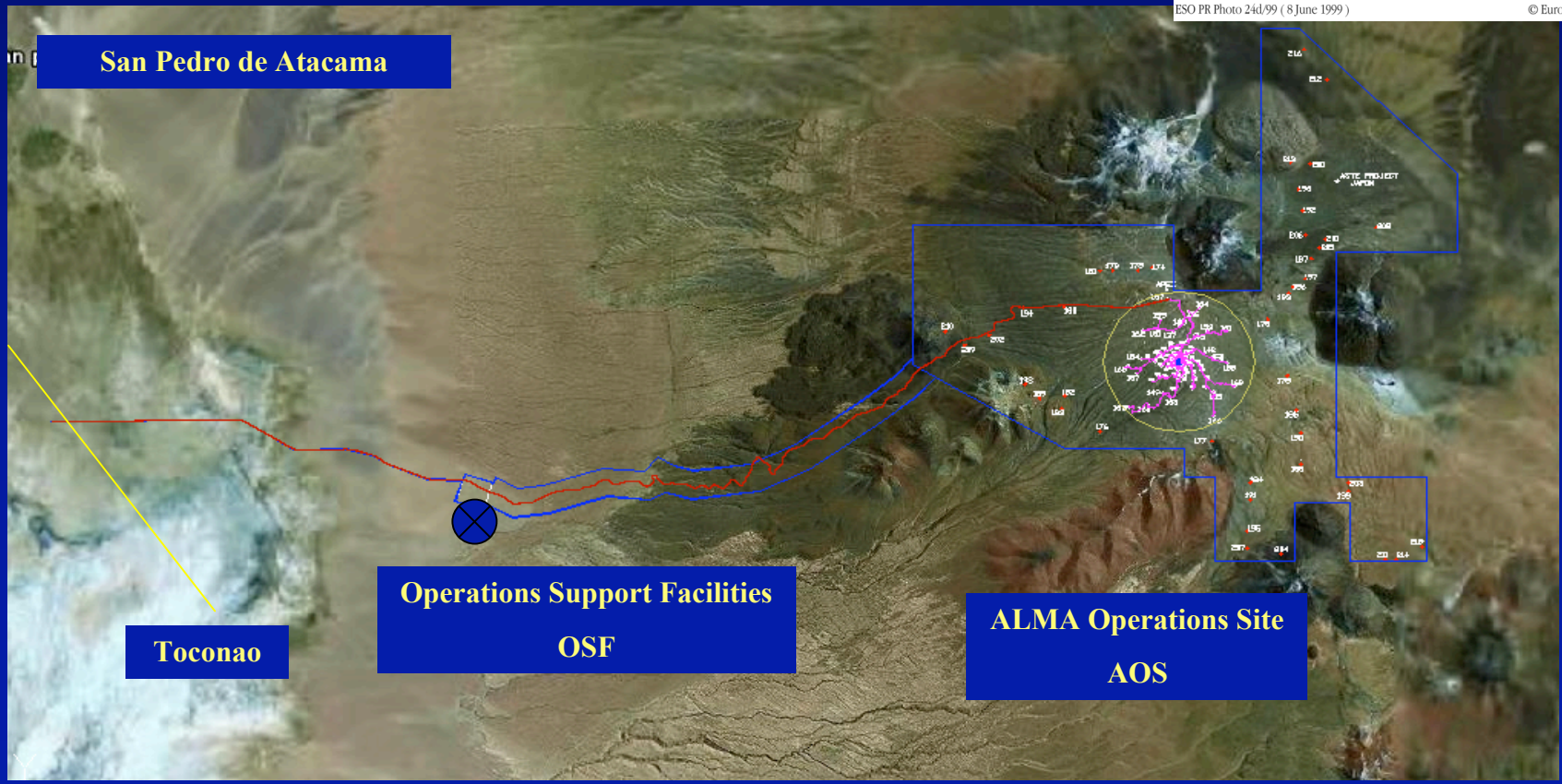
- Antennas: accurate pointing (2” rms over the sky, 0.6” rms offset pointing), precise surfaces (< 25 microns) for observations up to 900 GHz
- SIS receivers covering the bands from 3mm to 0.3 mm (2 polarizations, 8 GHz BW)
- Signals are amplified, digitized and send to central building on optical fibres
- Central correlator(s): 16 and 64 station correlators, 2 x 8 GHz bandwidths, tunable filterbank for low and high resolution observations.
- Photonic LO
- Phase correction through fast switching and 183 GHz WVR

ALMA Site(s)



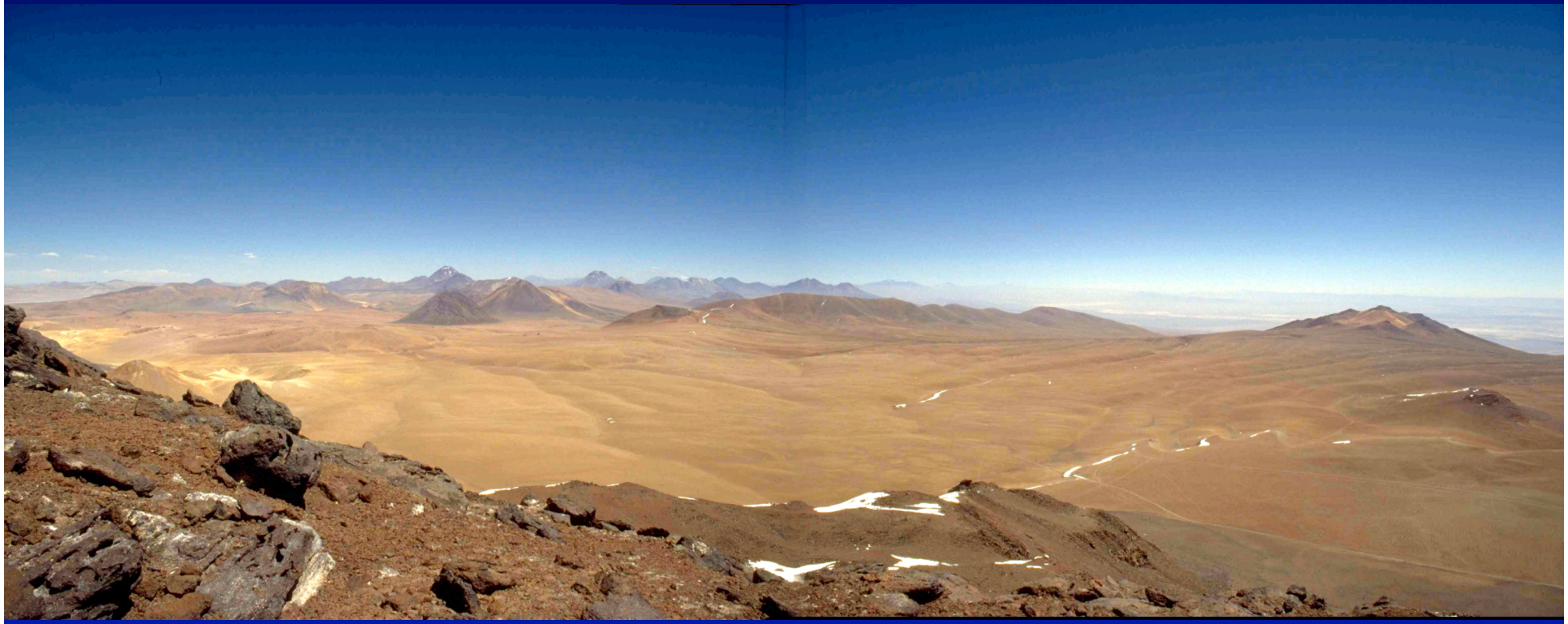
Geographical Map with VLT and ALMA Locations

ESO PR Photo 24d/99 (8 June 1999)



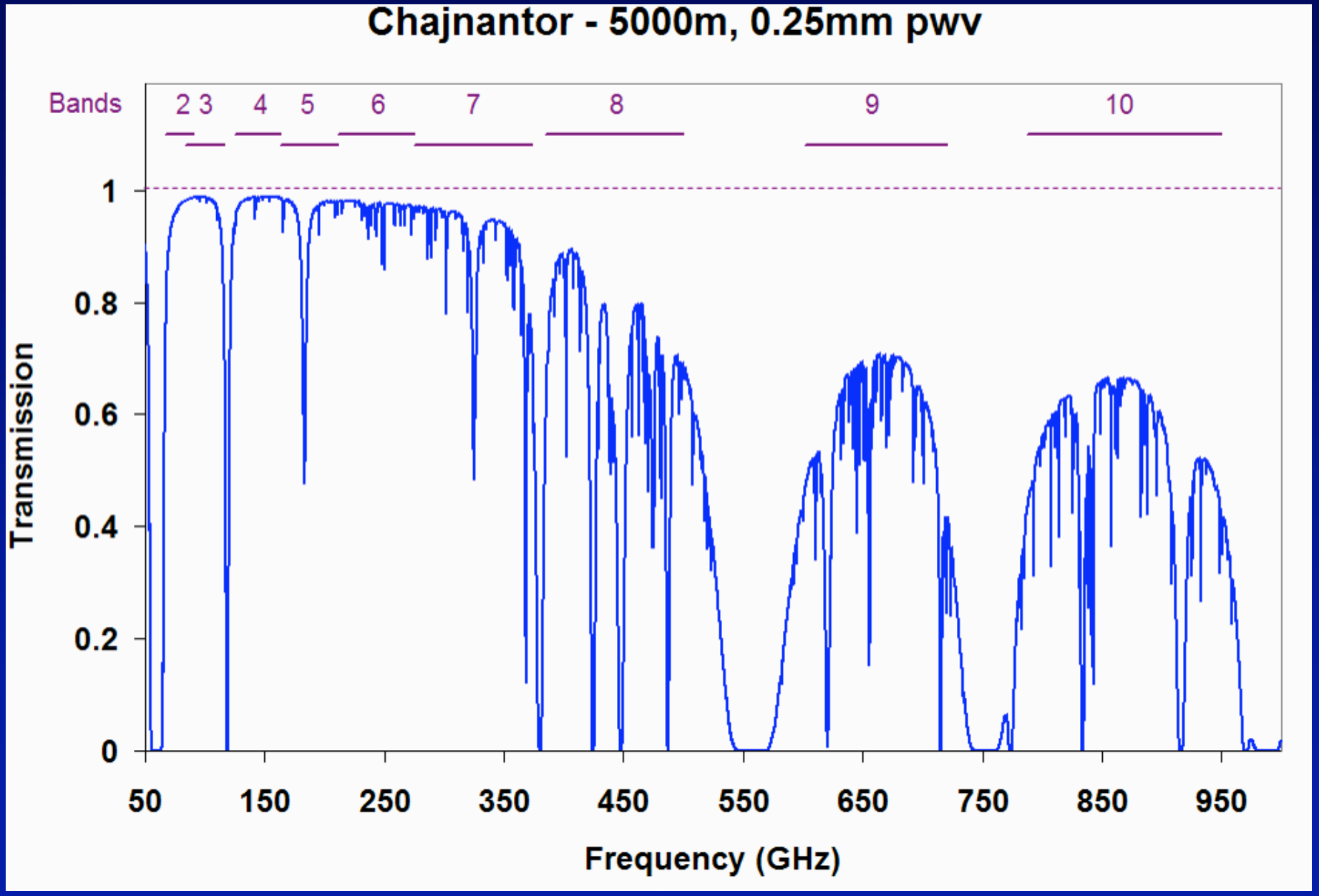

ALMA Sites
To AOS (43km)
OSF Site (15km)
PARE
60
PELIGRO

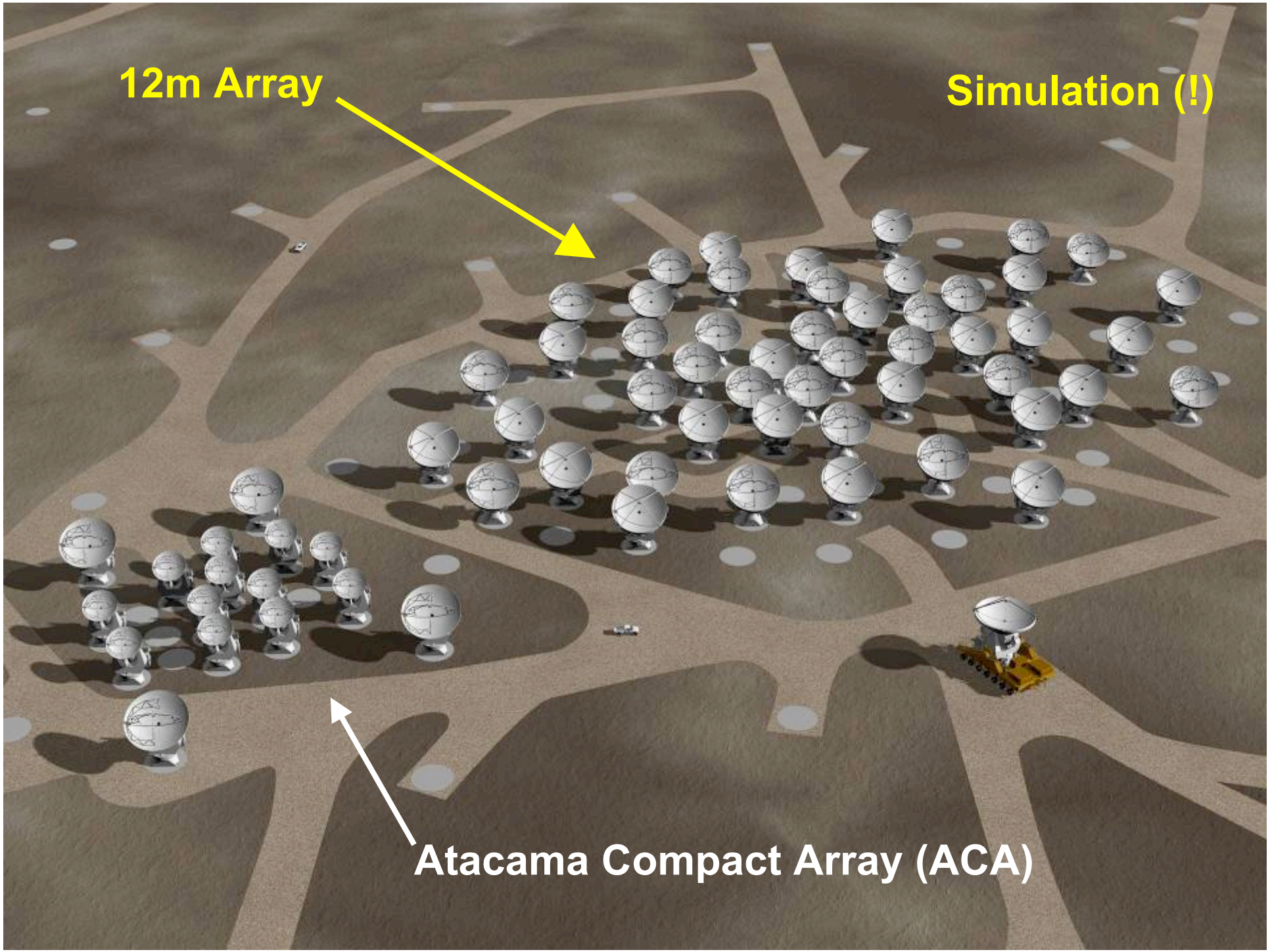
5000m Chajnantor plateau – looking south
Array Operations Site

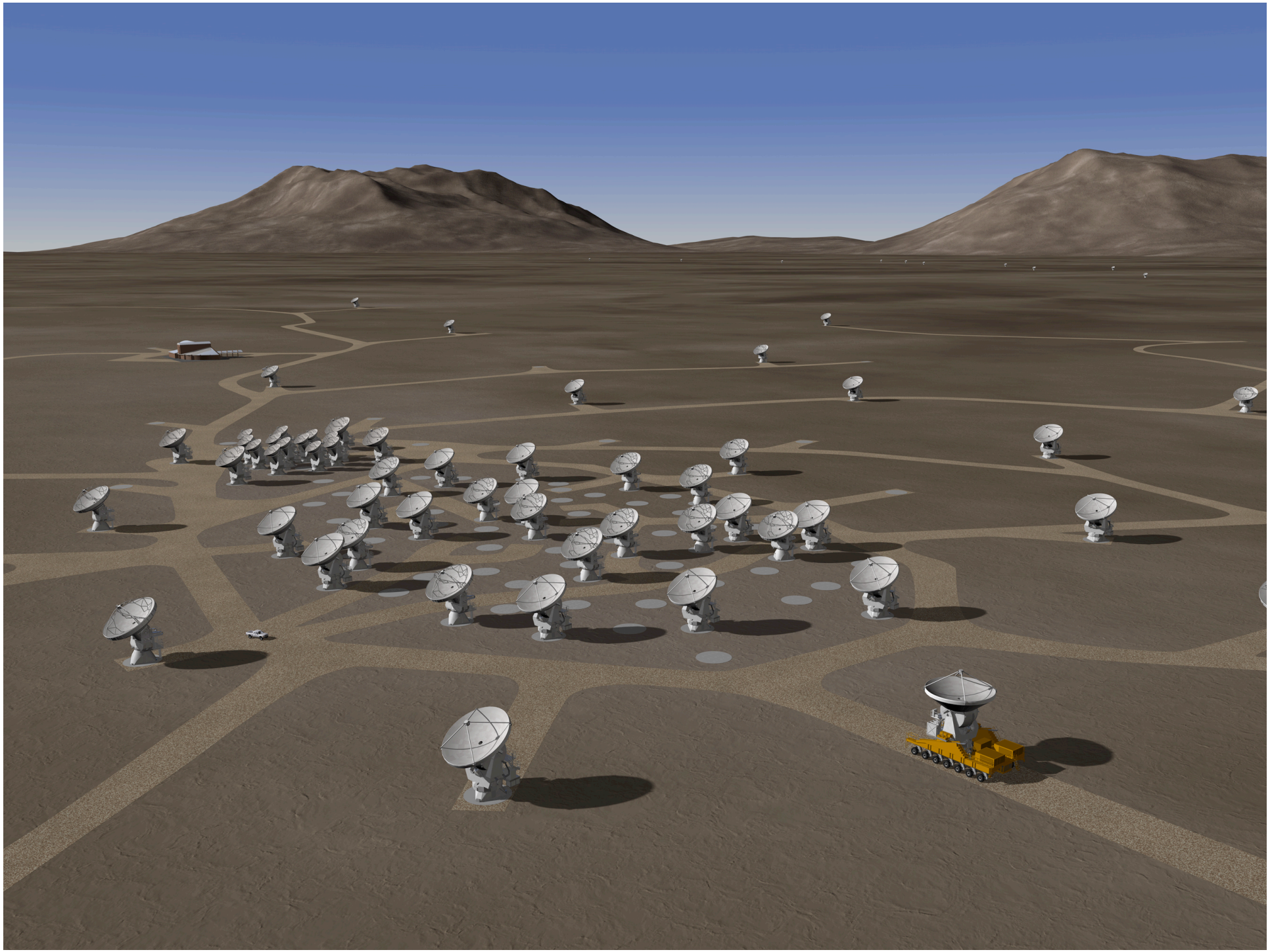


Chajnantor Plateau – looking north

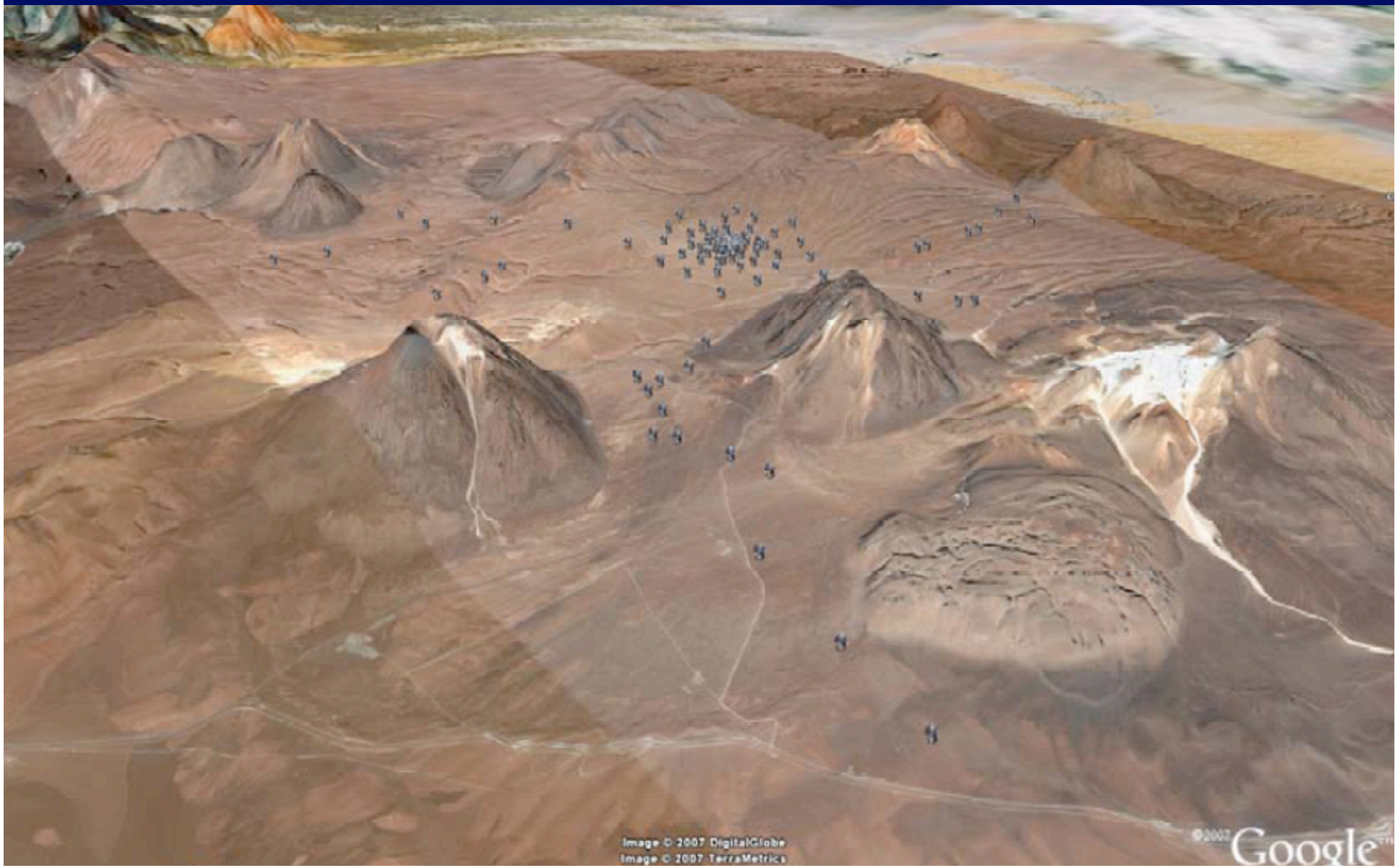
Receivers – up to 10 cartridges in one cryostat



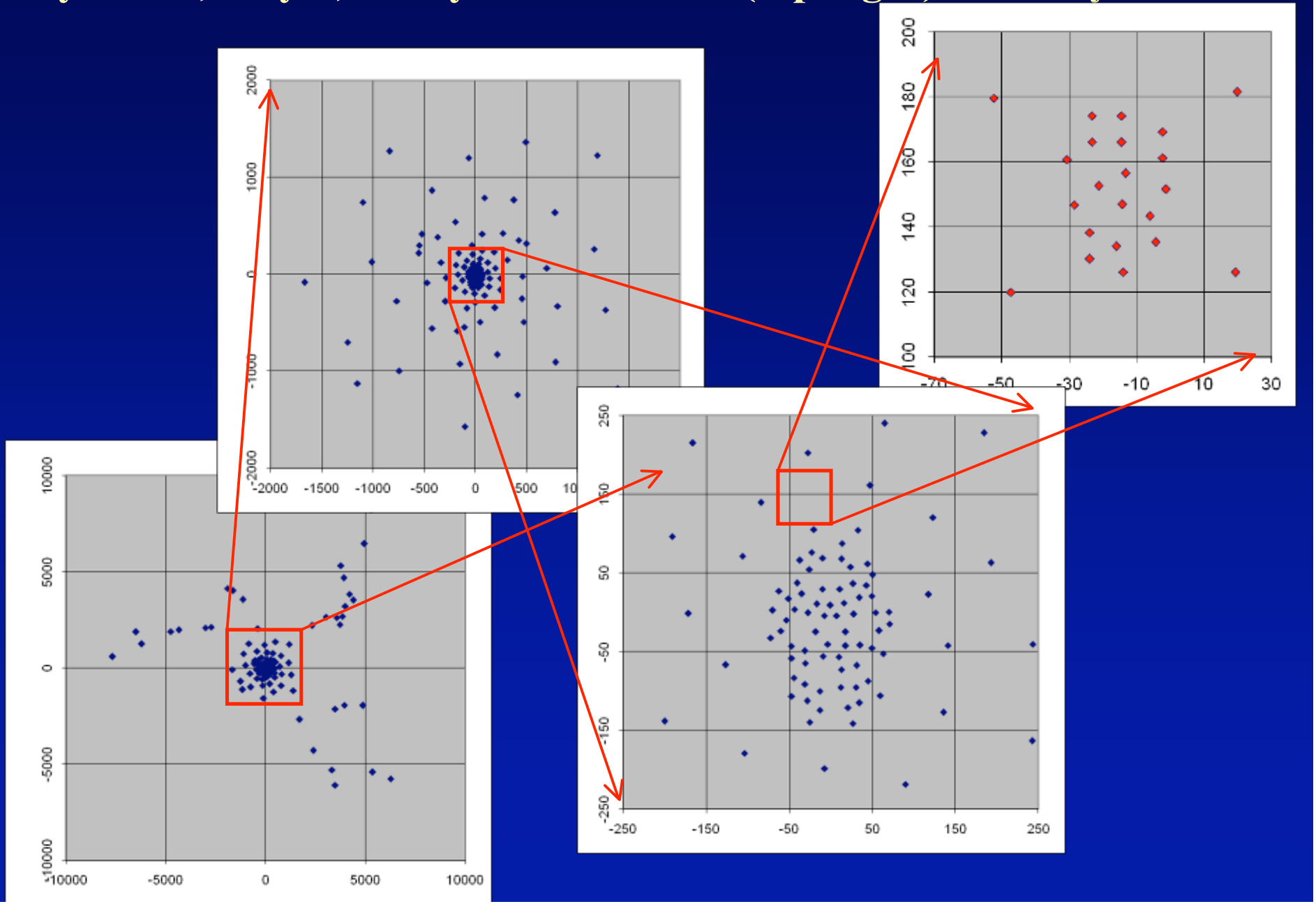

12m Array
Simulation (!)
Atacama Compact Array (ACA)



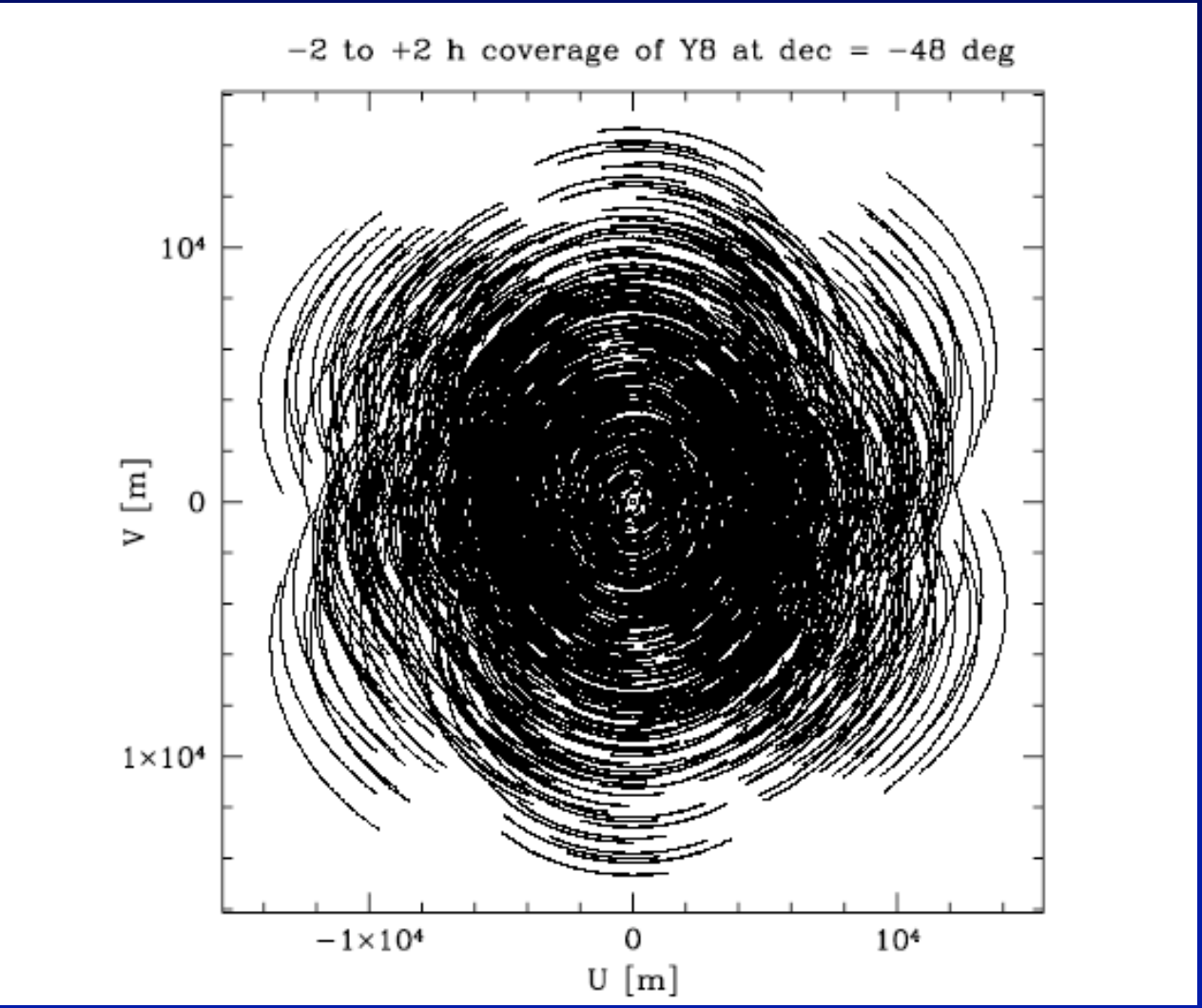
Google-Earth view of site with antennas in the most extended configuration – baselines to 16km



Configuration scheme going from the largest to the smallest. 20 by 20km, 4 by 4, 0.5 by 0.5 and ACA (top right) in 0.1 by 0.1km



In general the coverage of the U-V plane
is extremely good and so image quality is high



5000m: occupied – acceptance tests

3000m: some work needed: being planned

Grading of Central Area Complete

Foundation being kept warm while it cures

16-station Correlator installed and running

First Quadrant of the 64-element Correlator in the AOS building

Four MELCO Antennas being tested

Two Vertex Antennas under test – Four more being assembled

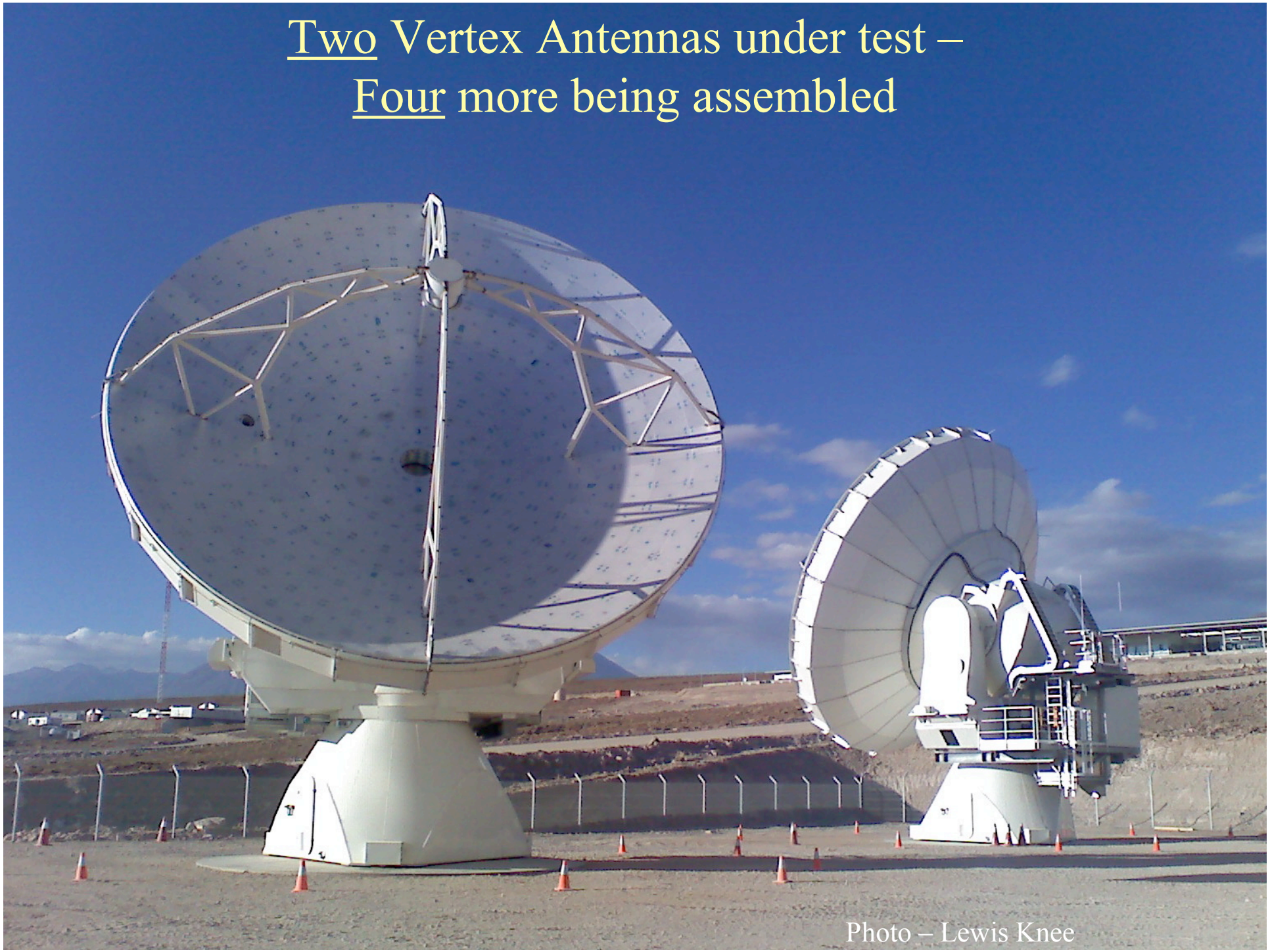


Photo – Lewis Knee

Dishes measured by holography at 104 GHz
Use source on tower at ~300m distance and correct for the curved wavefront

AEM design

- CFRP cabin
- Stiff yoke
- Direct drives

All-CFRP Backup Structure

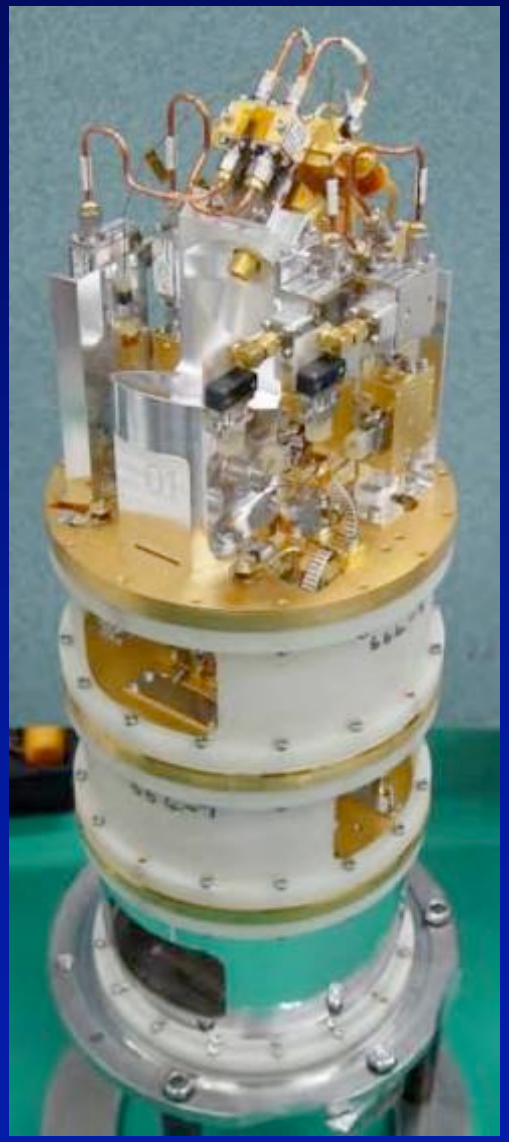
Transporters arriving to San Pedro de Atacama

First Move of ALMA Antenna (July 8, 2008)

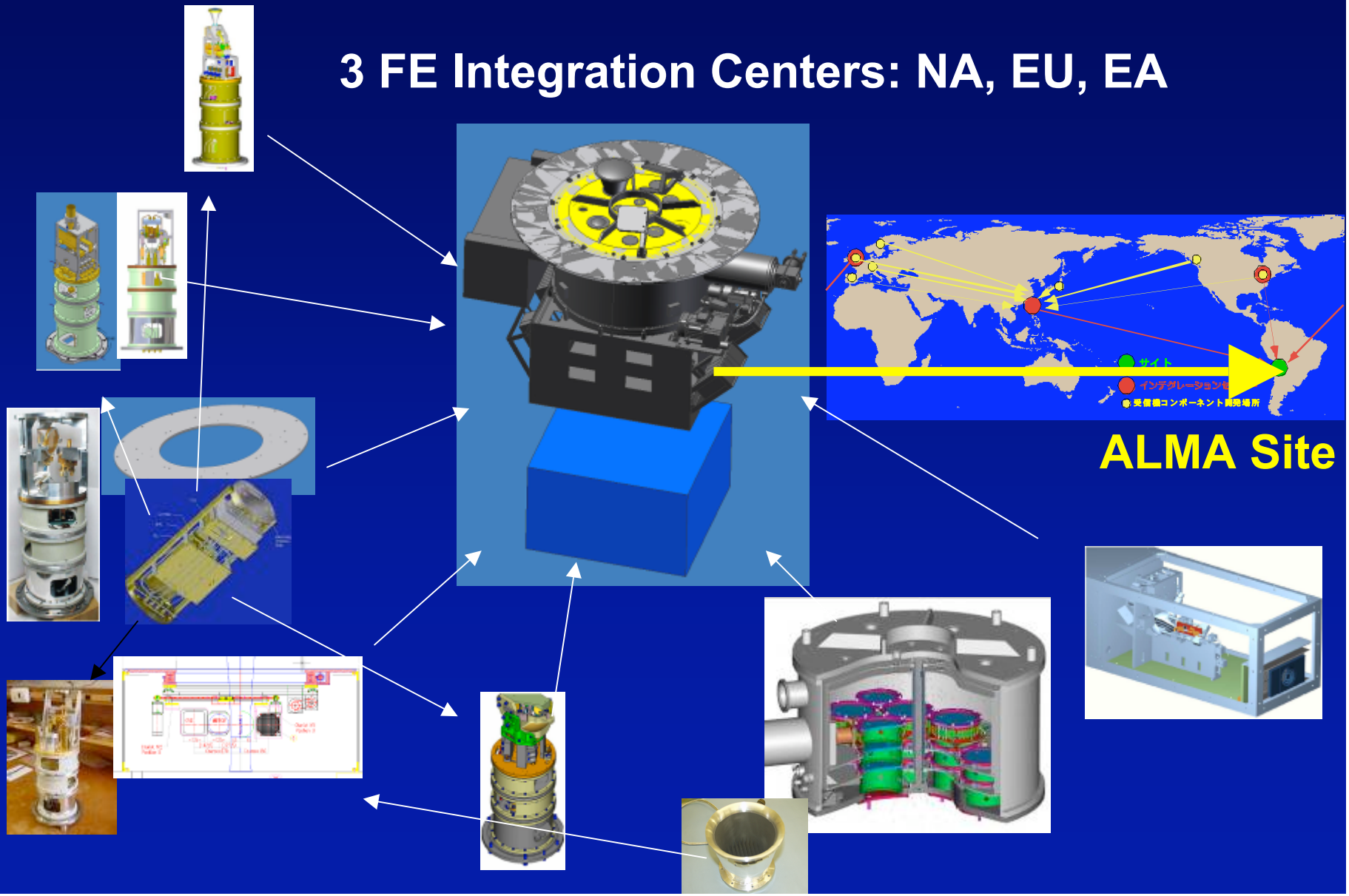
Receiver Cartridges

Band 4

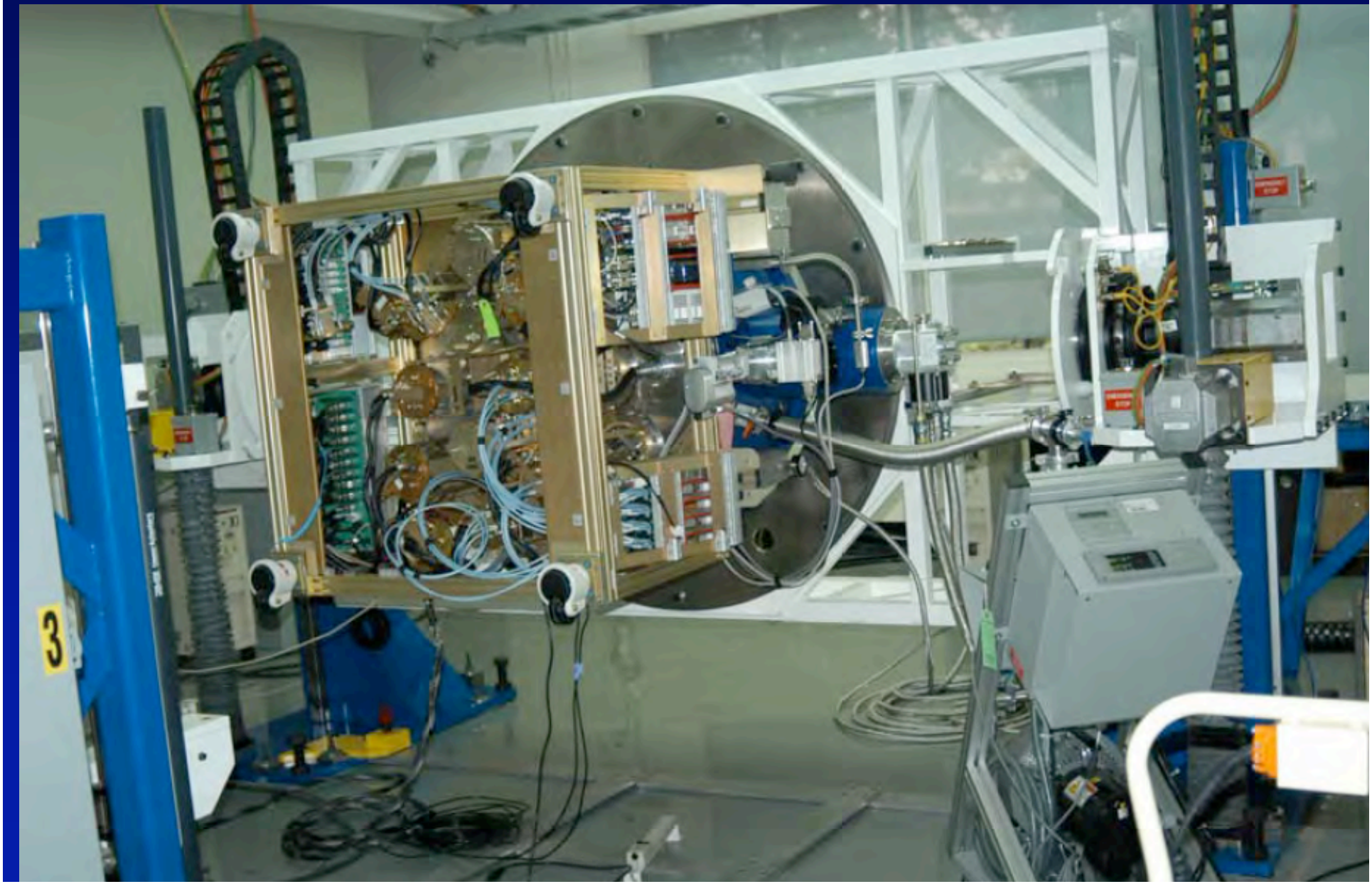
Band 8



ALMA Front End System Integration



Testing and Verifying Performance is HARD!



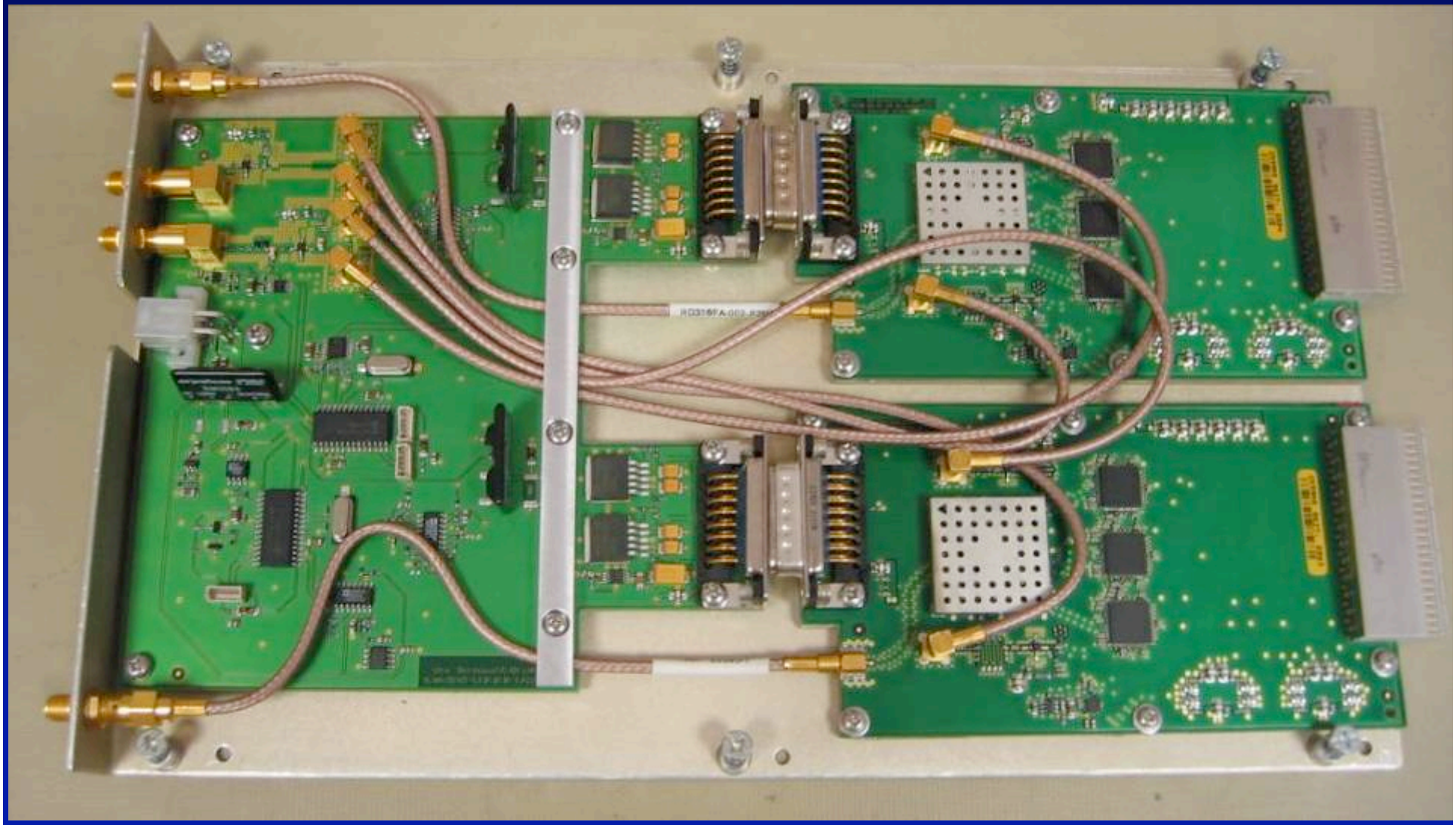
First FE/BE under test at OSF

Back End racks being lifted into MELCO #2 receiver cabin

Dual-channel Digitizers on the Antennas

3 bits at 4 Gs/sec per channel

Data rate is 120 Gb/s per antenna



ALMA Tunable Filter Bank Cards

Software

- Hugely important aspect of ALMA
- Multiple levels from individual micros controlling devices, through the overall real-time control and data taking, on to data reduction and calibration and up to the broad issues of user support – proposal writing tools and the like.


Santiago Central Office
ALMA
ATACAMA LARGE MILLIMETER ARRAY

ALMA STATUS – Sept 2008

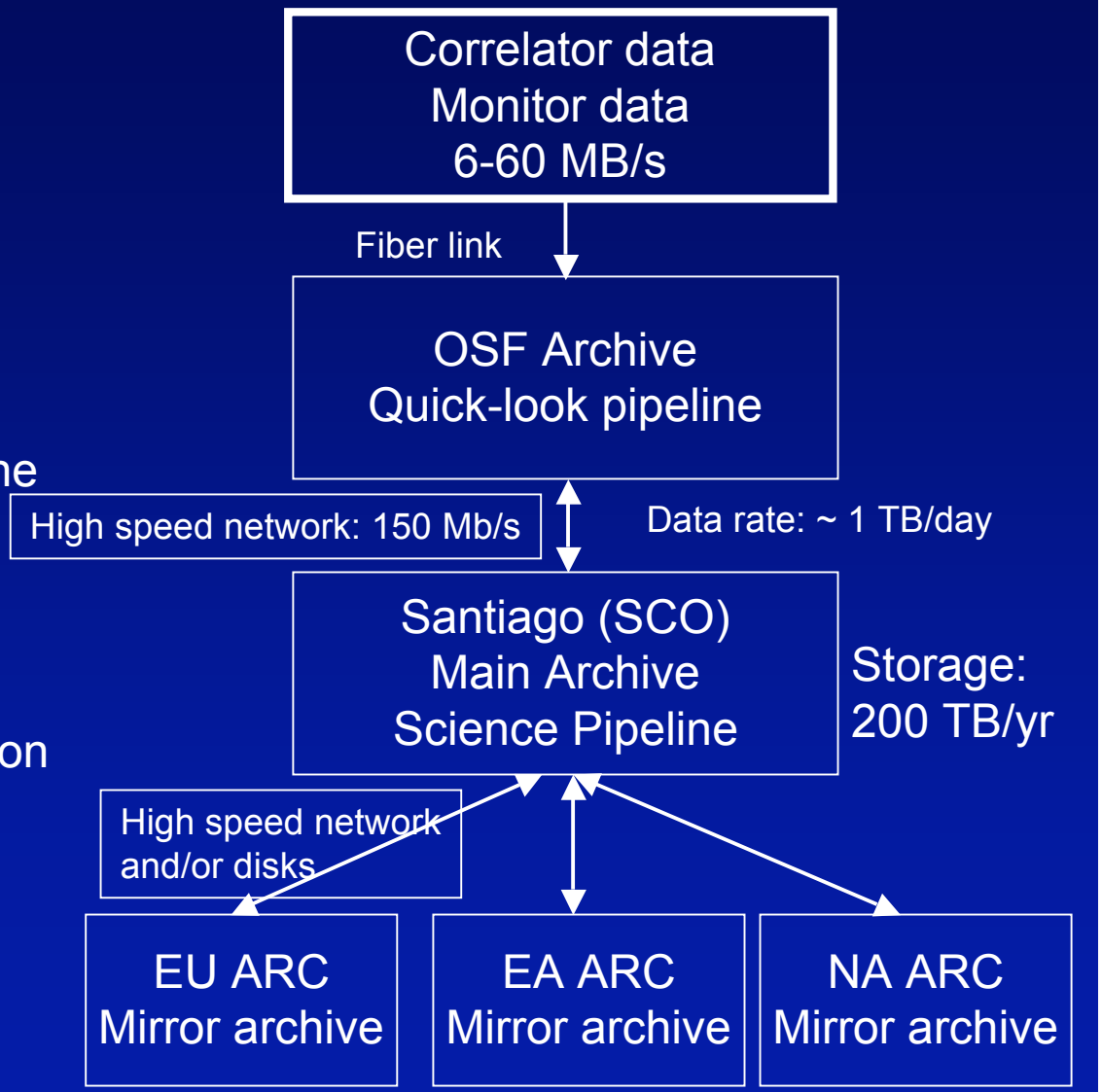
- Main buildings done. Roads & pads on high site starting.
- 10 antennas on site – testing / acceptance in progress
- Transporters on site and accepted. Some “tuning” needed
- First receiver system and 2 sets of electronics on site
- 16-input correlator and first quadrant of 64-input installed
- Mass production underway of almost all other items
- Systems and software testing on-going at VLA site
- Some development work still going on in other areas:
  - Band 10 front-ends
  - Production radiometers
  - Laser Local Oscillator refinements

Archiving

Archive content:

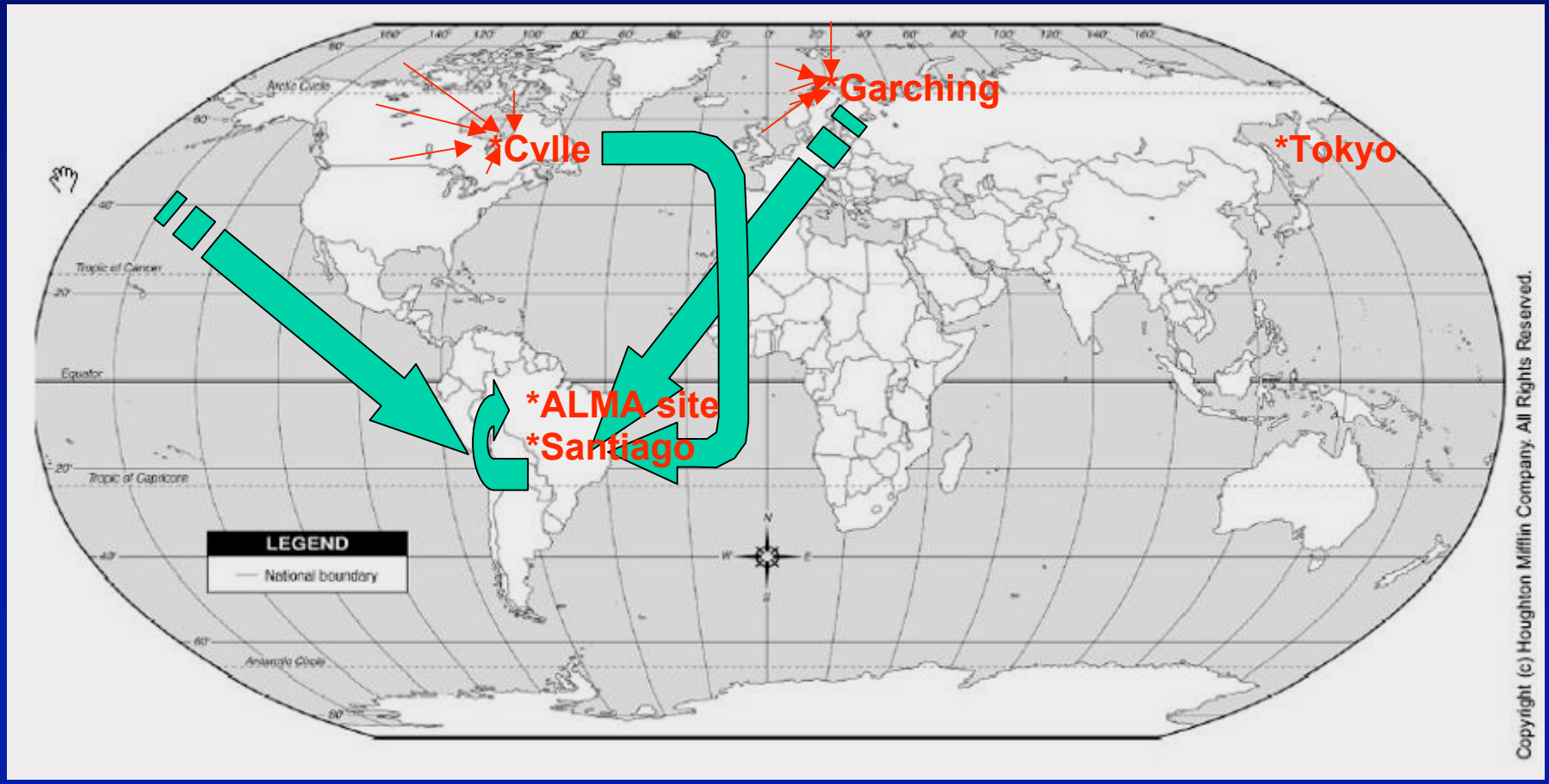
- All raw and calibration data
- All monitor data
- All data products produced by the standard pipeline (images etc.)
- Observing logs
- Proposals
- SBs
- Publications and other information

Virtual Observatory compliant



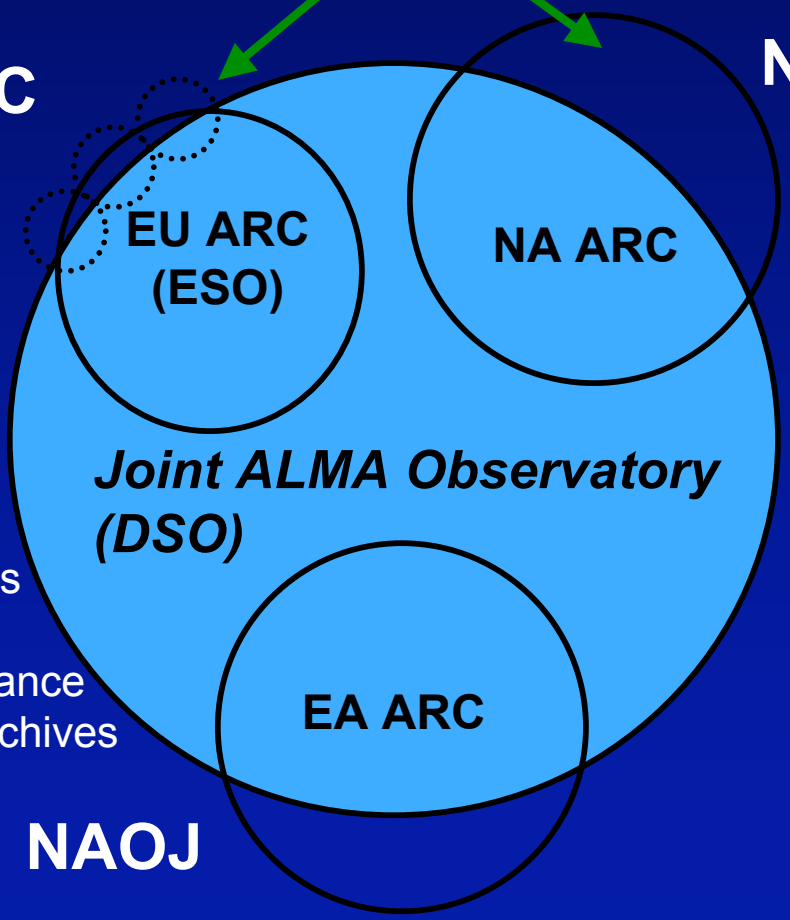
ALMA Regional Centers

The ARC's will provide support to the user community. This is where proposals will be sent, data will arrive and expert help on analysis will be provided.



Science Operations: organization

Enhanced User Services

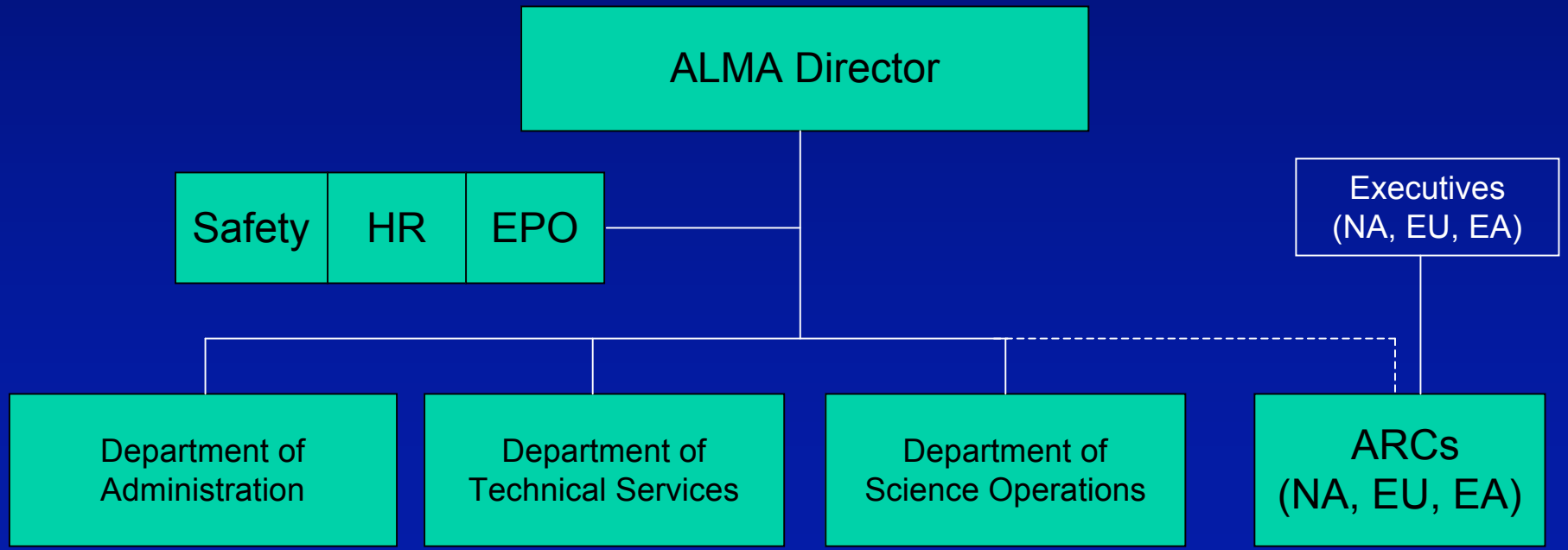


DSO provides:
- Array operations
- Scheduling of projects
- Execution of observations
- Data quality assurance
- Calibration plan maintenance
- Delivery of data to the archives

The ARCs are the interfaces to the user community.
The ARCs provide:
- software tools for proposal preparation, observation preparation, and data reduction
- user support
- delivery of data to the PIs

The Joint ALMA Observatory (JAO)

- ALMA is operated by the JAO.
- The ALMA Regional Centers (ARCs) form an integral part of JAO operations.



www.alma.cl

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership among Europe, Japan and North America, in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in Japan by the National Institutes of Natural Sciences (NINS) in cooperation with the Academia Sinica in Taiwan and in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC). ALMA construction and operations are led on behalf of Europe by ESO, on behalf of Japan by the National Astronomical Observatory of Japan (NAOJ) and on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI).