



# SKA as a green infrastructure

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Michael Kramer

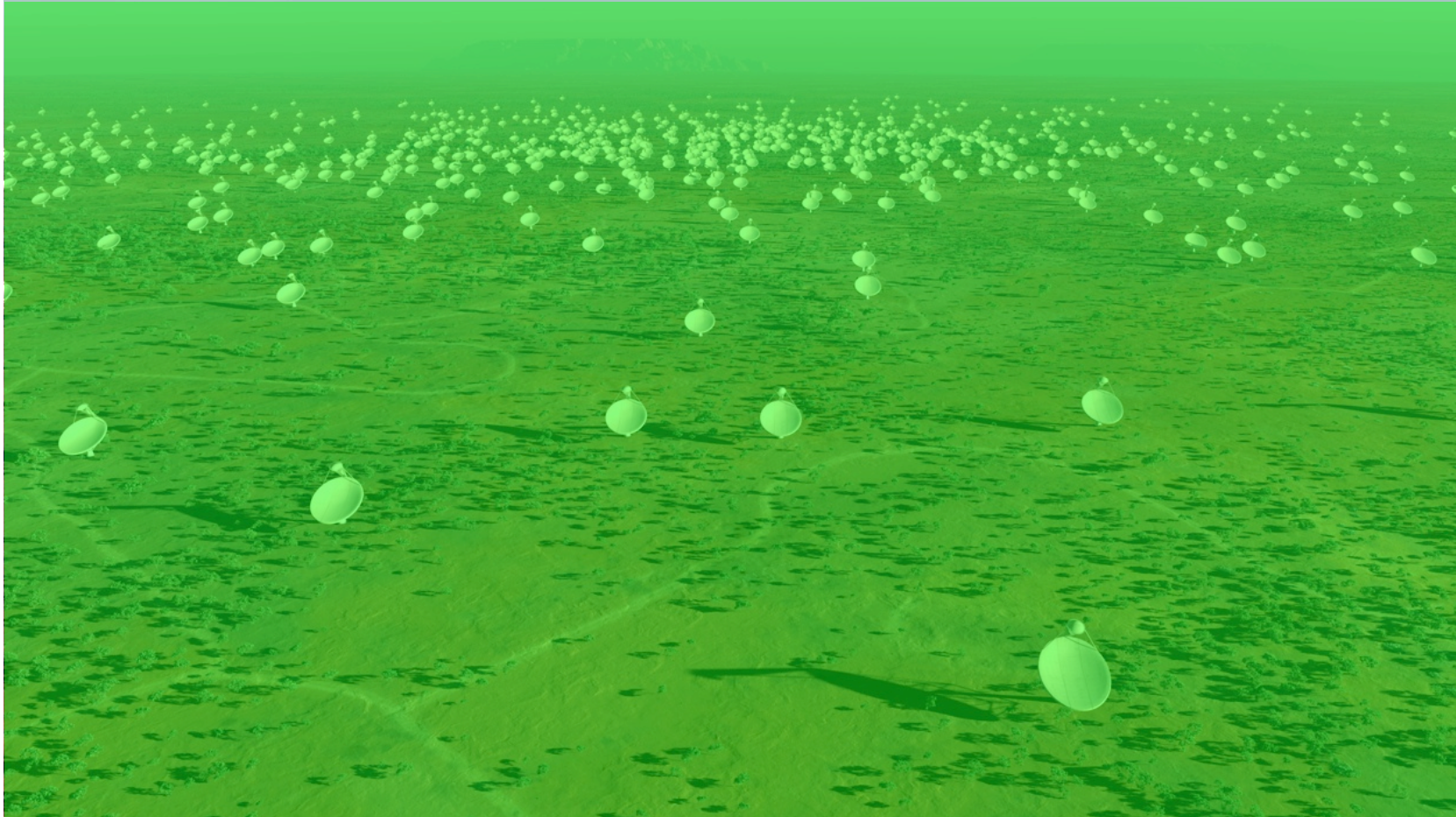
20 June 2012





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Michael Kramer  
20 June 2012

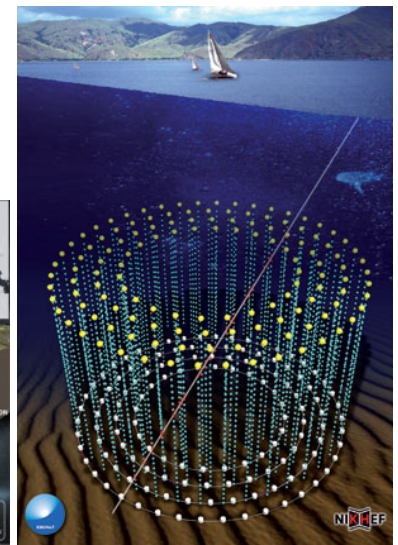
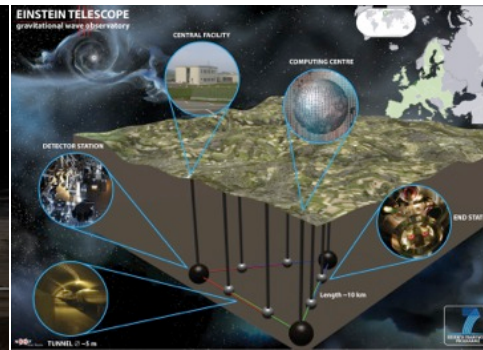
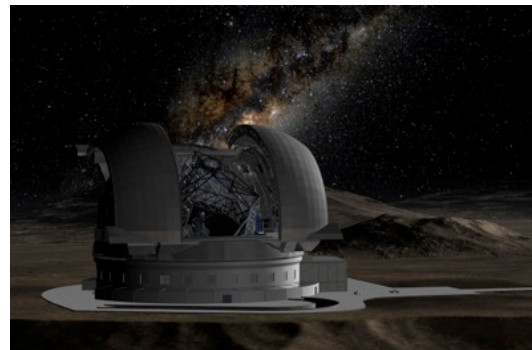
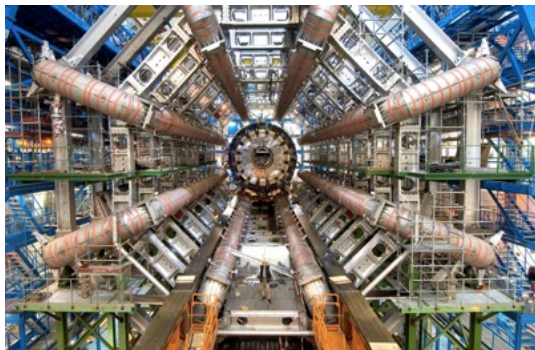


# Time for **Big** Machines

We live in exciting times:

- we are on the verge of confirming some of the most revolutionary theories
- we find clues as to whether these theories are complete or not
- we may find a way to describe large and small scales with one theory
- we are about to trace the complete history of the universe
- we are about to study extra-solar worlds and Earth-like planets
- we are about to open a truly new window to the Universe

But.... It takes increasing efforts to make such fundamental and important discoveries – it needs (typically) BIG machines





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These machines need to be powered – for a long time, hopefully!

➔ Operation costs as well as carbon footprint must be addressed!

This is a realization for a many projects – see talk by Thomas Parker

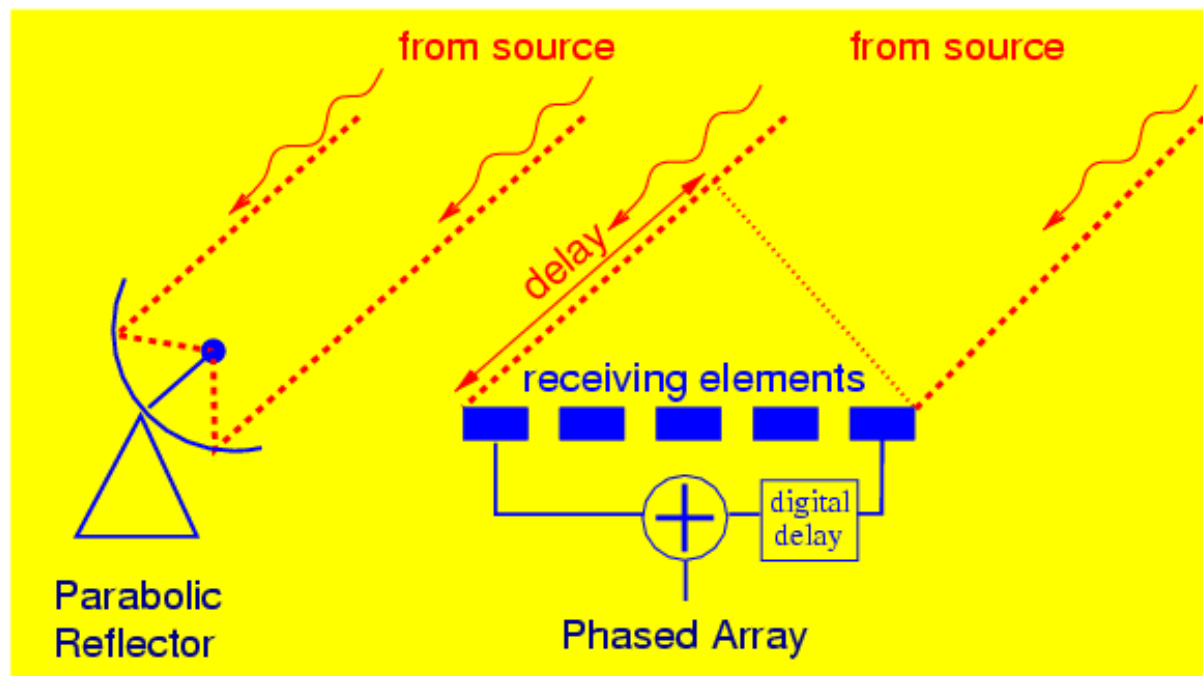
- here, a radio astronomical example: the SKA!





# A Revolution in Radio Astronomy

- Go digital! Ability to sample, digitize & process wide bandwidths
- Use of commodity computing power (incl. GPUs) and FPGAs
- Ways of obtaining “cheap” collecting area
- Replacing hardware (i.e. metal) with electronic and software
- Build “radio cameras” to increase “field-of-view” on sky and even allow to look in (sometimes) vastly different directions:



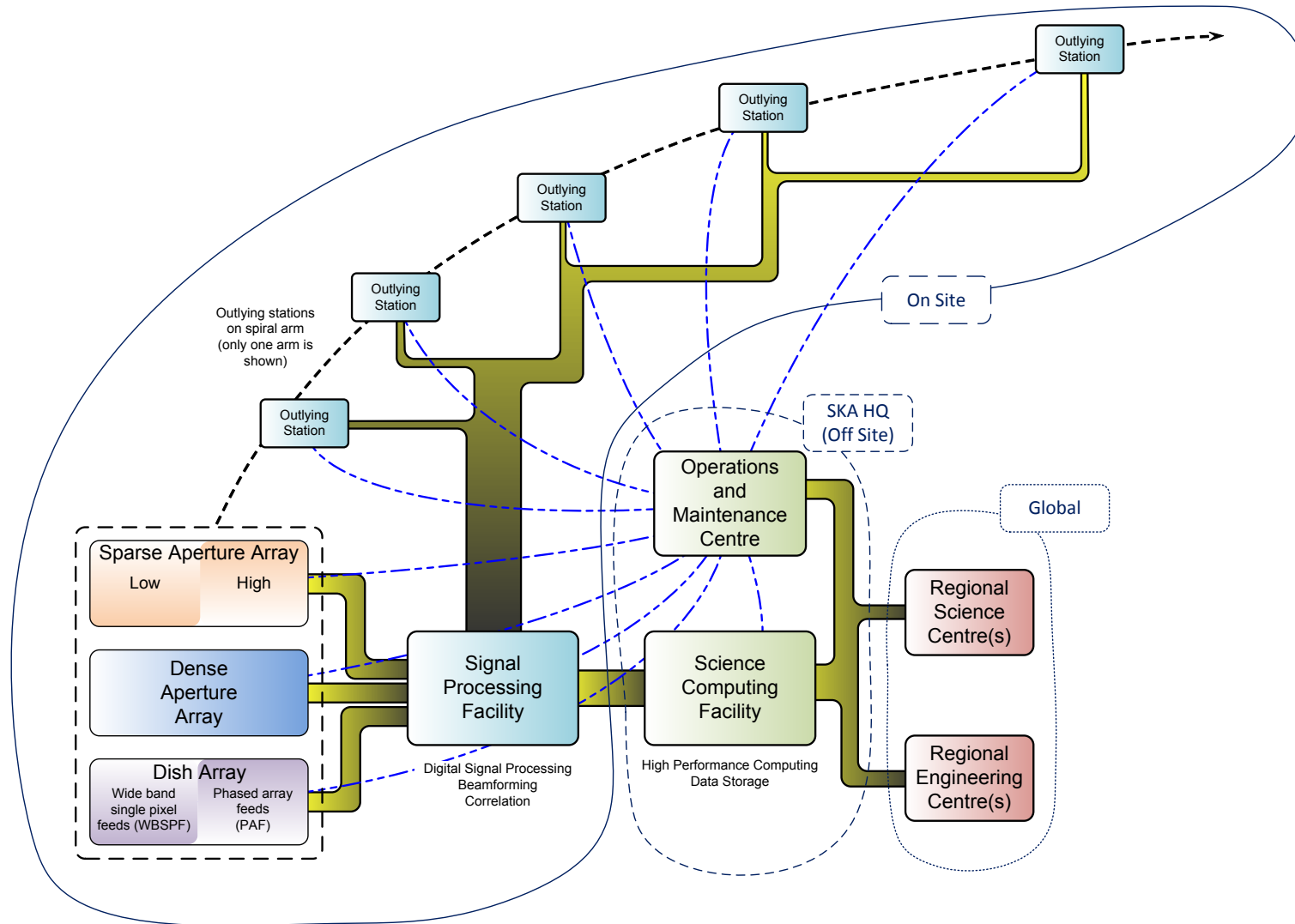
These components are power hungry – we need to feed them!







# System Block Diagram





# Signal transport networks



European Very Long  
Baseline Interferometry  
Network (1 Gbit/s)

EC-FP6 EXPReS

## SKA data rates

80 Gbit/s/beam/dish (<200km)

40 Gbit/s/station (20 dishes) (>200km)

} ~100 Tbits/sec!

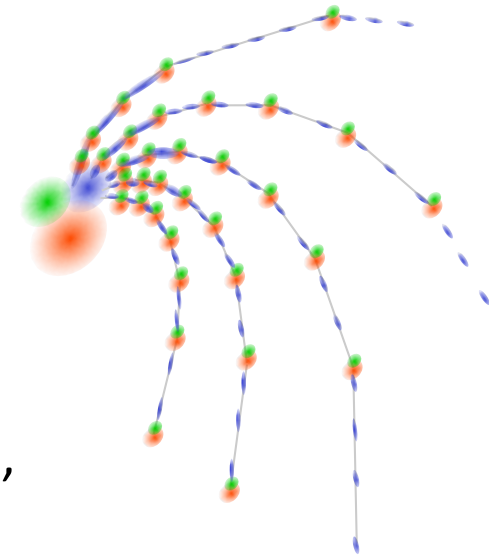
About 1 Exabyte per day!! → We need Exa-Scale HPC – that needs power!!





# Energy supply

- Digital electronic needs **power** and needs **cooling**
- Running costs probably **dominated by energy costs**
- Sites are far away from civilisation centres and **power grid**
- **Different power requirements** – energy mix!
  - Core(s): ~30 to 50 MW
  - HPC centre near core: ca. 50 MW
  - Distant stations: each ~100 kW for ca. 80 stations
  - Differences in peak and average demand (Electronic, cooling, telescope movements)
- Continuous operation 24/7: **Storage required?!**
- Avoid variations in power supply: **power stability**
- **Environment:** Temperature changes, wind, rain

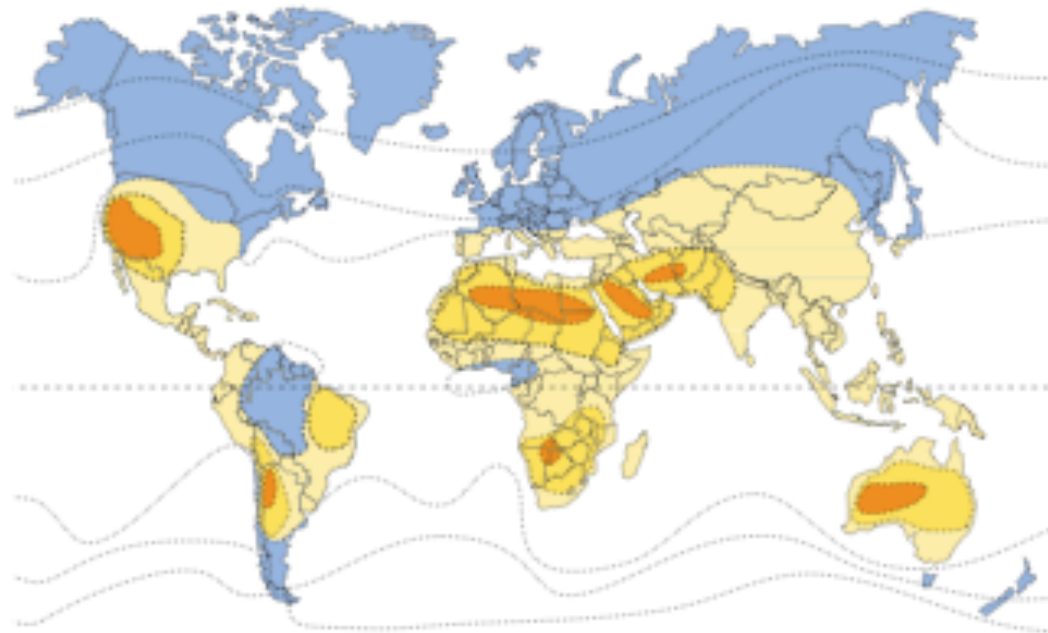






## Power supply: Solar Energy?

- Supply with solar energy obvious and best (and only?) solution ?



Suitability for solar thermal power plants:  
■ Excellent ■ Good ■ Suitable ■ Unsuitable

Quelle: Schott

- Excellent light house project for renewable energies (already for “SKA Pathfinders”)
- Sustainable energy solution for the whole life time (~50 year)
- Opportunities to open new markets.



# The challenges

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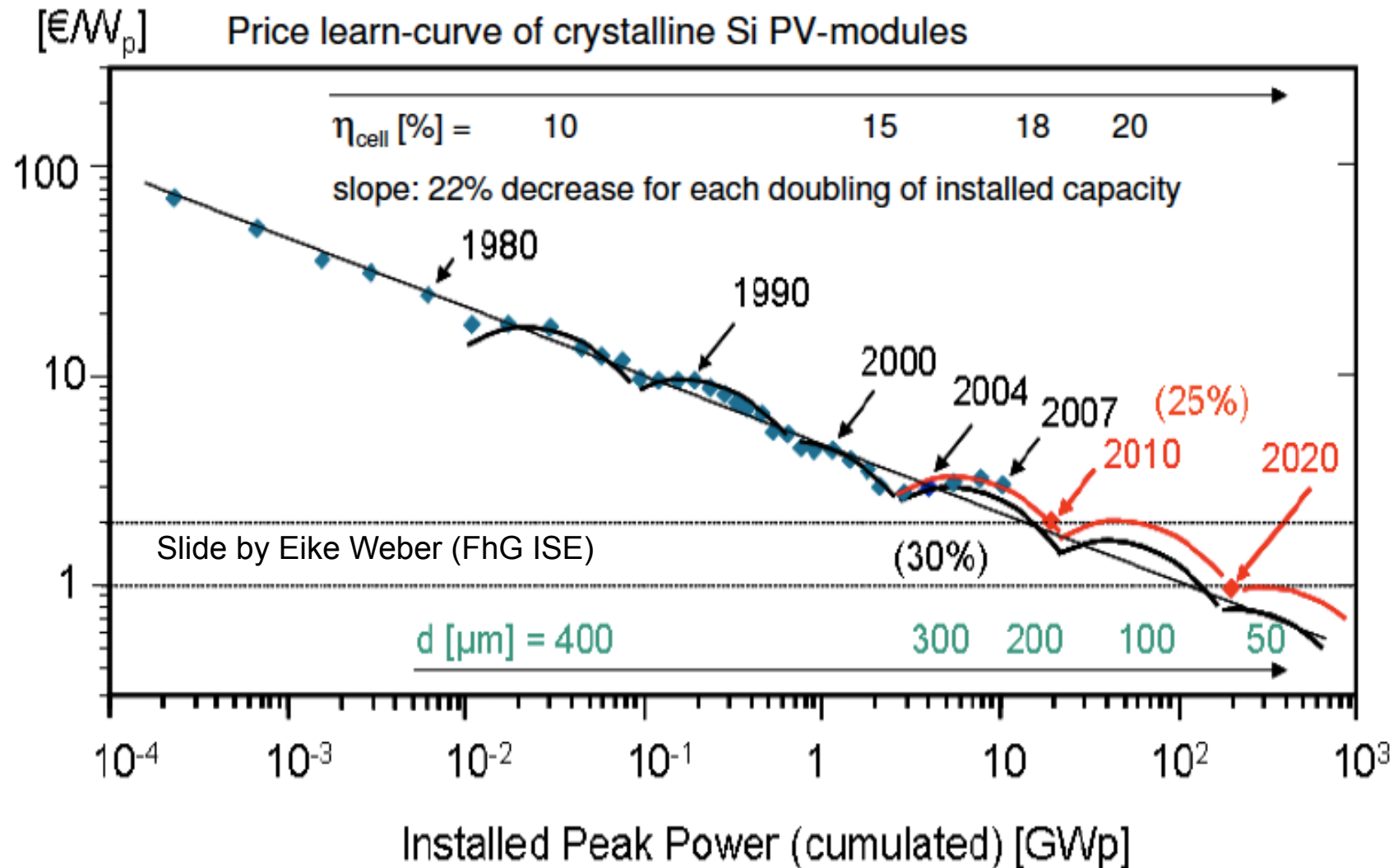
Power generation is less of a problem, but

- How to store it for 24/7 operation?
- How to avoid causing radio interference?
- How to make it affordable?





# Cost evolution



Note: The SKA will drive innovative solutions in generation, distribution, efficiency and demand reduction in a harsh environment.





# Vision in partnership with Fraunhofer ISE

SKA as lighthouse project for future Mega-Science Projects

World-class science with 100% renewable energy and 0% carbon footprint:

## FhG-MPG Kooperationsprojekt

„solarSKA“

**Hybride CSP-CPV Kraftwerke zur regenerativen  
Energieversorgung für die neue Generation von Radioteleskopen**



# CPV-Teilsystem: Speicheroptionen

Redox-flow



MW /  
MWh

NiMh



Source: [www.saftbatteries.com](http://www.saftbatteries.com)

Lithium



MW

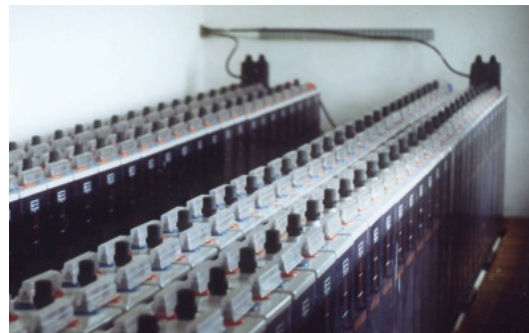
NaS



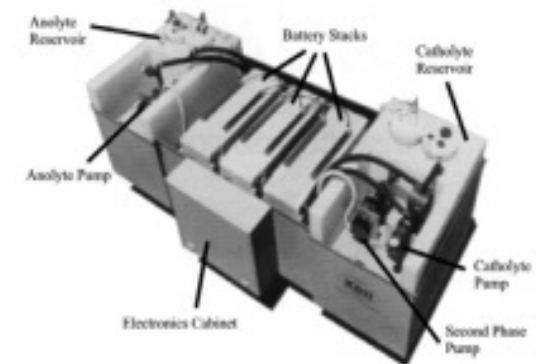
Source: [www.ngk.co.jp](http://www.ngk.co.jp)

MW /  
MWh

Lead-acid



Zinc-bromine



Source: B.L. Norris



MAX-PLANCK-GESELLSCHAFT

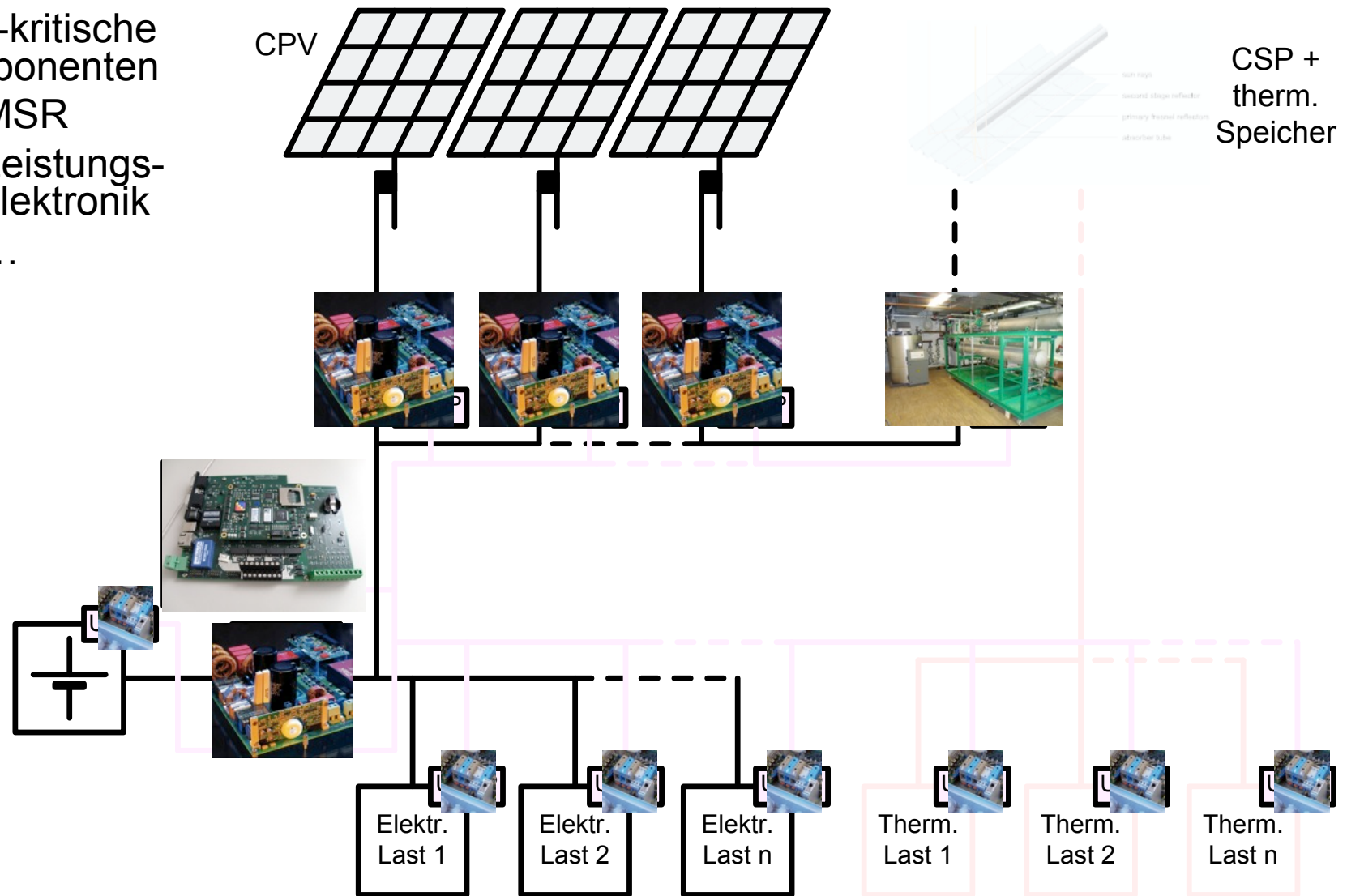
Max-Planck-Institut  
für Radioastronomie



# SolarSKA: Hybrides CSP-CPV Kraftwerk

EMV-kritische  
Komponenten

- MSR
- Leistungselektronik
- ...







# Challenges and ways to make it possible

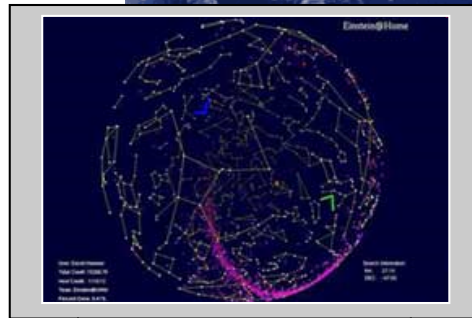
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- Don't shoot yourself in the foot:
  - The SKA will be ultra-sensitive – we must avoid producing Radio Frequency Interference on our own, NB:  
Mobile on the phone = 3<sup>rd</sup> brightest radio source
  - Balance between power transport, power electronic, losses
- Try to **reduce power requirements** from the start  
(**green HPC**, low-power devices, efficient architecture)
- Use **combination of technologies**,  
e.g. add geo-thermal cooling
- Develop effective, efficient and inexpensive **storage solution**
- New Markets: 1.6 Billion people without access to power grid!!
- Use the public attraction of astronomy!





Public is very keen to be involved: An Example...



www.einsteinathome.org

...finding pulsars with your screen saver!

Over 300,000 volunteers providing 450 TeraFlops



**n-tv** 13. August 2010, 14:04  
Home Politik Wirtschaft Börsen  
Frage & Antwort  
Wissen » PSR J2007+2722  
Astronomen entdecken spektakulären Pulsar  
Ein globales Netz von Astronomie-Fans feiert einen spektakulären unterbeschäftigter Heim- und Bürocomputer hat das Projekt Einstein@Home einen neuen Pulsar aufgespürt - dabei war der kosmische Leuchtturm gar nicht in der Suche.

Sonntag, 15. August 2010

**PSR J2007+2722 im Fuchsch**  
**Amateure entdecken Radiopulsar**

Der Neutronenstern befindet sich 17.000 Lichtjahre von der Erde entfernt und dreht sich 41 Mal pro Sekunde um seine eigene Achse. Entdeckt hat ihn unter anderen ein Student aus Mainz.

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Home > Science Magazine > 10 September 2010 > Knispel et al., p. 1305  
Performing your original search, allen knispel kramer, in Science will retrieve 0 results.  
Originally published in Science Express on 12 August 2010  
Science 10 September 2010:  
Vol. 329, no. 5997, p. 1305  
DOI: 10.1126/science.1195253  
BREVIA  
Pulsar Discovery by Global Volunteer Computing  
B. Knispel,<sup>1,2</sup> B. Allen, J. M. Cordes, J. S. Deneva, D. Anderson, C. Aulbert, N. D. R. Bhat, O. Bock,  
D. J. Champion, S. Chatterjee, F. Crawford, P. B. Demorest, H. Fehrmann, P. C. C. Freire, M. E. Go  
J. W. T. Hessels, F. A. Jenet, L. Kasian, V. M. Kaspi, M. Kramer, P. Lazarus, J. van Leeuwen, D. R. I  
R. Marheineh, M. A. McLaughlin, C. Maccarone, D. I. Nitz, M. A. Pan, H. I. Platzer, D. Privitera



# Conclusions

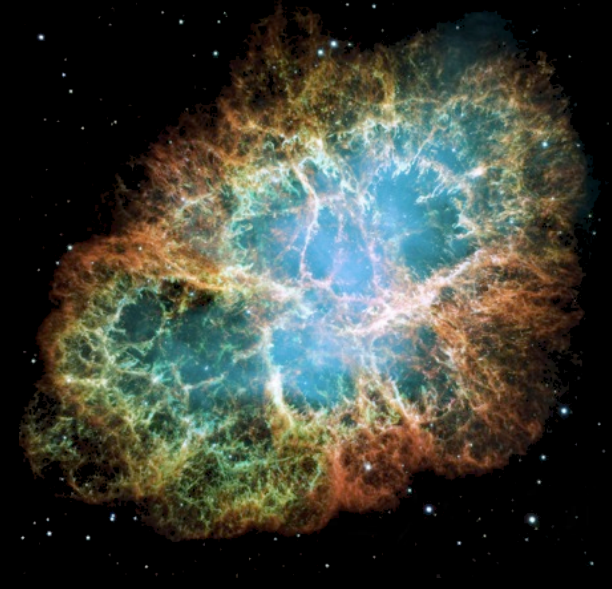
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- Green energy solution should be considered for other remote sites (e.g. APEX, ALMA)
- The SKA can serve as a **lighthouse project** to demonstrate 24/7 operation with 100% renewable energy independent of grid-solutions
- It can be a prime example for **sustainable Mega-Science** with 0%-Carbon Footprint
- With astronomy (and SKA's Key Science, e.g. Einstein, Black Holes ..) appealing enormously to the public, the **SKA can break ground** for other projects
- Required **energy mix (mini-grid solutions with storage)** is likely to produce solutions for many applications
- Key to the success of a 100% RE-SKA will be the development of **innovative systems solutions**: PV, CPV, CST solar power, wind if available, plus storage
- It is not clear whether we can afford it, but **"Green Astronomy"** is likely to be spectacularly popular
- **In any case, we may not be able to afford to pollute the Earth for the exploration of the Cosmos**

**It is not easy – but we should certainly try it!**



If you let an astronomer dream...



100,000,000,000,000,000,000,000,000,000,000 MW!  
= One second of Crab's energy output sufficient for Universe's lifetime!

