Sustainable Energy for ALMA

ALMA Development Workshop

Richard Prestage (NRAO) and Roger Angel (University of Arizona)

22 March 2011

THE UNIVERSITY OF ARIZONA

Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

NRAO

Outline

- ALMA Power Requirements
- Alternatives for Sustainable Energy
- Concentrating Photo-Voltaic (CPV) solar power as a disruptive technology
- Current work by University of Arizona
- Areas where ALMA Design Studies are required
- Summary

ALMA Power Requirements

- Average Power Consumption: 4.2MW
- Baseline Permanent Power Supply (PPS):
  - Three multi-fuel turbines running on Liquified Petroleum Gas (LPG – propane)
- ***Yearly fuel cost $US 9.6M / year***

- May be augmented by "combined-cycle" bolt-on option:
  - Uses waste heat to produce steam and hence extra eletricity
  - Cost of this system is approximately $US 13.6M

- Although turbines are "multi-fuel", only LPG delivery and storage infrastructure is anticipated.
  - ALMA will be dependent on a single type of fuel

ALMA Power Requirements

	4.2MW no CC	4.2MW with CC
Average Power (MW)	4.2	4.2
Yearly Energy (GWh)	36.8	36.8
Yearly Fuel Consumption (Ml)	17.3	10.6
Yearly Fuel Cost	US $9.6M	US $5.9M
Yearly Fuel – Olympic Swimming Pools	7	4
Yearly Fuel – 747 10 hour plane flights	133	80
Specific Energy Cost	26¢ / kWh	16¢ / kWh

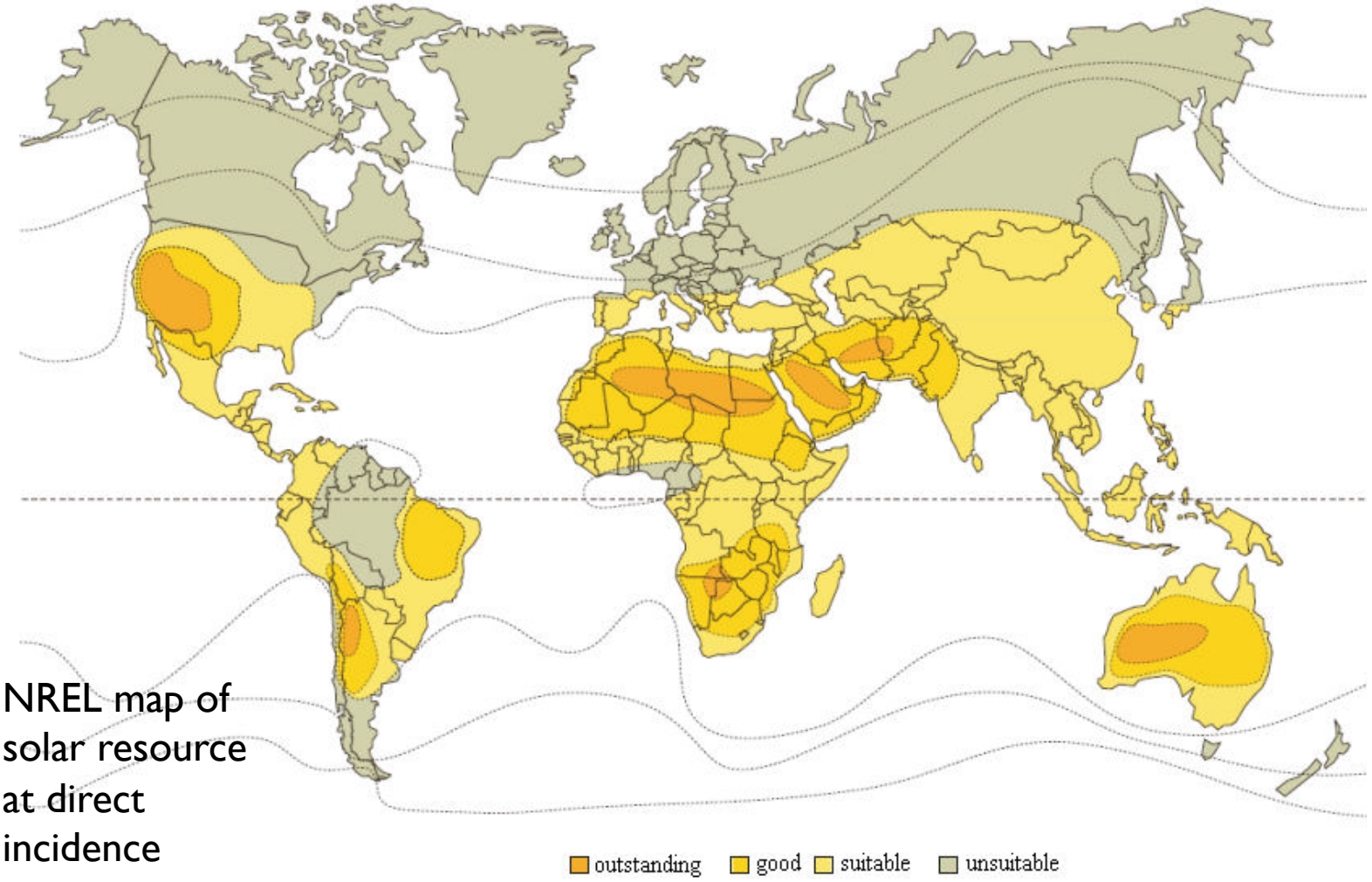
- CC reduces energy costs by 10¢ / kWh for $14 million capital cost
- Adding 4 MW of solar with 30% capacity factor would save a similar factor
- Installed cost of $3.50/watt needed and possible for solar

Alternatives for Sustainable Energy

- Possible alternative energy technologies to supplement and eventually replace multi-fuel turbines. Note considerations favorable for renewable:
  - Large load, high cost by conventional fuel generation
  - Remote desert location
  - Clear sky – exceptional solar resource for tracking PV
- Three main alternative energy sources:
  - Wind
  - Solar
  - Geothermal

Wind and Geothermal have a variety of problems => Solar

More than enough desert sunshine to power the world



NREL map of solar resource at direct incidence

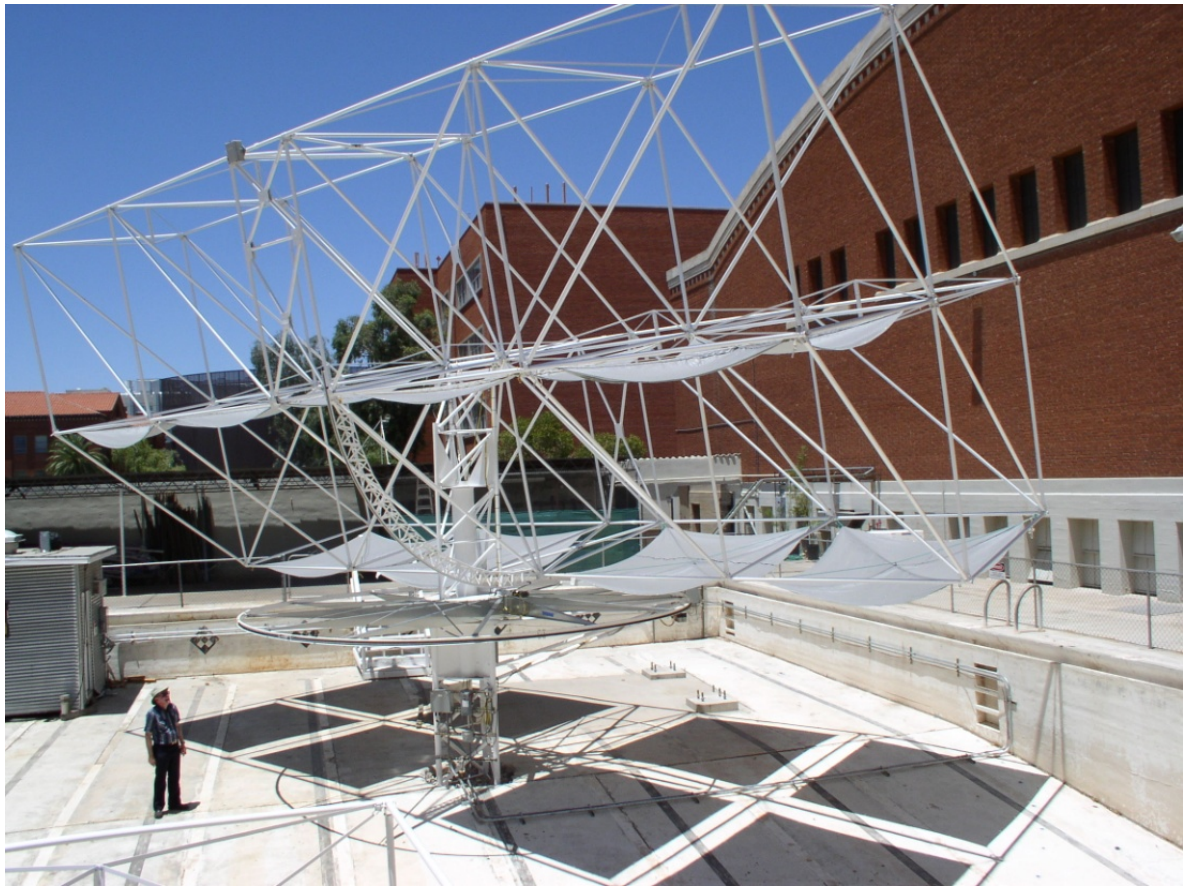
ALMA + Solar: A Match Made in Heaven

- How could the world's most advance large-scale science / technological experiment not run on sustainable energy?
  - Do we really want to burn 7 swimming pools of LPG per year?
  - Huge public support / PR opportunities
- ALMA (and EVLA) are ideally situated for solar energy
- Application (providing incremental power, no storage necessary) is ideal
- A large, highly-qualified workforce is available right on site.

Concentrating Photo-Voltaic Technology

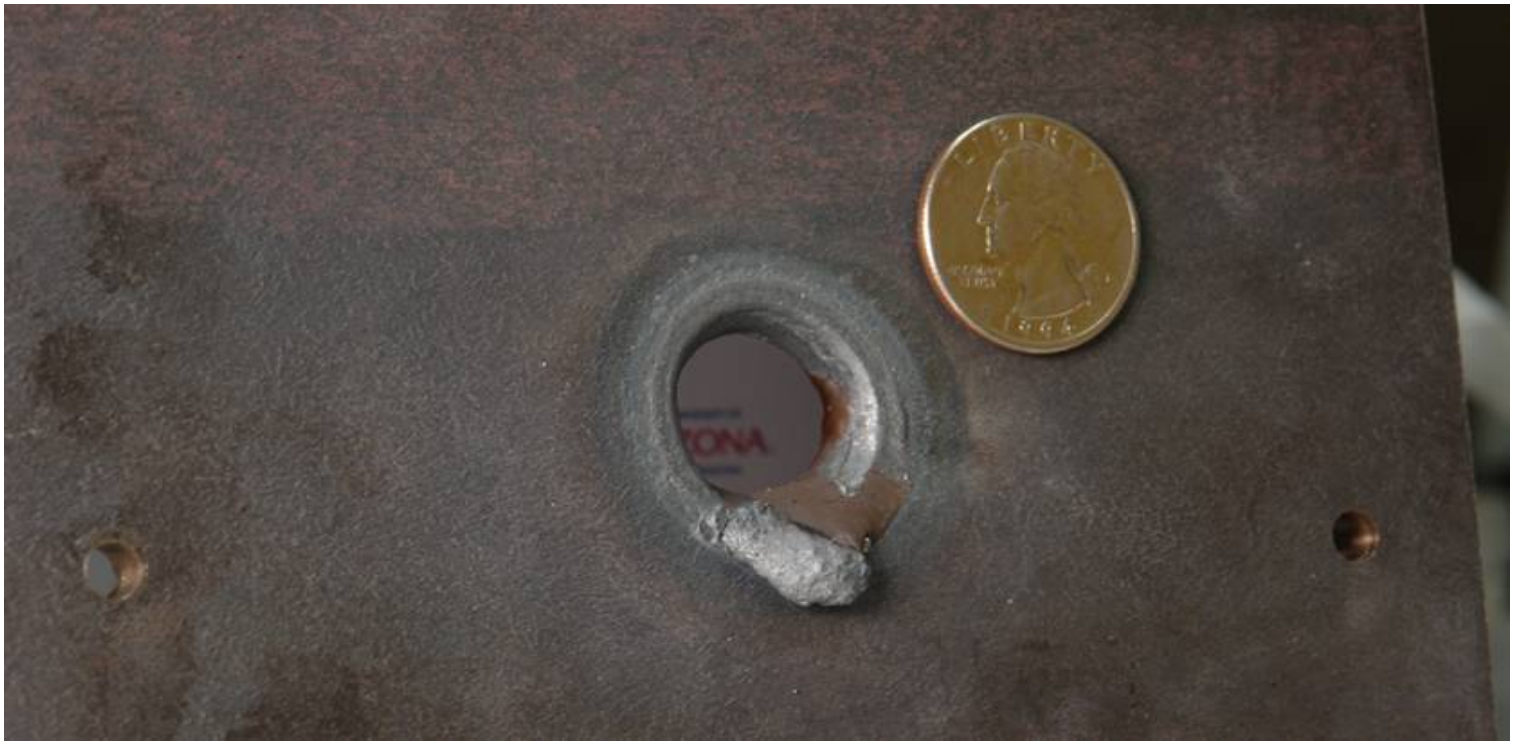
- Energy from burning fossil fuel, nuclear reactions and hydro is concentrated - inexpensive to convert
- Sunlight energy is dilute - expensive to convert. Need to concentrate the light:
  - Photovoltaic flat panel - PV
    - fixed or
    - single axis tracking
  - Concentration with thermal conversion - CSP
    - single axis (trough) and dual axis (dish)
    - with/without thermal storage
  - Concentration with photovoltaics - CPV
    - single axis (trough, low concentration)
    - dual axis (dish, high concentration)

Current Work by University of Arizona



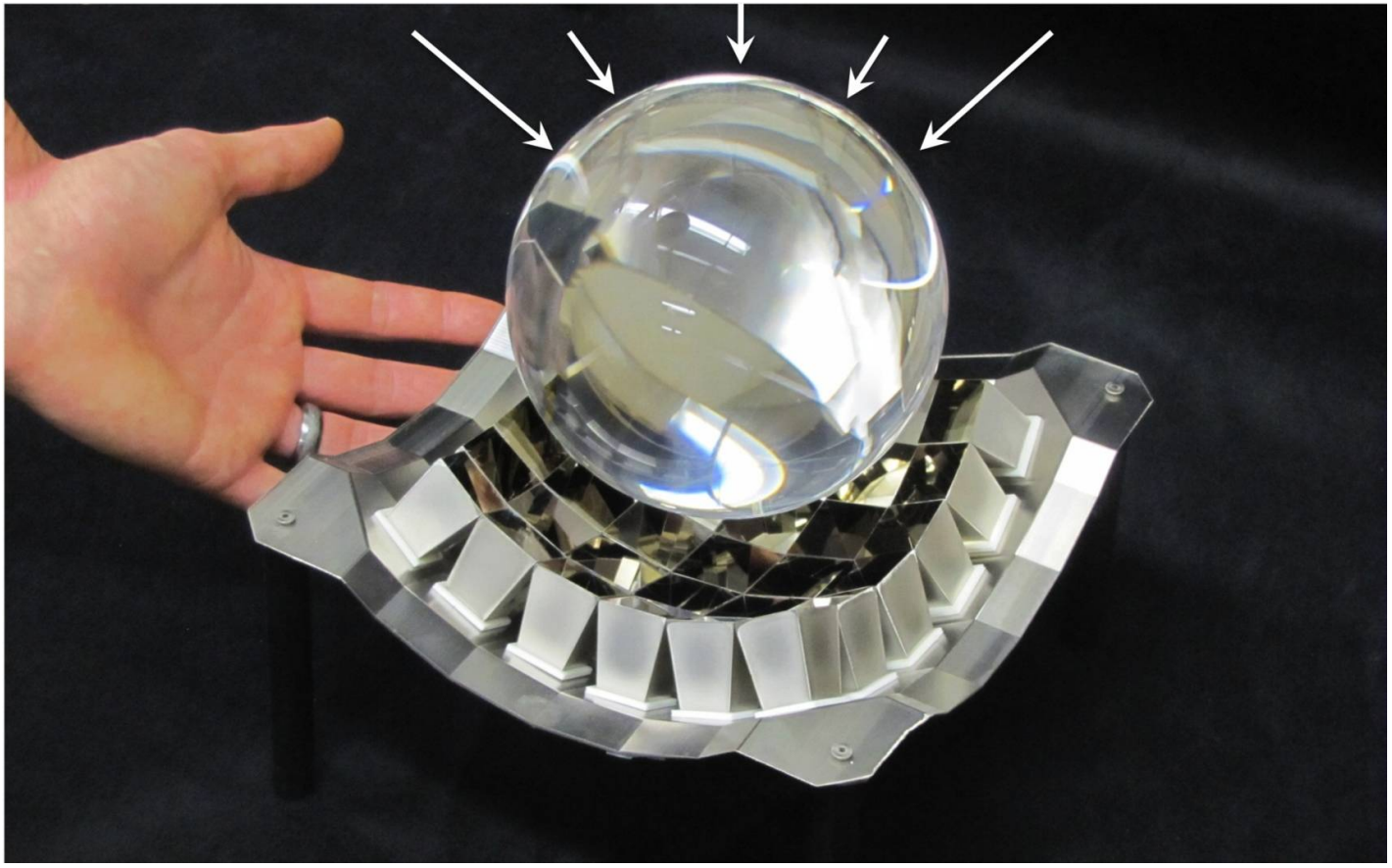
20 kW prototype at UA. The full scale mechanical tracker weighs 2 tons including foundation, and tracks 99% of the time within 0.1° accuracy

15 sec exposure at focus



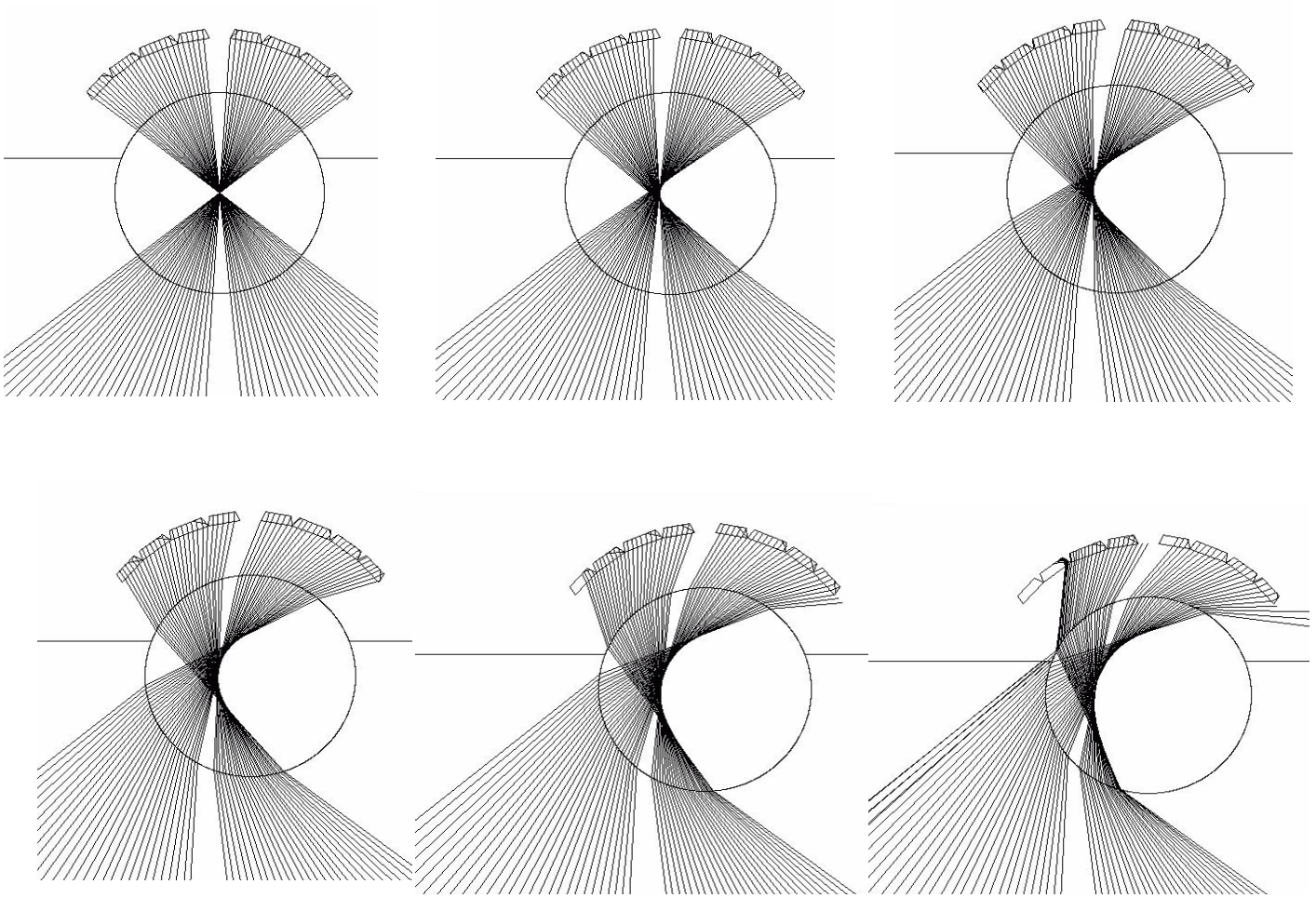
- melts a quarter-sized hole in ¼" thick steel
- don't try this at home
- optics can spread this energy uniformly across concentrator PV cells

UA solution allows use of large dish collectors

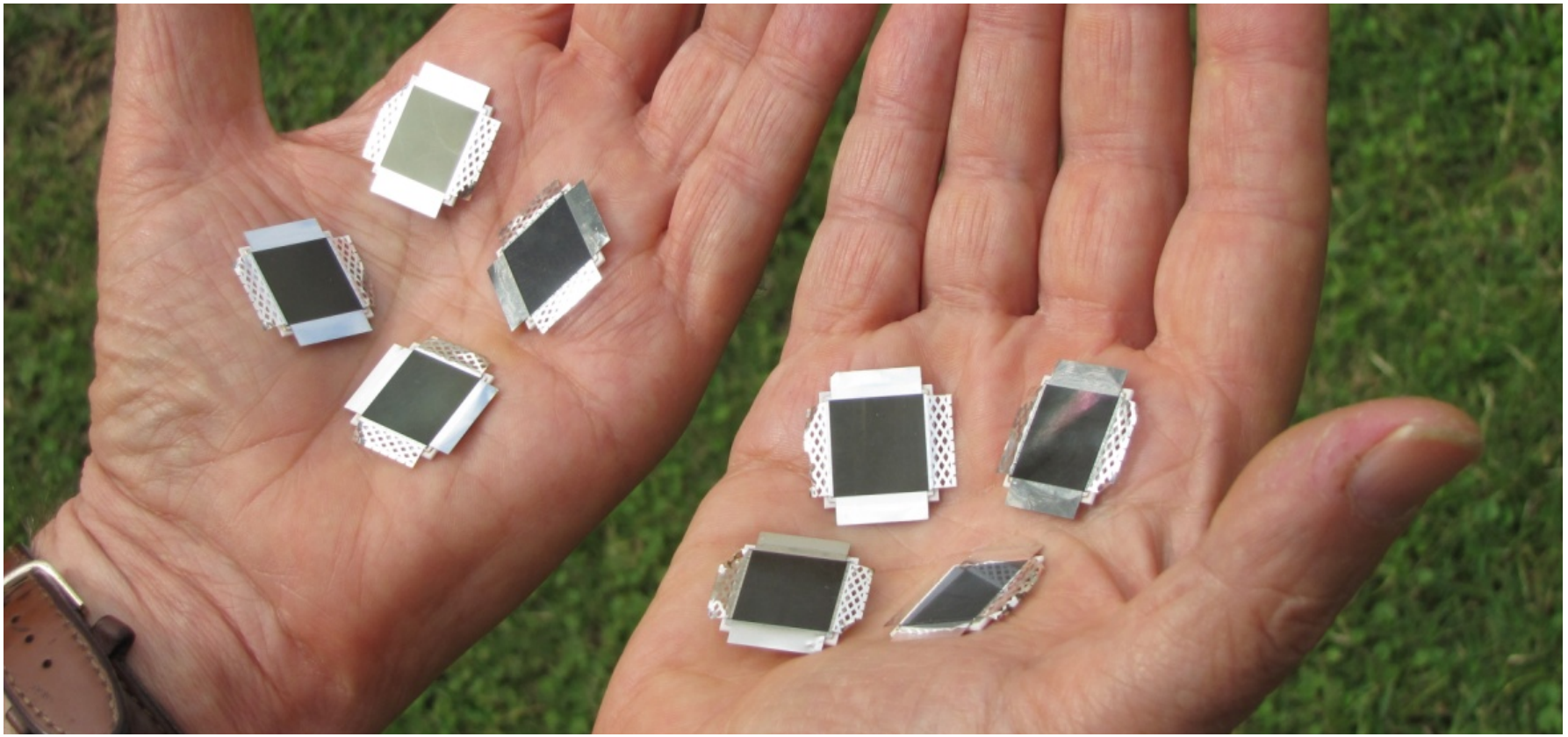


- Unique receiver optics take in strongly focused sunlight energy and apportion it equally to cells

The ball lens stabilizes against tracking error



Eight triple junction PV cells used at the focus @ 1000x concentration



Requirements for Design Studies

1. ALMA Solar Power Design Study
   – Study to confirm current power costs, define solar power generator location, required capacity, etc. in more detail than existing design studies.
2. Sun – to – grid optimization
   – Maximally effective system requires detailed optimization of complete system. This is a system integration problem; NRAO has ideal expertise.
3. Detailed mount analysis
   – Synergy with development of large N small D Interferometers
4. Inverters
   – U. of A. solution requires fairly specialized inverters for maximum DC-AC conversion. Intelligent, compact electronics required.

- Each problem amenable to ~ six month design study for $50k
- Need further work and discussion with University of Arizona to decide best path forward

Acknowledgements

- Large team at University of Arizona
- Drexel ALMA Research Team
- Lewis Ball for detailed ALMA Energy Costs

The Future…