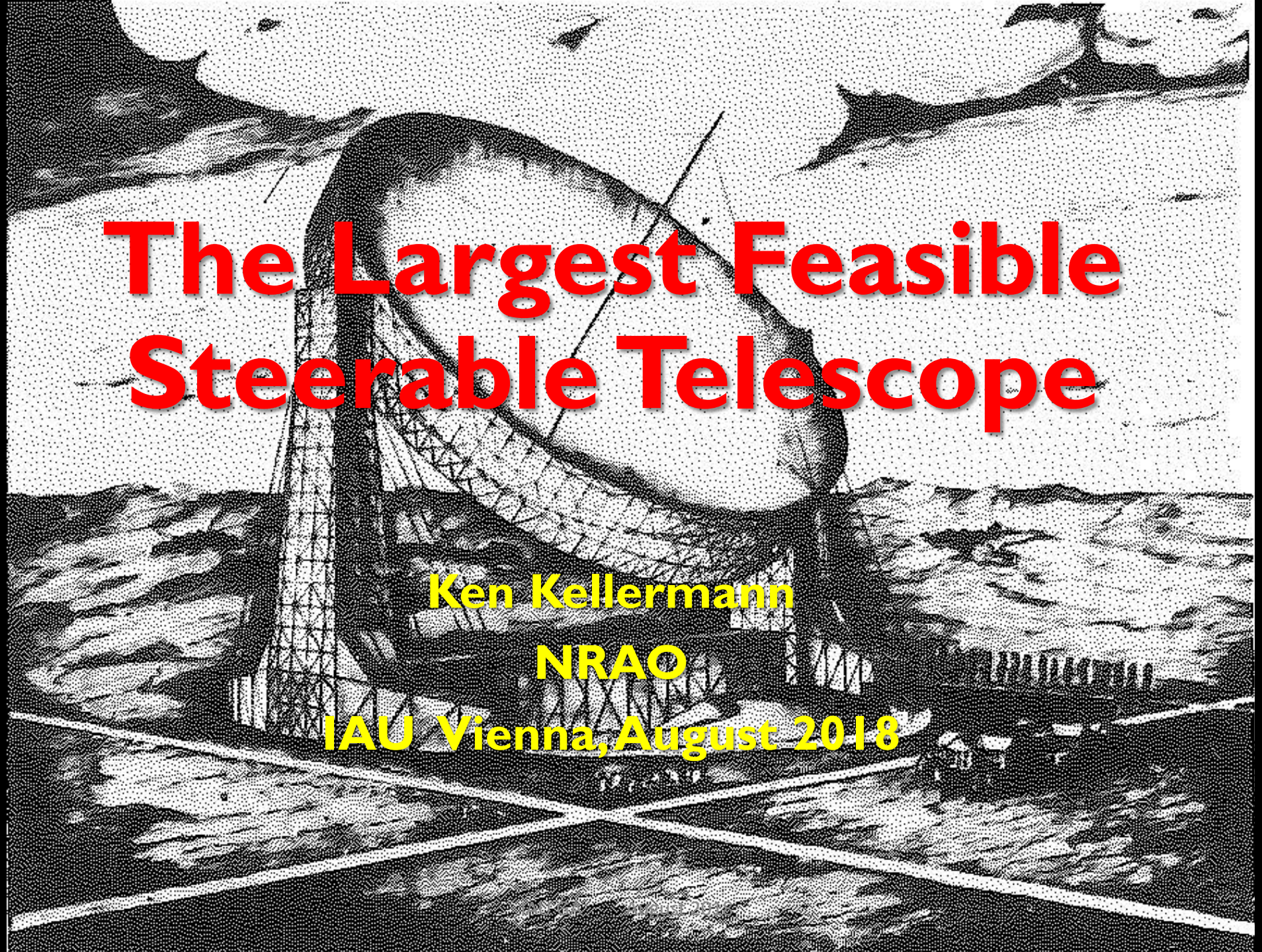


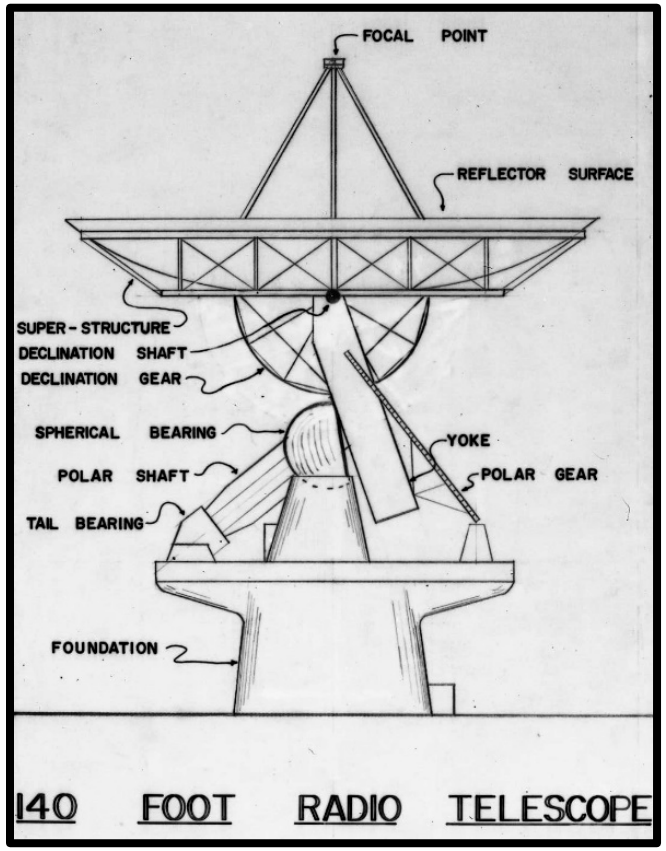
The Largest Feasible Steerable Telescope

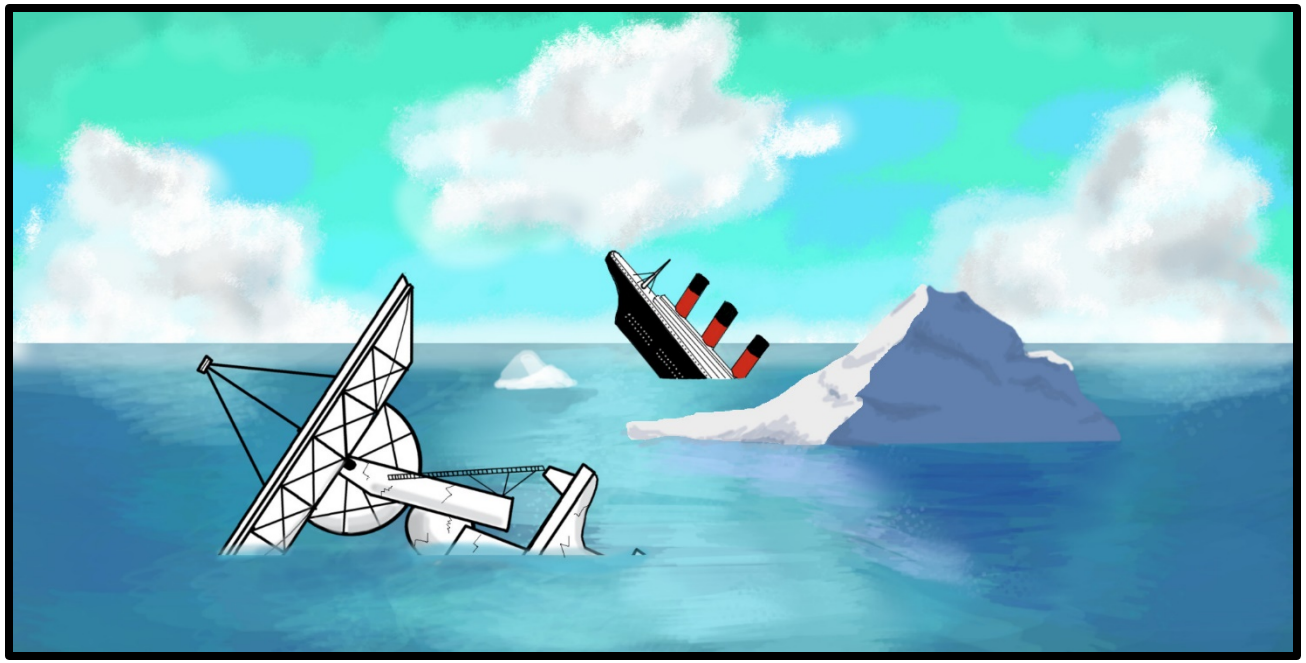
Ken Kellermann
NRAO

IAU Vienna, August 2018

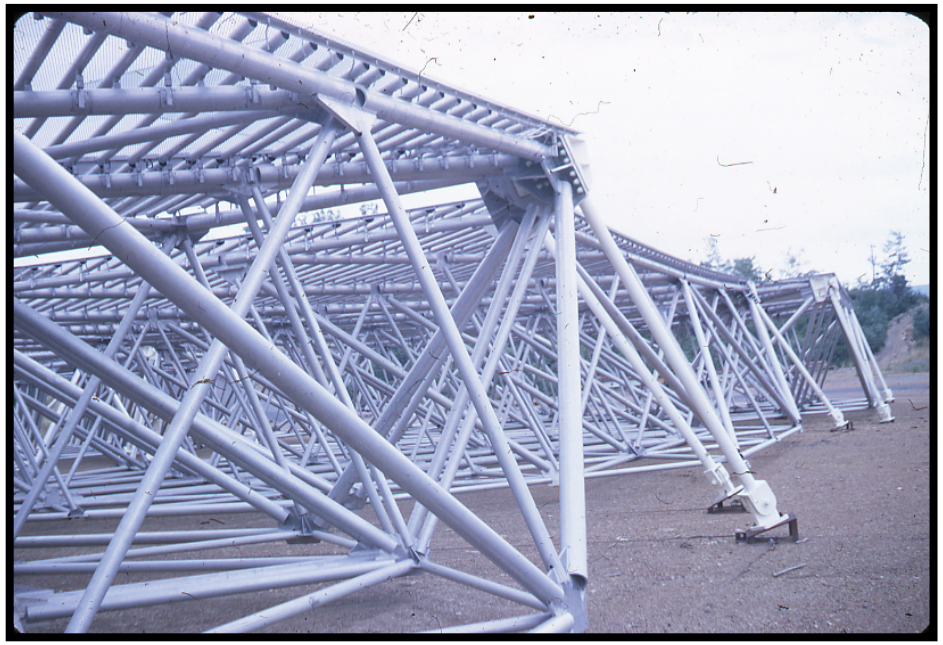
The 140 foot Telescope

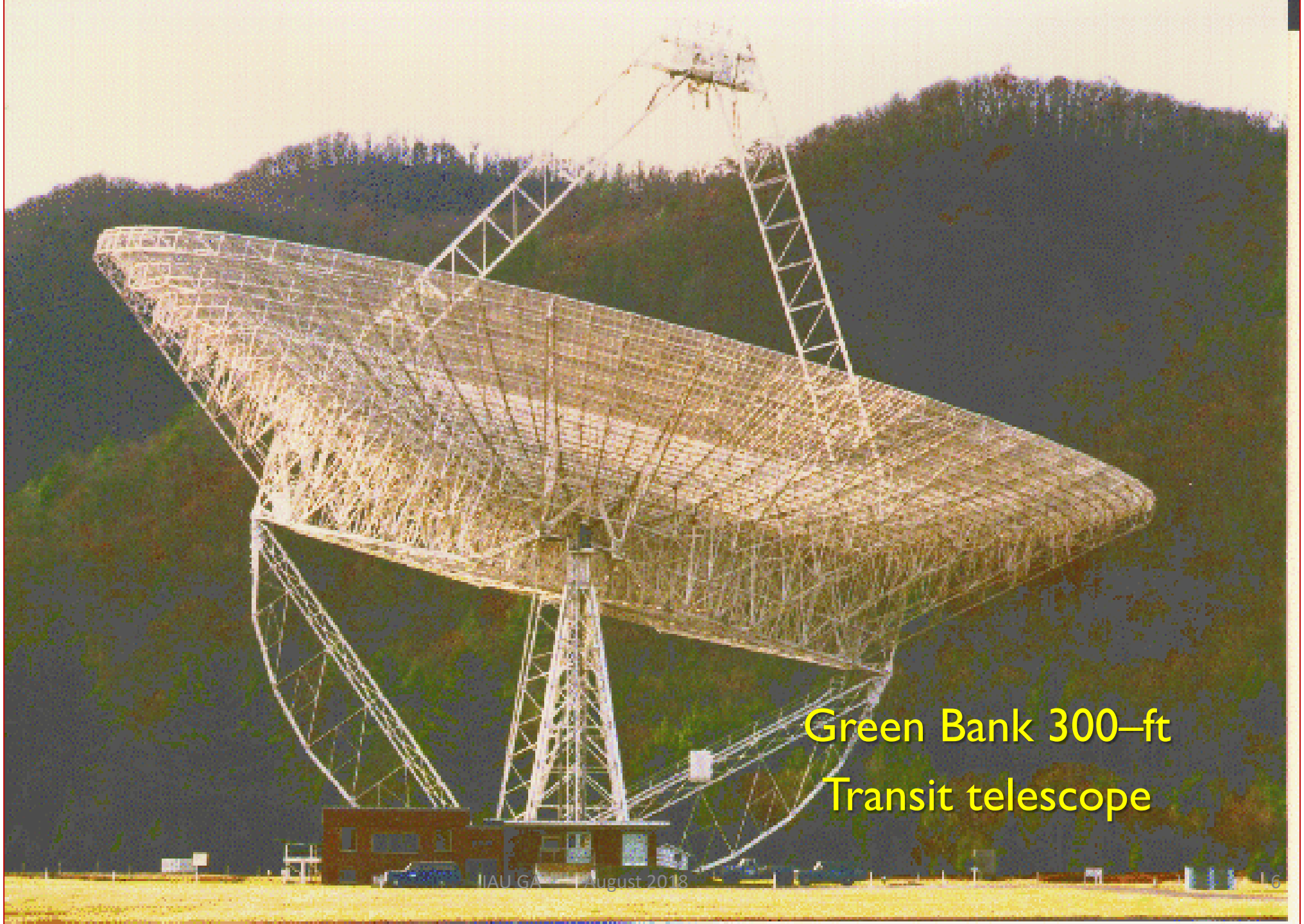
- Argued over size/wavelength limit
  - No reason to go shorter than 10 cm
- Start with 40 meters ($\lambda > 3$ cm)
  - rounded up to 140 feet
- Polar or Alt-Az Mount
  - Astronomers didn't trust computers – polar mount
  - Donald Menzel: Must be able to observe Sun any time
  - "NRAO's worst decision ever"
- Conceptual design by Ned Ashton (NRL 50-ft)
- Bids ranged from $4 million to $12 million
- June 1958 AUI signed contract with Bliss Corp.
  - Cost: $4.75 million
  - Completion: Summer 1960 (24 months)





Sugar Grove 600-ft antenna




Green Bank 300–ft
Transit telescope

This isn't the largest radio telescope in the world.
But it is the largest equatorially mounted telescope in WV.

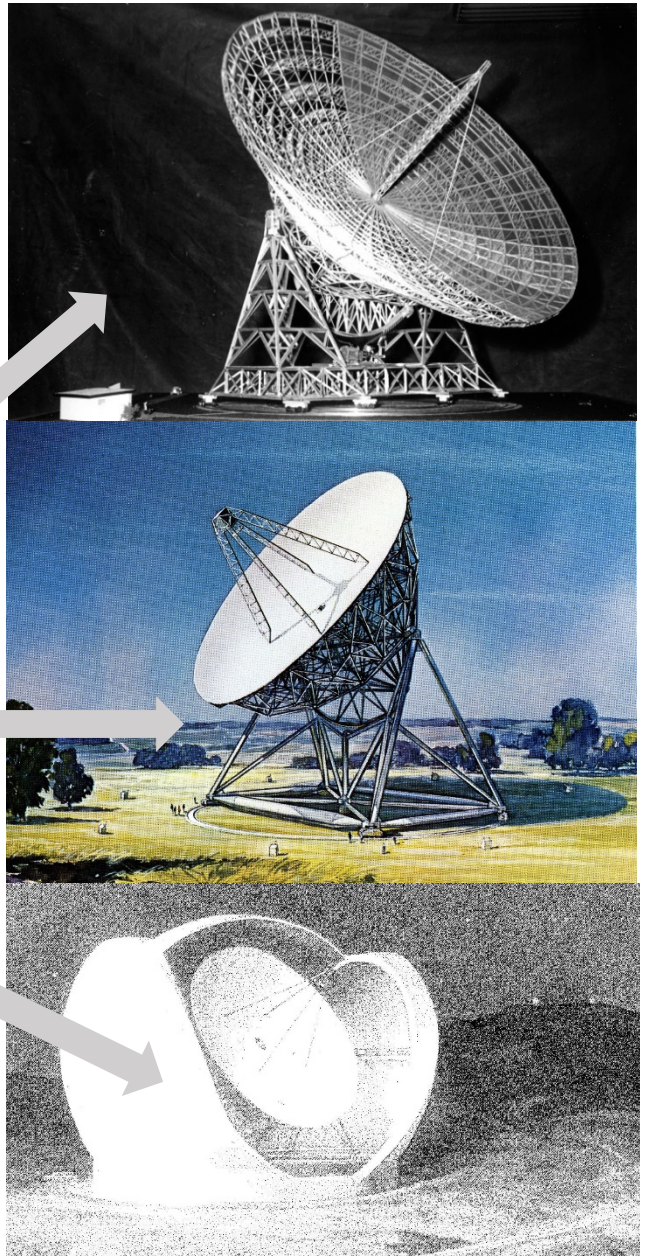
Dave Heeschen

Decade Review Priorities

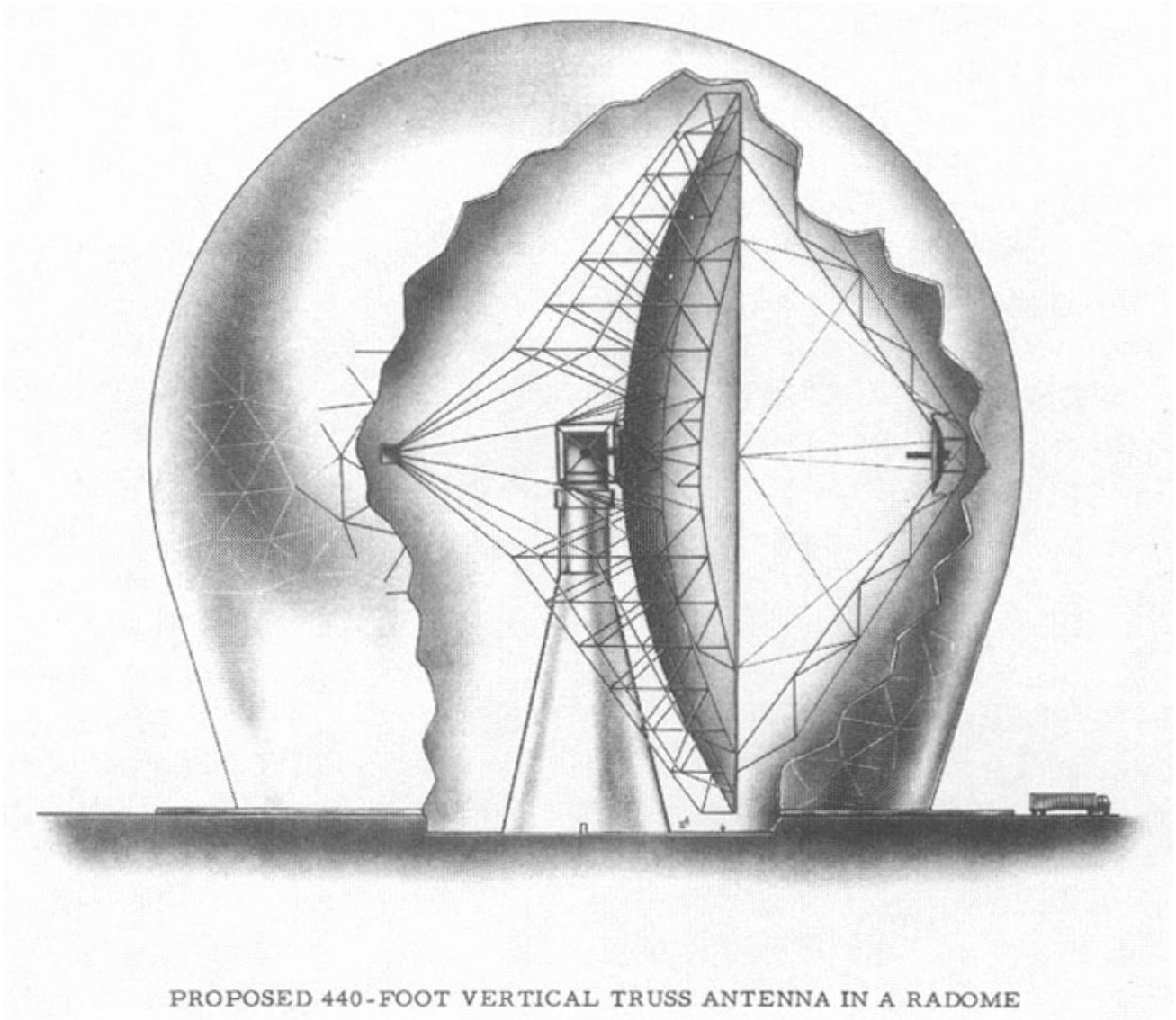
Year	Chair	Recommendation
1961	Pierce	Large Array
1964	Whitford	Large Array
1970	Greenstein	VLA
1981	Field	VLBA
1991	Bahcall	MMA

Largest Feasible Steerable Telescope

Year	Size	λ(min)	Cost ($)
1969	300 foot	1.3 cm	8.3M
1972	65-m	3mm	9.4 M
1977	25-m	1 mm	30 M



NEROC 440-foot Radome Enclosed Telescope



PROPOSED 440-FOOT VERTICAL TRUSS ANTENNA IN A RADOME

NSF Langenberg Committee - June 1988

Group A

Considered Absolutely Essential

VLA, VLBA, BIMA, OVRO, CSO

Class B

Highly Recommended

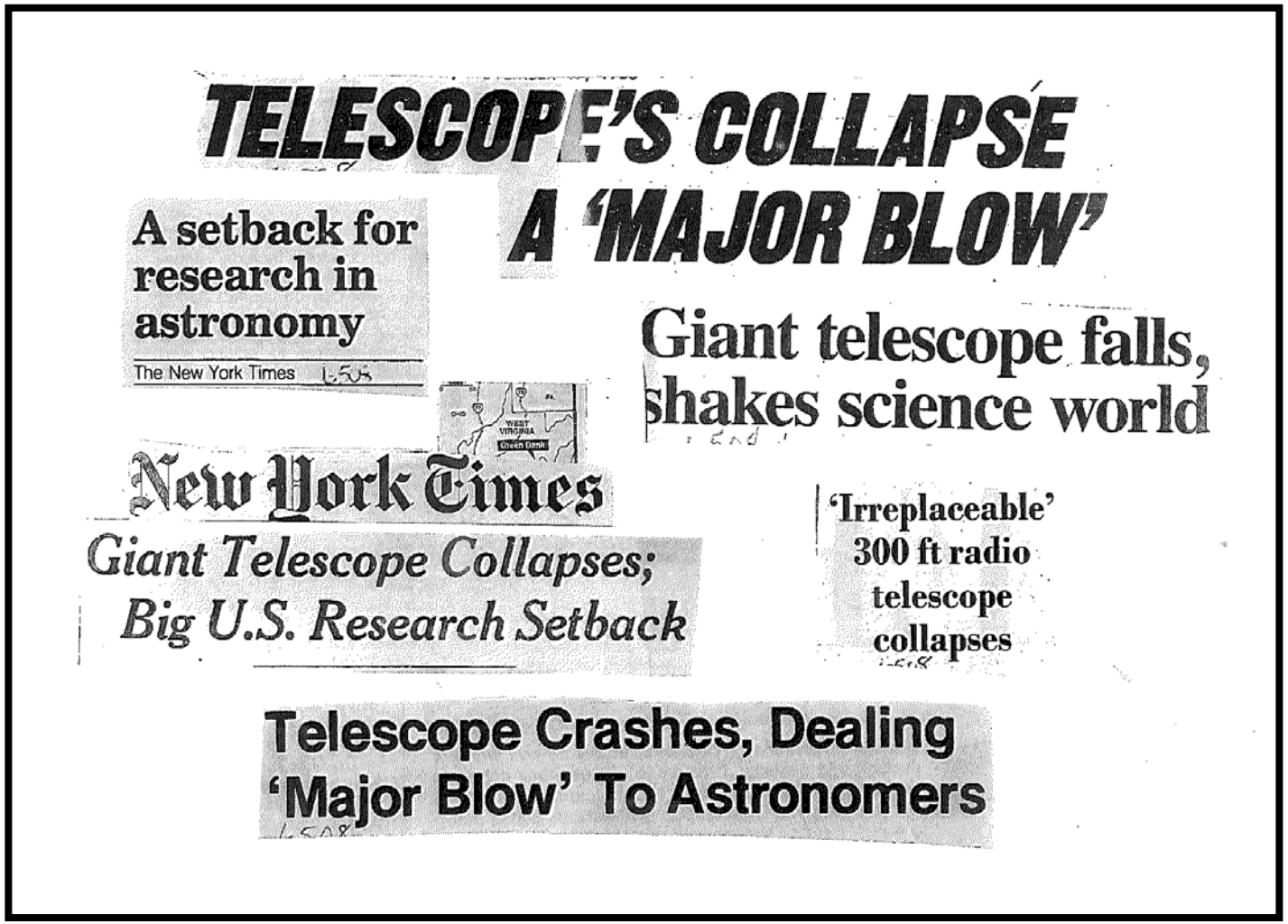
NRAO140-ft, NRAO-12m, Five Colleges, Arecibo

Class C

Less Competitive

Haystack, NRAO 300-ft, OVRO 40-m

NRAO 300-ft transient telescope


TELESCOPE'S COLLAPSE A 'MAJOR BLOW'
A setback for research in astronomy
The New York Times
Giant telescope falls, shakes science world
New York Times
Giant Telescope Collapses; Big U.S. Research Setback
'Irreplaceable' 300 ft radio telescope collapses
Telescope Crashes, Dealing 'Major Blow' To Astronomers

A National Disaster

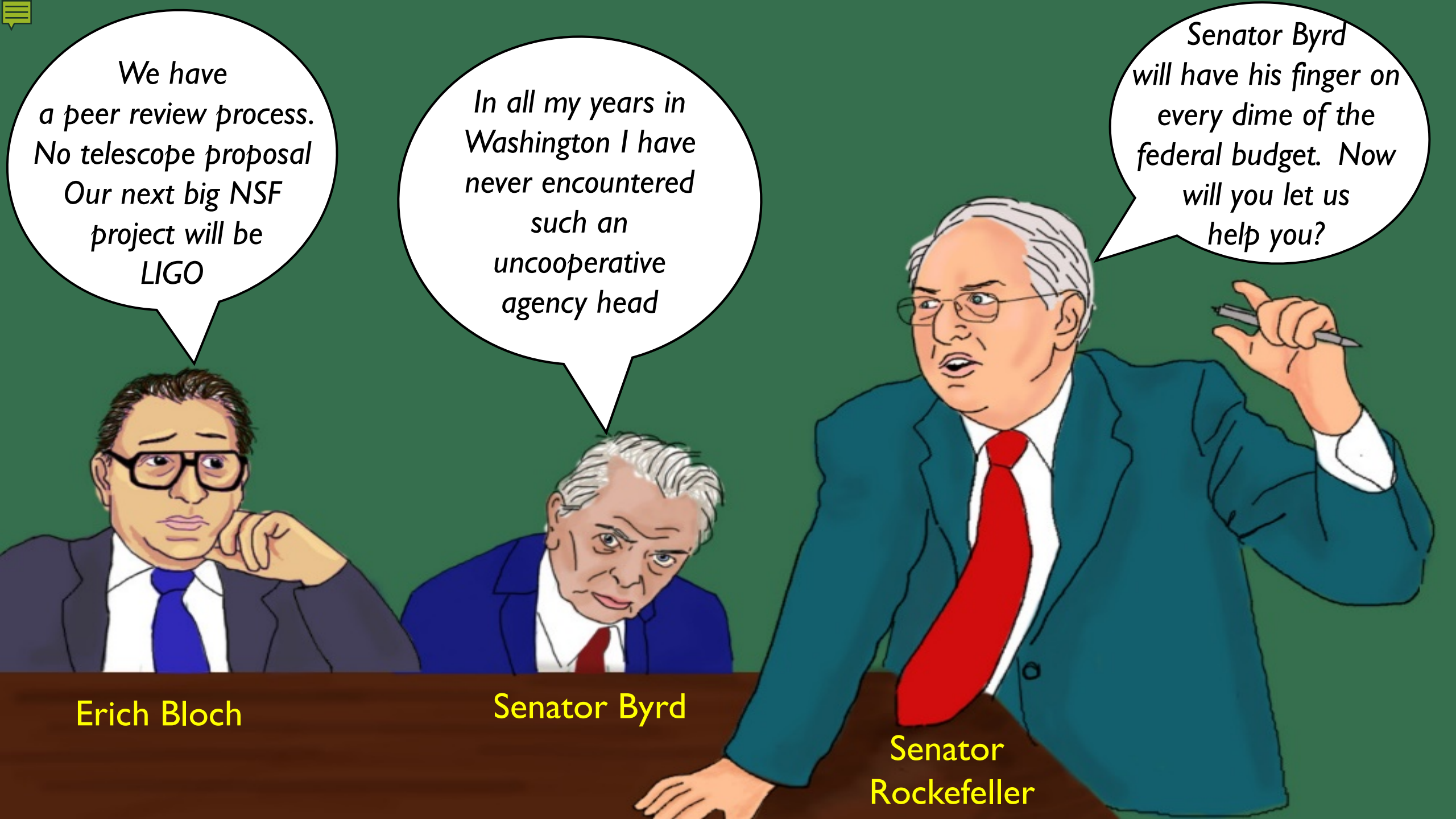
The collapse Tuesday night of one of the world's largest radio telescopes **will hinder astronomy over the long term** and hamper an experiment planned for a space shuttle mission, experts said. *Washington Post*

In a mysterious accident that **may have set back astronomical research by years,** a 300-foot radio telescope collapsed Tuesday night in a tangle of twisted metal girders.
New York Times

In a **devastating setback to the international search for extraterrestrial life**, a giant radio telescope being used to probe the stars has been destroyed.
Philadelphia Inquirer


Senator Robert C. Byrd, D-WV
Chair of Senate Appr.
Committee


Eric Bloch
NSF Director


We have a peer review process. No telescope proposal Our next big NSF project will be LIGO
In all my years in Washington I have never encountered such an uncooperative agency head
Senator Byrd will have his finger on every dime of the federal budget. Now will you let us help you?
Erich Bloch
Senator Byrd
Senator Rockefeller

Fast Track Funding

- 17 Feb, 1989 – CRS: Radio telescope best for WV
- June 23 – 1989 Dire Emergency Supplemental Appropriations Act
  - $74.5 million spread over two years to replace 300 foot telescope
- June 30 – President G. H. W. Bush signs NSF bill
- June 30 – AUI/NRAO submits proposal to NSF ($74.5 M)
- July 31– NSF Panel Review (All Excellent)
- August 15– NSF funding to NRAO for design work ($500 K)

NRAO had $74.5 million but

- No design
- No community consensus
- Senator Byrd wanted action
- NSF wanted action

$$Cost \propto (Diameter)^{2.7} (wavelength)^{-0.7}$$

Wide range of views on what to build

- **Large** collecting area - 100m diameter
- **Short mm wavelengths** – λ > 3.5 mm
- Radome or **open air**
- **Active surface**
- Symmetrical or **unblocked**

- June 1, 1990 – Request For Proposals
- Bids
  - Radiations Systems Inc. (RSI) - $57 million
  - Brown and Root (TIW/Vertex) - $83 M
  - Fru-Con (MAN/Krupp) - $103 M
- Dec 19, 1990 - Contract Awarded to RSI
  - $55 million
  - Completion August, 1993

- RSI/NRAO/NSF all anxious to get the job finished fast
- RSI Implementation – before design completed
  - Built foundation
  - Fabricated members
- Design weight – 12 million pounds
  - Design faulty
    - Moving structure would collide with mount
    - Not able to sustain large number of cycles
- NRAO provided optimized design
- Final weight - 17 million pounds = $$$$$
- RSI loosing money
- RSI sold to COMSAT
- COMSAT sold to Lockheed Martin

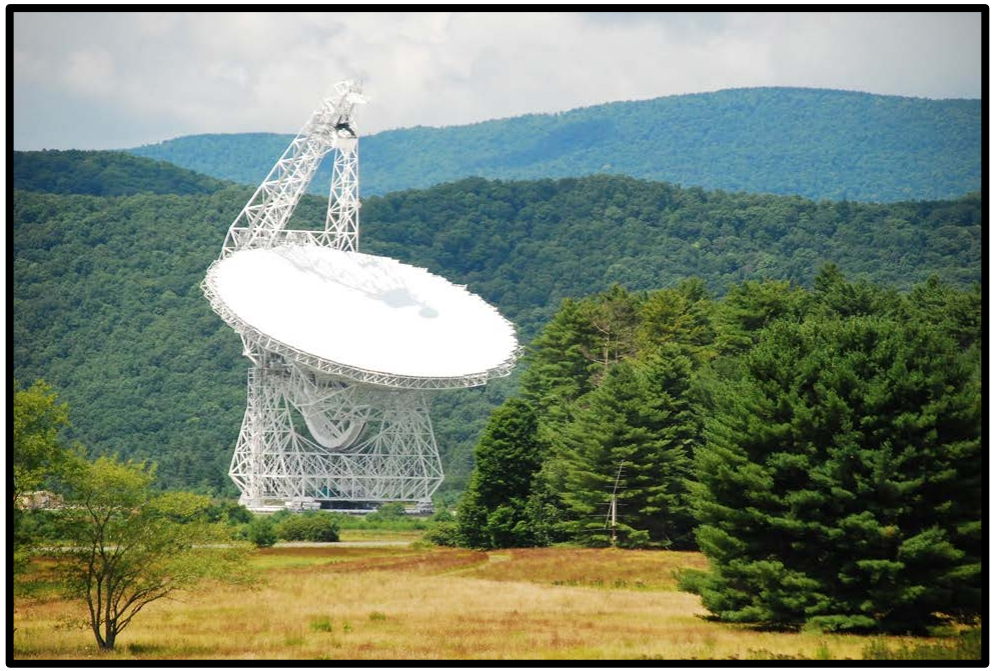
- Completion delayed 1994, 1996, 1997, 1998, 1999, **2000**
- COMSAT sued NRAO for $29 million
  - NRAO design changes
- NRAO counter-sued for $3.8 million
  - Poor project management
  - Additional Administrative costs
  - Seven Years of Lost Astronomy Data
  - Impact to NRAO reputation
- Arbitration
  - $6.6 million awarded to COMSAT
  - $2.5 million awarded to NRAO
    - Claim for lost data not accepted
- Net $4 million + $5 million for legal fees:
- NRAO faced = $9 million bill

Summary

- RSI bid overly optimistic
  - Proposed price too low
  - Schedule unrealistic
  - RSI wanted the job/knew how much money NRAO had
- NRAO should have recognized RSI bid unrealistic
  - RSI lowest bidder
  - RSI bid responsive to RFP
  - NRAO forced to accept RSI bid
- 6 years behind schedule
- Cost to COMSAT-RSI $120 million
- Final cost to NRAO/NSF $78,560,000
- $4 M (4.7%) over budget

GBT finally completed in 2000

- Largest moving structure on land
- Meets or exceeds all design specifications
  - Pointing good to a few arcseconds
  - $\eta_{3.6\ mm} \sim 30\%$ (night, low wind)
- Work continues to improve daytime performance



Largest Feasible Steerable Telescope

It took nearly half a century of discussion and debate, and numerous NSF and Academy committees. But in the end it was a freak accident coupled with the ambitions of a powerful Senator to finally build a large US fully steerable radio telescope.

Lessons (re)Learned

- Beware the lowest bidder
- Have a strong leader (or patron)
- Don't take committee advice too seriously
- Have good in-house expertise to generate costed design
- Have veto power over sub-contractors
- Control risk
- Measure twice – cut once (Finish design before building)
- Have clear points of contact, authority, and responsibility
- Have a firm schedule with penalties and bonuses
- Learn from mistakes and mistakes of others
- Be careful what you ask for

Open Skies: The National Radio Astronomy Observatory and its Impact to US Radio Astronomy

by

Ken Kellermann, Ellen Bouton, & Sierra Smith Brandt

Springer, 2019