Optics working group

Summary of workshop discussions & recommendations

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Workshop guiding questions for optics group

Telescope design

- Assess the technical feasibility and cost impact of possible telescope designs, wrt:
  - aperture size, range 20 - 50 meters
  - field of view = 0.5 to several degrees
  - Possible wavelength coverage: need for THz capability (high surface accuracy and a high site) vs. large aperture
  - observing/operation efficiency
  - need for enclosure or ground shield
  - high receiver flexibility vs. cost-efficient optimization
- What specification meet the desired science case now and in a projected future?
  - Minimum size? (resolution, mapping speed, confusion limit, feathering with ALMA, FoM)
- What optical design has a sufficiently wide FoV and receiver cabin to accommodate future wideband and wide field instrumentation?
- What technological developments are anticipated that AtLAST would need to adapt over its lifetime?
- Need for future work on technology studies? Source of funding for these?
- How to engage industry: VA, MTM, …

Workshop guiding questions for optics group

Instrument requirements & accommodation:

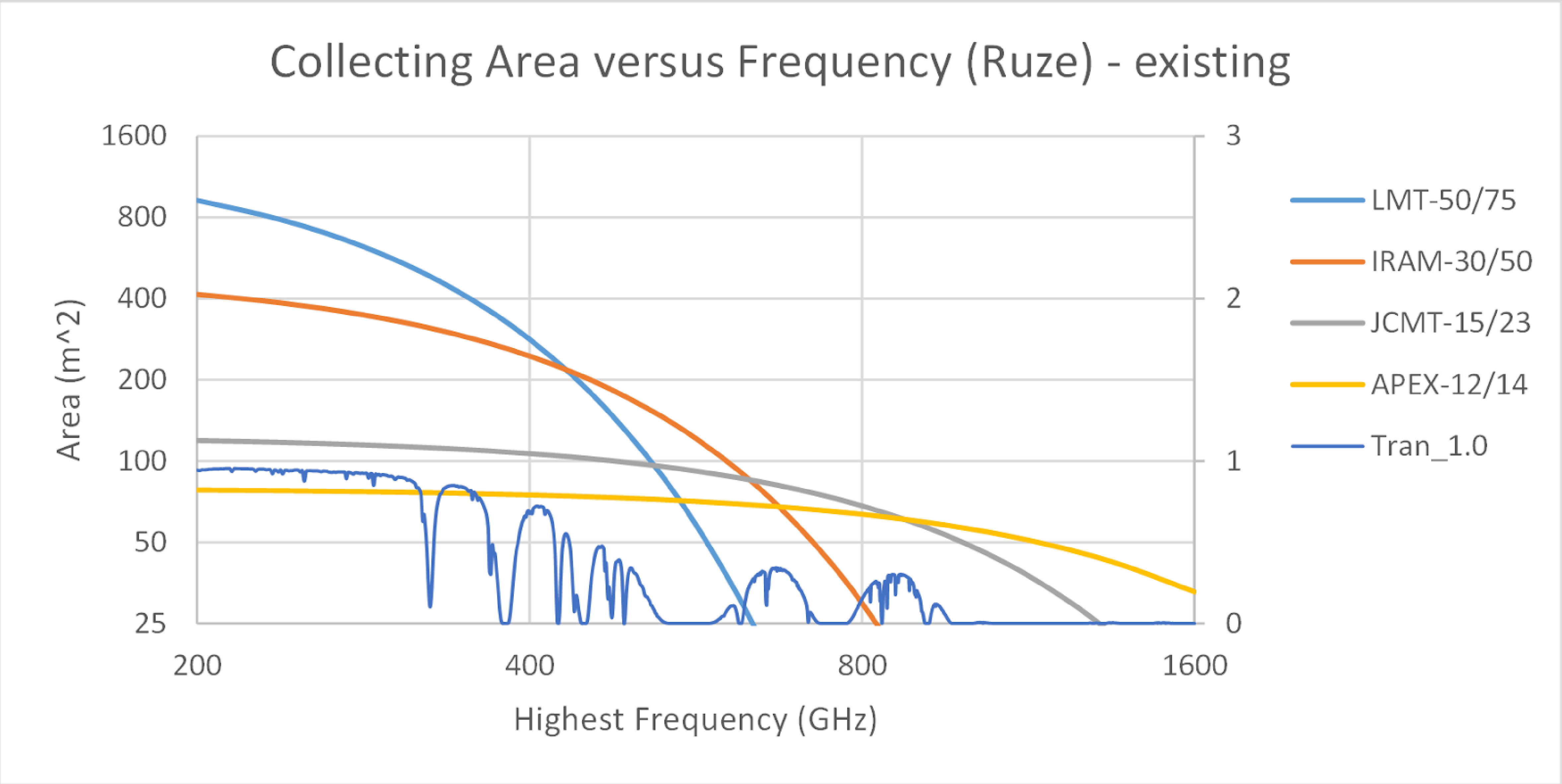
- Telescope focal plane dimensions
- Implications for re-imaging optics
- Access to instrument ports & switching
- Receiver cabin requirements – projected instrument volumes, mechanical stability & alignment etc
- Overall telescope structure – optimal placement of receiver cabin(s) – balance, access, sky rotation etc…
- Projected number of instruments – possibility of simultaneous observations using dichroics / beam splitters?

Telescope architecture

- On-axis design should be baseline UNLESS there is a compelling science case for an unobscured design
  - E.g. precision polarimetry key science driver
  - E.g. detector loading concerns
- Cassegrain / Gregorian-type solutions
  - Crossed-Dragone not an option for large apertures considered here
- Active surface control should be baseline
  - Correct for thermal & gravitational effects
  - Structure should be stiff enough to not worry about wind
  - But – could consider real-time surface correction…
- No compelling case for an enclosure
  - Costs considered prohibitive for 25-40m class telescope
  - Recommend spend a more on provision of “special measures”
    - De-icing system
    - Telescope structure
    - Active surface

Surface accuracy

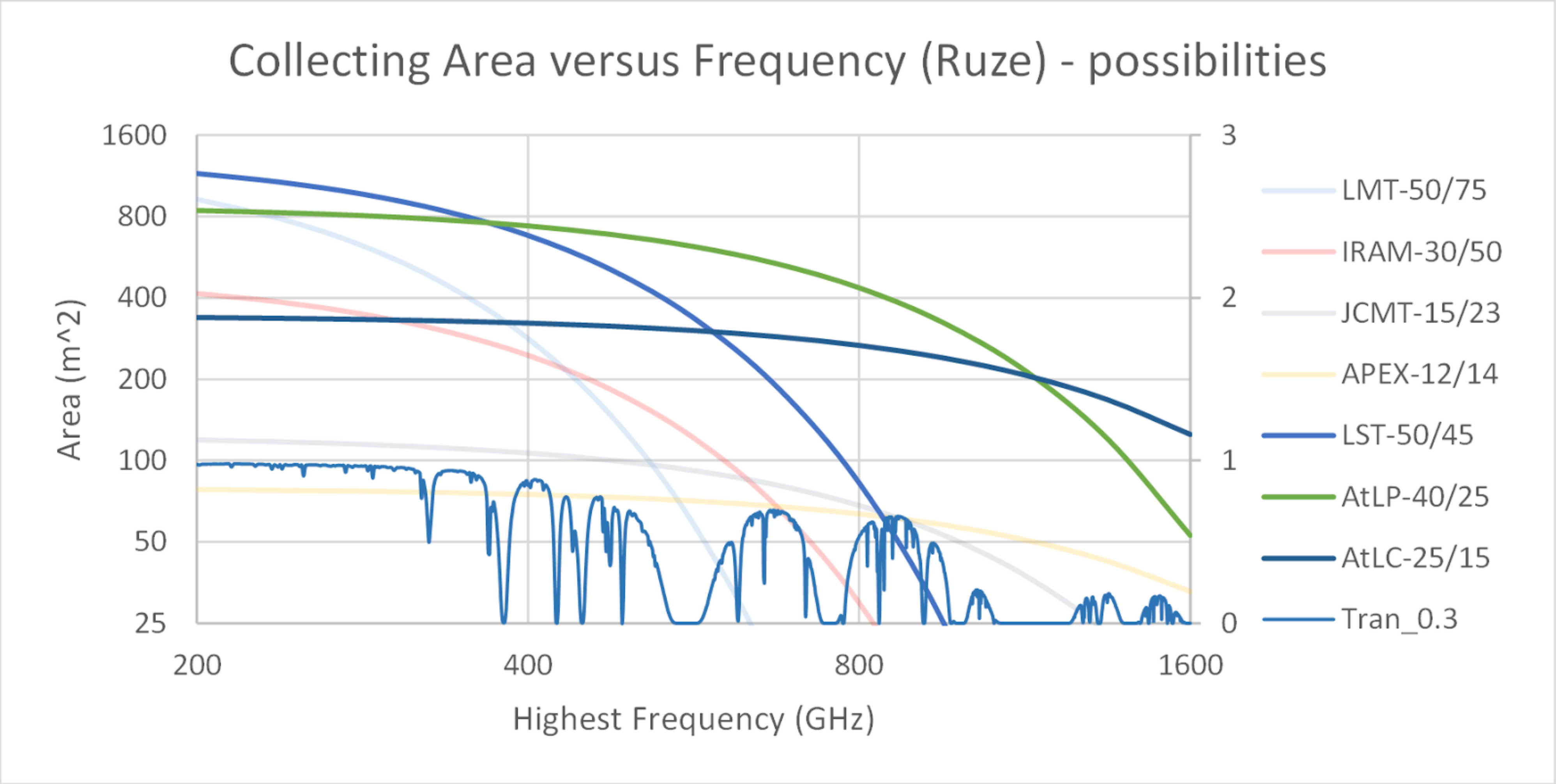
- Assume 350µm operation baseline
- Require better than 17µm RMS overall
  - CCAT – 25m diameter, 12µm RMS. Vertex / MTM design
  - More challenging for 40m class
- Current state-of-the-art:
  - LMT – 50m - ~75µm RMS. Could get to ~45µm RMS with current structure (panel upgrade)
  - IRAM – 30m - ~45µm RMS
  - JCMT – 15m - ~25µm RMS
  - APEX – 12m - ~14µm RMS



Area = $\pi/4 \,.\, D^2 \,.\, 0.7 \,.\, \exp[- (4\pi\ \sigma\ \nu / c)^2]$

Plots by Richard Hills (quick ‘n dirty…)

Configurations under discussion

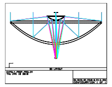


- Also quick 'n dirty…

Field of view

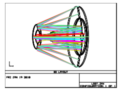
- Will produce quantitative examples of implications of Fov
- E.g. 50m / 1° FoV / f/6 = 5m diameter focal plane with 3.1m radius of curvature (LST example). LST secondary is 7m diameter.
- Implies (large) reimaging optics will almost certainly be required
  - Will enable flattening of focal plane
  - More convenient location for receiver cabin
  - Correction of aberrations
- Consider e.g. 0.5° for 50m class, 1° for 25m class?

Field of view - example



- E.g. 0.3° / 200µm, 0.8° / 1500µm
- f/2.5 – 1.3m focal plane diameter
- Just enough room for a fold mirror so you can rotate between receivers
- Receivers would have to move with telescope (no access while observing)
- Secondary =8m in order to get throughput & fast focus, curved focal plane
- Cold re-imaging optics can correct the beam further out – make that hole in the primary big enough.
- ~125k 2f*lambda pixels at 200µm and 50k 2f*lambda pixels at 1mm – we will be able to make & readout that many pixels in the future.

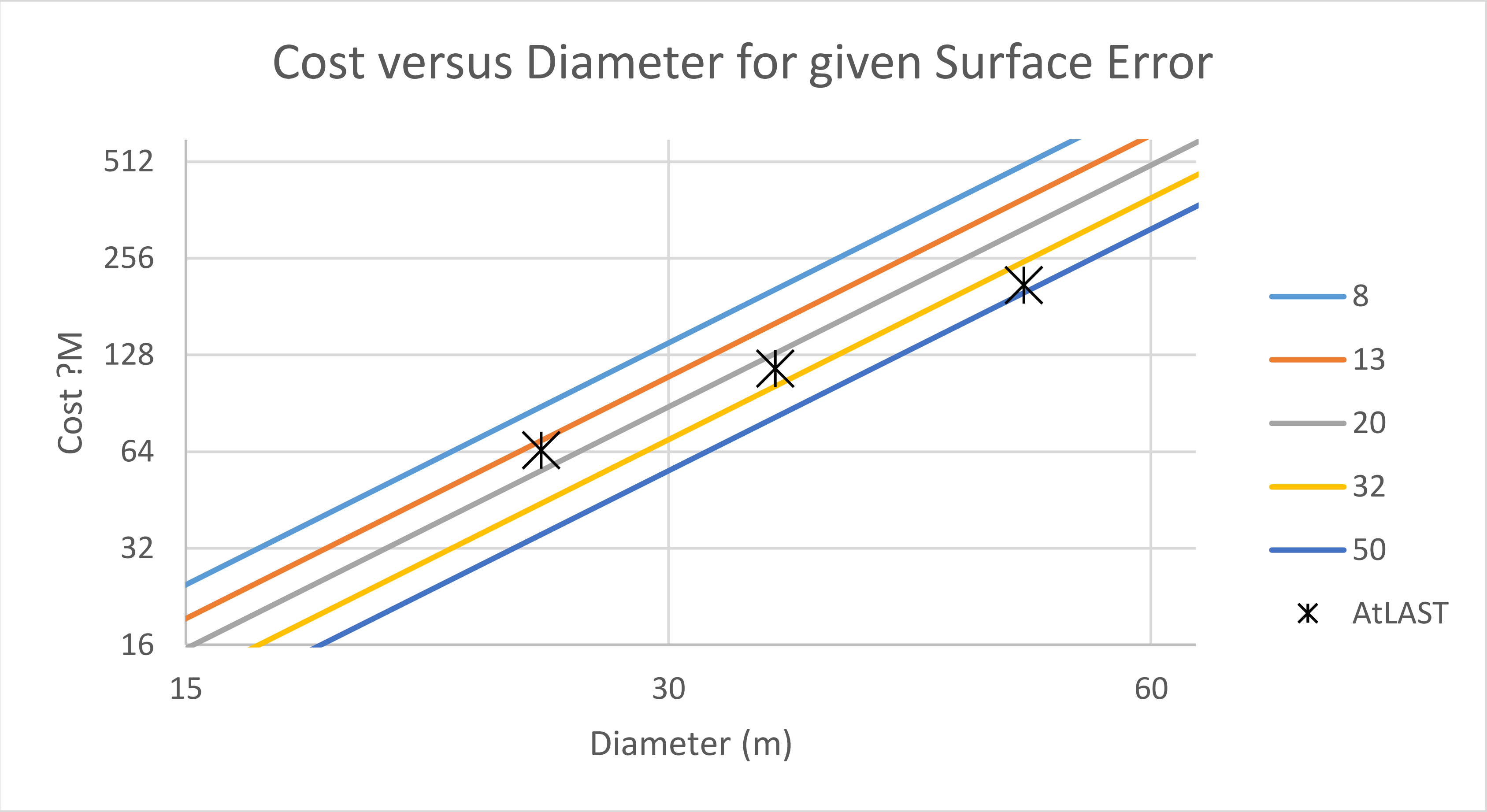
Field of view – 3-mirror example



- Three- mirrors designs can get larger fov (3 deg at 200μm) & a flat focal plane – but can we use such a fov (even in 30 years) – would be a pain to put the Rx there too – bit of a non-starter for something we might want more than one Rx on.

Plots of the historic cost equation - not to be taken seriously!

- Cost ∝ $D^{2.5} / \lambda_{min}^{0.5}$
- Telescope ONLY perhaps 50% of project? (25% for instruments, 25% for infrastructure, management, etc)
- Ignores added costs for higher sites.
- Assumes "non-political" procurement process.



- Normalized by assuming that a 25m diameter with a 25um surface costs 50?M.

Summary

- Key output from this group will be input to white paper
- In the absence of clear science drivers and instrument constraints at this stage, we will present matrices & plots to cover the full parameter space to guide the project
  - E.g. aperture vs RMS vs cost
  - E.g. aperture vs FoV vs performance etc
  - E.g. R.O.M. costings vs site vs everything…
  - E.g. quantitative implications on FoV vs aperture on focal plane, and receiver accommodation – cost / feasibility of reimaging optics
- Identification of breakpoints – technical possibilities & impossibilities, regardless of depth of pockets…

Enclosure: arguments

- Cost probably scales at nearly D^3, so becomes prohibitive at large sizes.
- Note that LMT/GMT 50m was originally to be in a radome, then a JCMT-style enclosure, but ended up open.
- Unless you go the whole way and use some sort of membrane, you don't get rid of all the wind forces or all direct heating by sun and cooling to sky. In fact the presence of the building may make these effects more complicated, e.g. thermal step function when you open the doors. Certainly harder to model the enclosed case.
- Weather protection is certainly important on sites where there is snow and ice, but those will also be a problem for a building. With good design it may actually be easier to get back into operation after a snow fall with an open design than with an enclosure. Should consider active de-icing system.
- Suggest we assume open-air design. Look for site with shelter from winds? (In northern Chile these are from the west under good observing conditions.)

Active Surface: arguments

- CSO, ALMA, IRAM 15 and 30m and Nobyama 45m are all Passive. Adjusters installed on JCMT but not used for compensation (reliability inadequate). GBT and LMT/GMT are active, but with relatively slow compensation.
- Active compensation much more practical now than it was >30 yrs ago: devices and especially multiplexed communication greatly improved and simplified. Our requirements are almost trivial compared to active mirrors on large optical telescopes.
- Once you decide that active control is essential for thermal and/or wind compensation, it is no longer relevant to worry about gravity deformations and in particular homology has no real value. Important issues for structure are stiffness and natural frequencies.
- Even the three-axis focus movement of the secondary is no longer required, although you might still want to have tip-tilt for fast pointing and perhaps chopping.
- Critical issue is metrology. Schemes using “multi-lateration” with laser beams look promising – absolute measurements and many beams are now available.