NGVLA antenna overview

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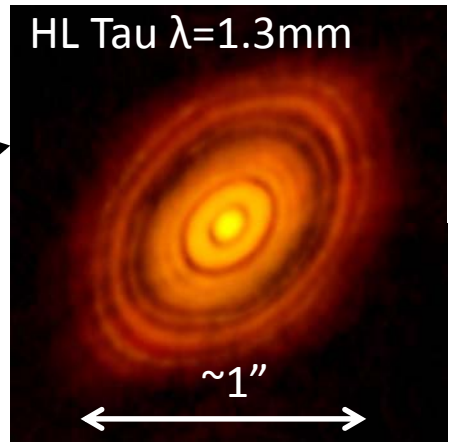
Top-level questions

- Total collecting area
  - 10× VLA?
    - number & size of antennas
    - any requirements for wide field of view?

Diameter	number
25m	270
18	520
12	1170

- Surface error
  - 180μm rms?
    - how important is λ=3mm?
    - efficiency
    - site

Surface rms	η
λ/10	0.206
λ/20	0.674
λ/40	0.906



Efficiency

Cost of an efficient antenna $\propto \lambda^{-1/2}$

Efficiency $\eta = \exp(4\pi\delta/\lambda)^2$

δ=surface error

Effective area of array $A_{tot} \propto \eta N$

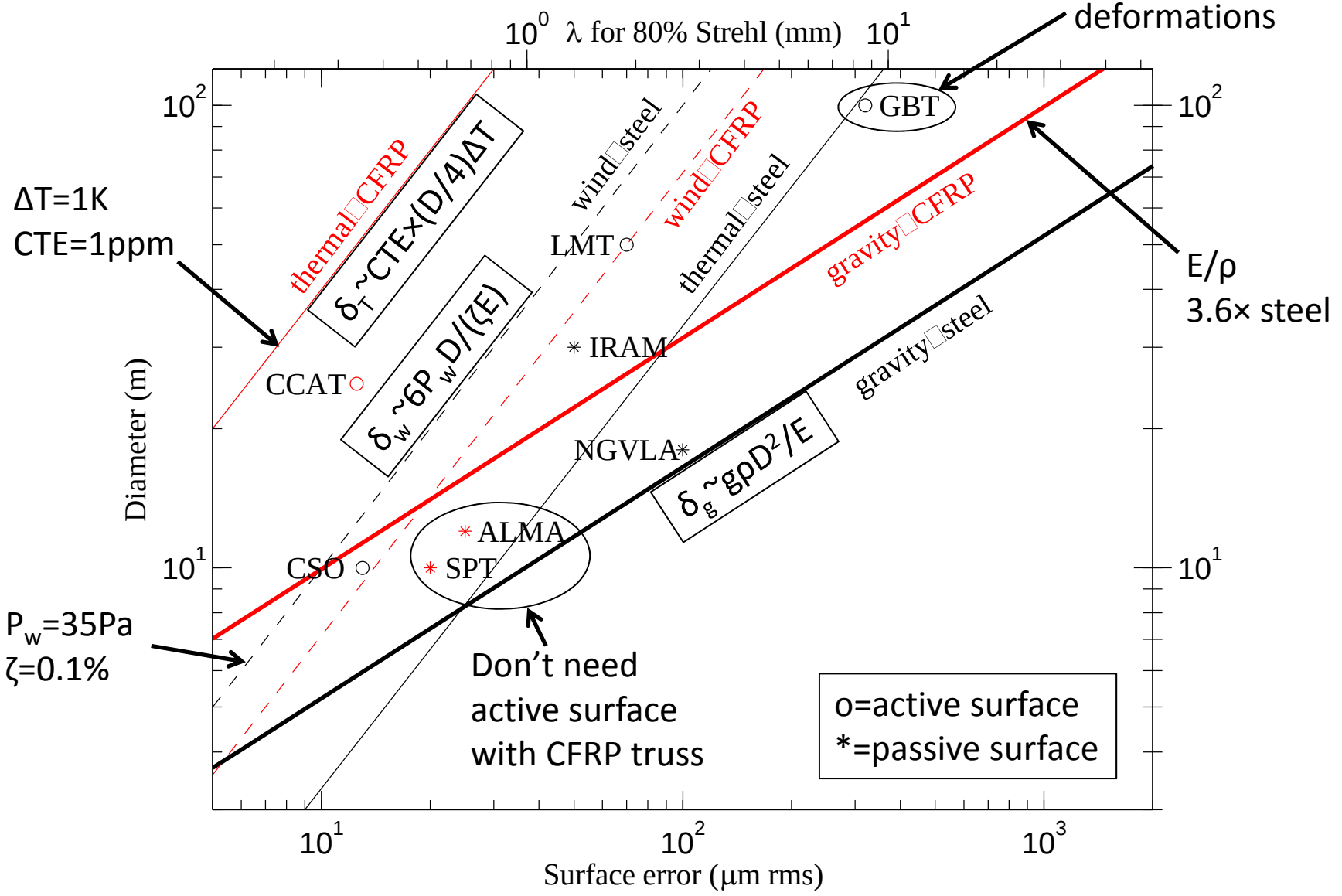
N=number of antennas

} Cost of all antennas $\propto A_{tot} \times [-\log(\eta)]^{1/4} / \eta$

For a given A_{tot}, D, & λ, efficient antennas minimize the cost

but you might choose lower efficiency antennas to get more area at longer λ

Antenna size vs. surface error



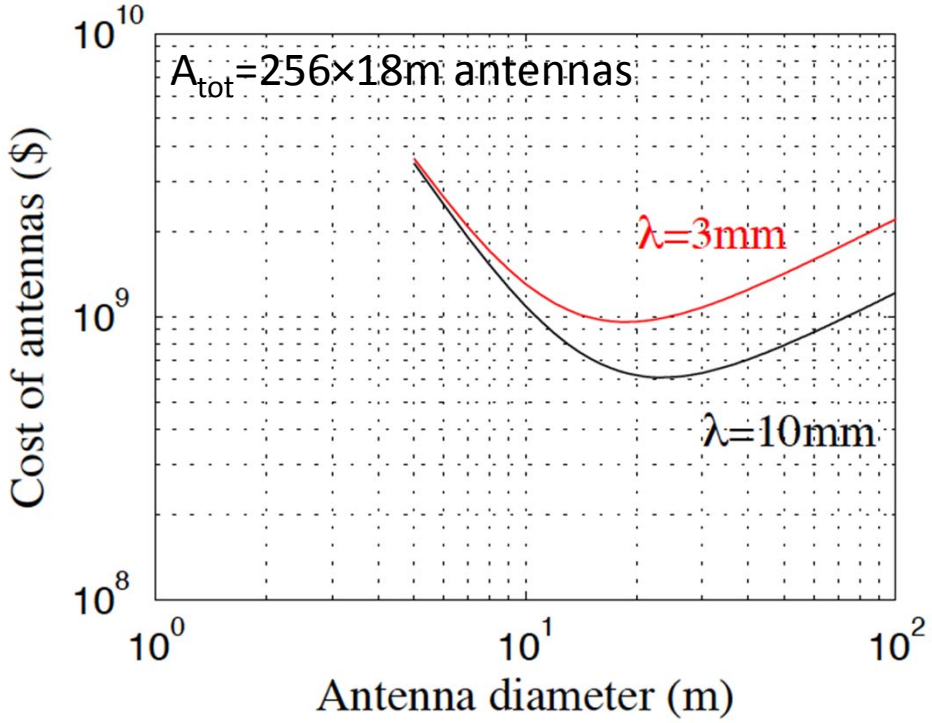
von Hoerner, AJ 1967

Cost vs. antenna size

Cost model for steel/Al antenna, η=0.8

Cost of all antennas = $N\times[1.5(D/18m)^{8/3}(\lambda/10mm)^{-1/2} + 1]$ \$M

Number of antennas — Structure, panels etc. — Servo, installation



Mid-level questions

- Reconfigurability

  Drives cost of structure & operations

- On or off axis

  Do any science goals demand very low scattering/sidelobes?

  If not, cost determines the choice

  mm λ

  Off axis cost ~2× on axis (SPT vs. ALMA)

  On axis blockage 3% (1% for secondary, 2% for support)

  Antenna cost ~$D^{8/3}$

  Cost off/on axis=$2/1.03^{8/3}$=1.8

  longer λ

  Off axis cost ~5/4× on axis (e.g., GBT)

  On axis blockage might be 10% (secondary diameter 10s of λ)

  Cost off/on axis~1

  Selecting feeds by tilting the secondary may favor on axis (cf. ALMA)

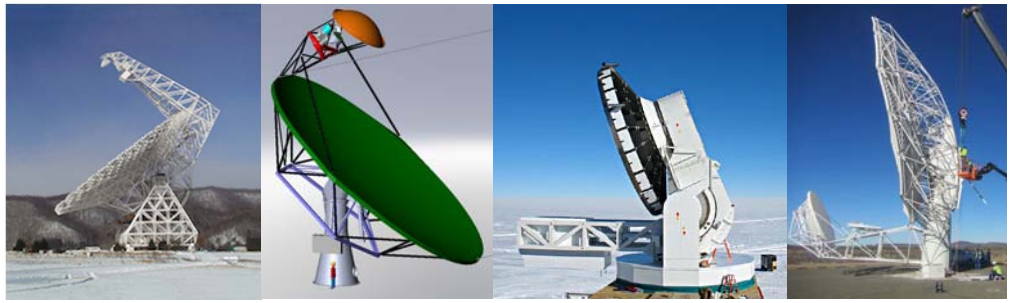
  RFI between adjacent antennas may be worse for off axis

Details

- Materials
  - Steel/Al vs. steel/CFRP
    - Don't need CFRP for performance, so this is mainly a cost decision
    - Long term stability a bigger concern for CFRP?
  - Panel size

- Pointing metrology
  - Traditional, stiff structure vs. floppy structure with metrology
    - Maintenance is a concern with metrology

- Offset arm at top or bottom
  - Bottom gives lower noise at low EL
  - Top gives less expensive structure

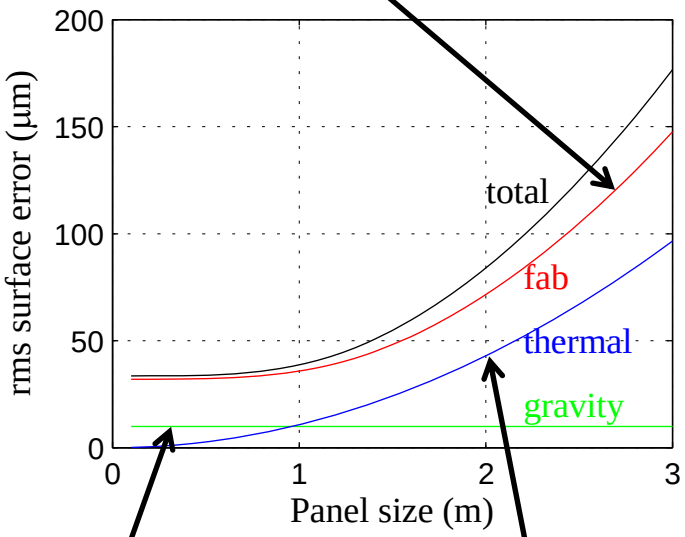


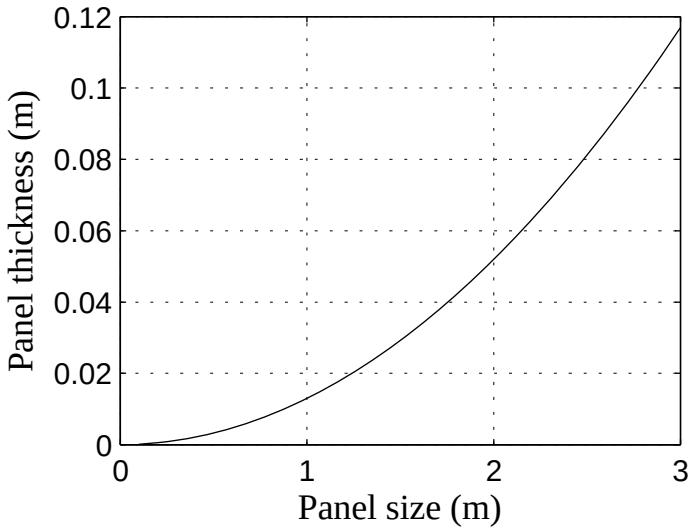
- Polarization
  - Feed will probably dominate
  - Stability generally more important than absolute value

- Shaping
  - ~7% improvement in efficiency
  - Requires a specific feed pattern
  - Can't tilt secondary to switch between feeds

Formed Al panels

$[\delta_f(\mu m)]^2=32^2+[16d(m)]^2$





$\delta_g=\gamma(q/F)(A/N)^2$

$\gamma=0.002$=support efficiency

$q=t\rho g$=pressure

$F=Et^3/12(1-\nu^2)$=flexural rigidity

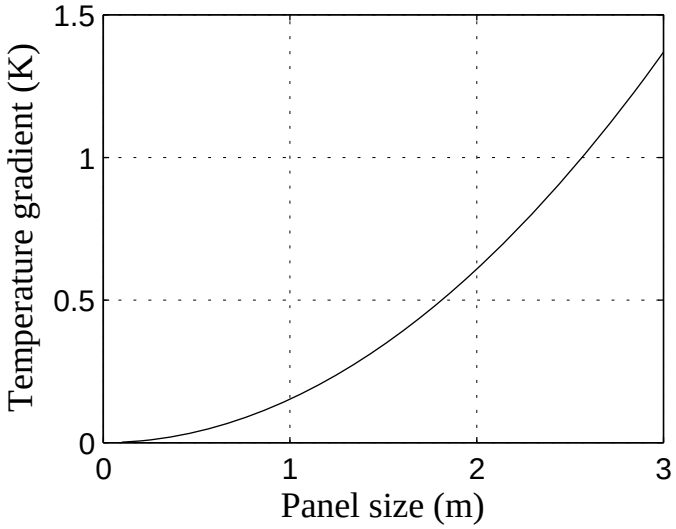
$N=3$=support points

Choose t to give $\delta_g=10\mu m$

$\delta_T=d^2\times CTE\times\Delta T/24t$

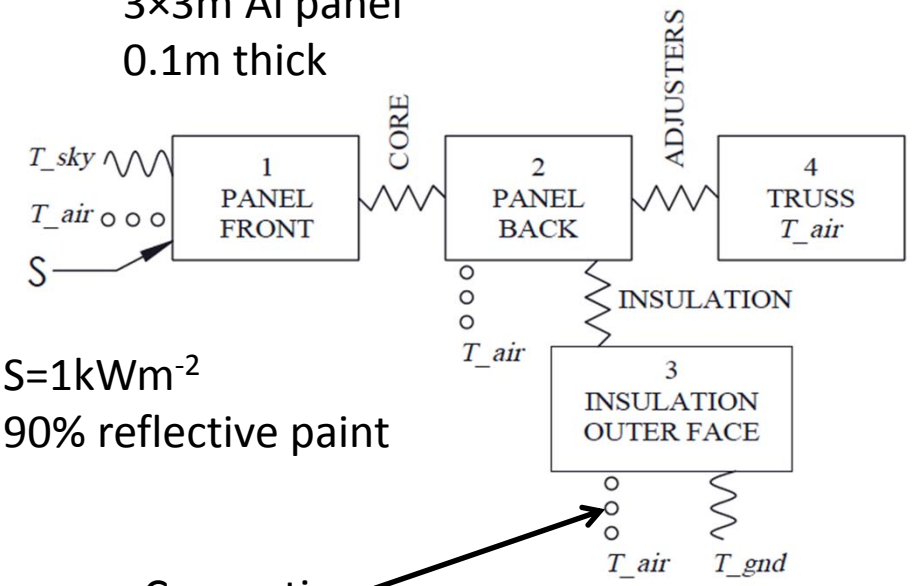
$\Delta T=[\sigma\varepsilon t/(2\times TC)](T^4_{sky}\varepsilon_{sky}-T^4_{gnd}\varepsilon_{gnd})$

radiation only



Panel thermal gradient

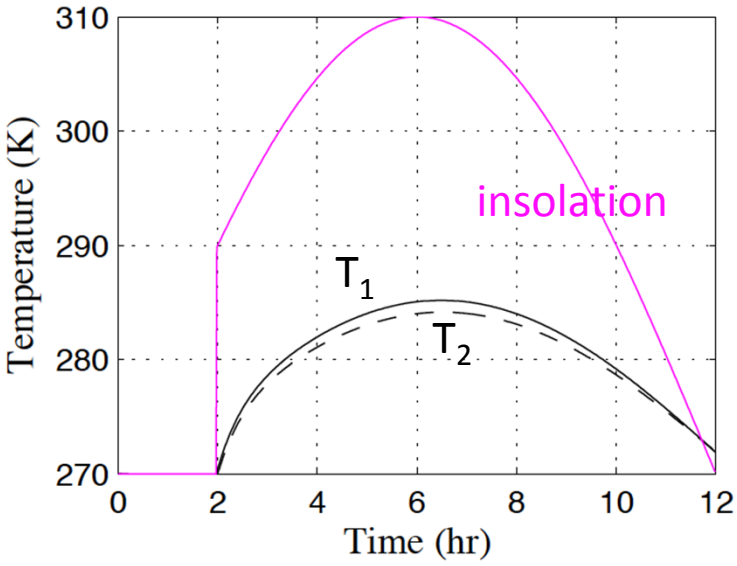
3×3m Al panel
0.1m thick

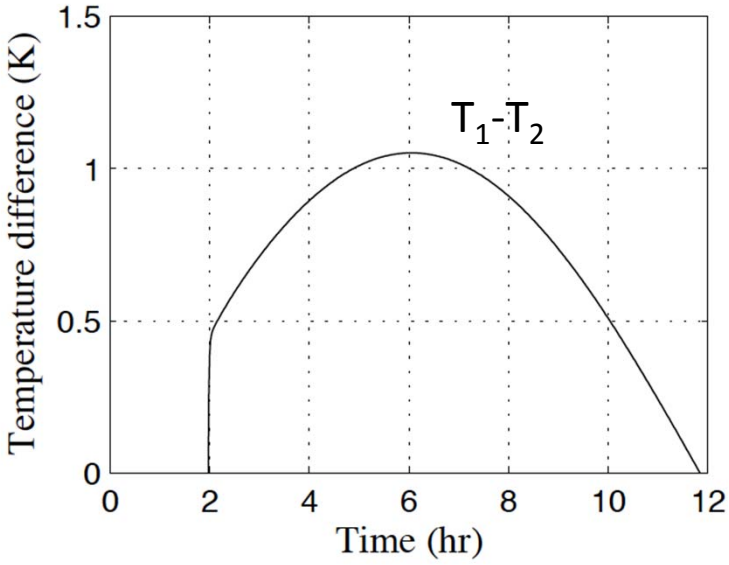


S=1kWm^{-2}
90% reflective paint

Convection
5 Wm^{-2}K^{-1}

25mm foam on
90% of panel back





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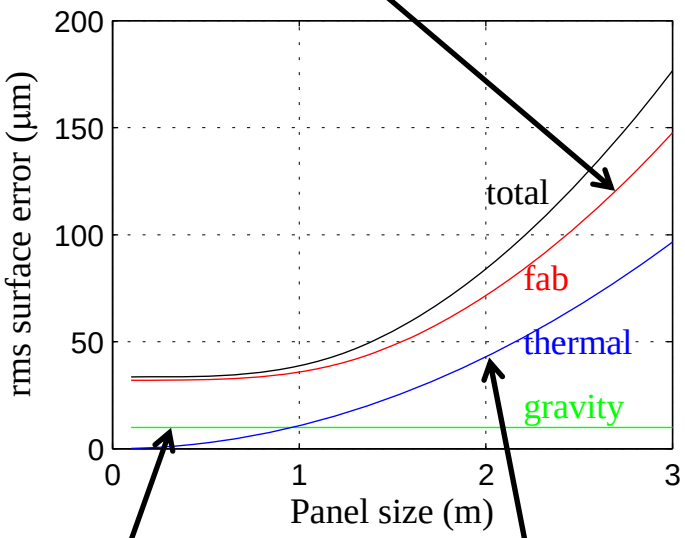

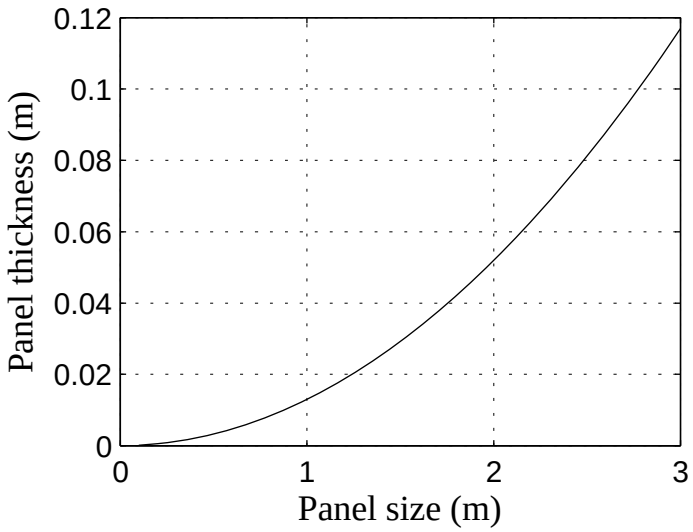

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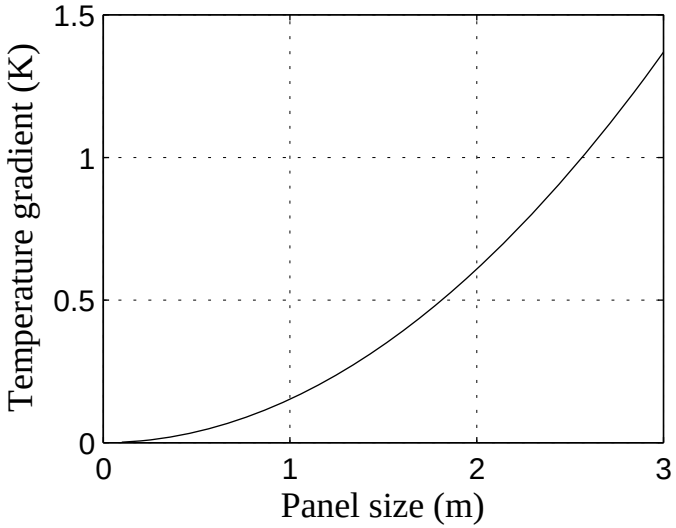

Next steps

- Understand science constraints
  - A_{tot} & surface error set the scope of this project (antenna cost, site)
    - D likely unconstrained
  - Reconfigurability is an important cost driver
  - Polarization, scattering, sidelobes, shaping probably not so important
    - but determine on vs. off axis, receiver details

- Identify candidate approaches
  - e.g., today's presentations
  - Start working with companies

- Develop models for cost vs. D, λ (and maybe on/off axis)
  - Limited information from companies
    - Scientists want max performance/$; companies want max $
  - Small contract(s) to develop cost models?

- Write antenna requirements
  - Need basic requirements for prototypes
  - Require good design practice?
    - symmetry
    - flexures at material change