SQUARE KILOMETER ARRAY
US CONSORTIUM

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ARECIBO OBSERVATORY/NAIC, CORNELL UNIVERSITY

Funding the Square Km Array

Speaker: Mike Davis, Arecibo Observatory
Funding the Square Km Array
An Exponential Approach, or
Cyclops by the Yard

Mike Davis
Arecibo Observatory
29 February 2000
A Fundamental Difference

- A large, expensive scientific project like the Green Bank Telescope or a new particle accelerator is scientifically useless until it is completed, commissioned and turned over to an operations team.

- The SKA is also a large, expensive scientific project, but it differs from these others in a fundamental way. As an array of small elements, system-engineered for the purpose, the SKA can 'grow' into existence, with useful interim stages along the way.
Can we take advantage of this?

- Linear growth is not very interesting, but exponential growth with a reasonable doubling time certainly is.
- This suggests consideration of an exponential funding approach:
- Assume you could find a donor or international agency willing to commit $250M, on believable assurances that this will be adequate to ‘grow’ the billion-dollar SKA *and operate it indefinitely*, through judicious investment of this sum.
Can It Work?

• Yes, with PATIENCE and sensible basic rules:
  – Don’t touch the principle - ever.
  – Generate BOTH construction AND operating funds using an income rate [2%] well below annual returns [10% after inflation], reinvest the rest.
  – Give FIRST PRIORITY to operating what is already in place.
  – Use a realistic lifetime [20 years] for array elements, and replace them at life’s end.
  – Allow for both ‘normal’ operating expenses [5% annually of the current array value], and
  – Aggressive enhancement of ‘Moore’s Law’ parts - critical components with short half-lives, such as computers and signal processing chips [another 5%]
Annual Construction

Startup Income = $5M
Net Annual Return after Inflation = 10% - Income
Operations = 10% of Capital
Useful Life = 20 Years

Figure 1. Annual Construction. The five curves represent different starting capital and income rates.
Cumulative Construction

Startup Income = $5M
Net Annual Return after Inflation = 10% - Income
Operations = 10% of Capital
Useful Life = 20 Years

Figure 2. Net Cumulative Construction. Includes only structures less than twenty years old.
Figure 3. Annual Operations, including replacement of Moore’s Law components (critical components with very short half-lives).
Cumulative Operating Cost

Startup Income = $5M
Net Annual Return after Inflation = 10% - Income
Operations = 10% of Capital
Useful Life = 20 Years

Figure 4. Cumulative Operations.
Annual Operating Cost as Fraction of Income

Startup Income = $5M
Net Annual Return after Inflation = 10% - Income
Operations = 10% of Capital
Useful Life = 20 Years

Figure 5. Operations as fraction of income.
A Few of the Problems

• It takes time [2040 - 2060]
  - Starting with a twice as much shortens this by one doubling time [9 years]

• 'Assured' Annual Funding
  - Open Access, Competitive Peer Review even more important than in the case of periodic agency review
  - Have to ensure that the best science gets done
  - Don't get in a rut set by initial conceptions of the best way to do the array

• Ups and Downs of the Investment World
  - Consider the past 50 years
  - Use CREF as investment model, correct for inflation
  - Goal: $500M Infrastructure and $50M/yr operation in 1999
A One-Time 1952 Endowment of $38M ($232M 1999 Dollars) Provides

$500M Cumulative Construction*

and

$50M Annual Operations*

[Assumes CREF Returns, US CPI Deflator, 2% Income]

[Millions of 1999 Dollars]

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Endowment</th>
<th>Cumulative Construction</th>
<th>Annual Operations</th>
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Endowment Has Grown to $6.2B

*NSF Estimate of Present Value of Radio Astronomy Infrastructure and Operations
Cumulative Construction, 1960-1998

Startup Capital = $38M[1952] = $232M[1999]
Investment = CREF, Deflator = CPI
Operations = 10% of Cumulative Construction
Useful Life = 25 Years
Replacement Factor = 20%

![Graph showing cumulative construction expenditure from 1955 to 2000 with key milestones labeled: 140-ft + 300-ft, Arecibo 1st Upgrade, VLA, VLBA, Arecibo 2nd Upgrade, GBT.](image-url)
Market Variations are REAL

- CREF Value (after inflation) dropped more than a factor of two in the two-year period 1973-74
- ESSENTIAL to average over past five years to determine next year’s funding
- Allows construction to be not started, reduced or canceled to protect operations
- Operations rose to 100% of annual funding in 1980-81 in the present model
- But no worse than the economy’s impact on government-supported funding
CREF Stock, 1952 - 1998
Unit Values, Corrected for Inflation
Deflator = US Consumer Price Index

(3 dB is a factor of two)

Year


Unit Value [dB]

0 3 6 9 12 15
Startup Capital = $38M[1952] = $232M[1999]
Investment = CREF, Deflator = CPI
Operations = 10% of Cumulative Construction
Useful Life = 25 Years
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Graph showing the distribution of income over the years from 1955 to 2000, with lines representing operations, construction, and escrow.
Some Final Notes

- With the funding mechanism in place, no reason to stop at ‘only’ 1 square km
- Earnings distribution of 2% may appeal to donor - 98% available for aggressive investment
- Ongoing, permanent growth may represent a more fitting remembrance of the donor than a static monument
- NOT the way governments normally fund projects -- we are breaking new ground here.