History of the Westerbork Synthesis Radio Telescope (WSRT)

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The need for radio telescopes of very large dimensions is so obvious that it does not require an introduction! – Jan Oort (1961)

- WSRT developed from Dwingeloo 25 m dish, and a proposed ≈5 km baseline, ≈100 element cross antenna (with Belgium)
- From the start, one of Oort’s concerns was angular resolution (optical: ≤ 1″ arc)
- For Oort, discrepancy of ≈ 2000× between optical & radio resolution: serious limitation
- A key goal: cosmology by source counts
Benelux Cross Antenna Project (BCAP) evolved over some years, became an EW synthesis array

- The first BCAP design was by Seeger (1958)
- Several cross designs followed (Christiansen involved from 1960)
- After Belgium left the project (1964), it had to be de-scoped
- Ryle’s OMT played an indirect role
- J Högbom role critical

W.N. Christiansen & C.L. Seeger
The mixed blessings (and politics) of international collaboration

- The involvement of Belgium (& Luxemburg) probably seemed a good idea in the 1950s
- The Benelux countries formed an early union after the Second World War
- However, radio astronomy did not have a high profile among Belgian astronomers
- By 1964, Belgian astronomy had to decide between the BCAP and ESO (funds were limited). Oort (& A. Blaauw) decided Belgium was more important to the European Southern Observatory
Original Westerbork Telescope

- Built 1967-70
- Project included:
  - Telescopes (12 × 25 m).
  - Buildings, access roads.
  - Cables.
  - Electronics & feeds (all Stokes).
  - Computer hard- and software.
- (White hangar is dish assembly hall.)
- Conservative approach
- Total cost: fl. 25 M (about € 50 M today)
Dishes assembled on template in ‘bouwhal’

Controlled environment seen as vital for precision assembly. Epoxy glue used to fix mesh to frames – innovative (no welding)

Each telescope has its own control building
WSRT 25 m equatorial dishes: light weight & elegant
Project led by Muller & Hooghoudt

- Both had graduated from the Delft Technical University.
- C.A. (Lex) Muller designed the receiver system.
- B.G. (Ben) Hooghoudt was responsible for the mechanical aspects, including the dishes.
- (Hooghoudt was a consultant to many big antenna projects.)
Ten fixed and two movable 25 m dishes

Dishes all have same geometry and 8 mm mesh surface. Only prime focus usable.

The movable dishes can be driven along 300 m long E-W rails
Early upgrades: lower $T_s$, wider band, two additional movable dishes, longer baseline

- Two new dishes built, first placed on original track (halved the time for synthesis)
- These telescopes (C & D) moved (1976-80) to new rail track 1.3 km east of original rails
- This improved angular resolution by factor of 2
Major upgrades over the years

- 12 $\rightarrow$ 14 $\times$ 25 m dishes; 1.4 $\rightarrow$ 2.7 km baseline
- Bandwidth: 4 MHz $\rightarrow$ 10 MHz $\rightarrow$ 8 $\times$ 10 $\rightarrow$ 8 $\times$ 20 MHz
- $T_s$ (L-band): 240 K $\rightarrow$ 30 K
- From L-band 1 channel (continuum only) $\rightarrow$ multi-channel filter-bank (analog) spectrometer $\rightarrow$ series of flexibly configurable digital backends
- The L-band (18-22 cm) frontend later joined by receivers at wavelengths of 3.6, 6, 13, 30, 49, 90 cm & 2 m; most bands incorporated in MFFEs
- Tied array system for VLBI & pulsar observing
The pulsar machine \textit{PuMa}
WSRT telescopes are equatorially mounted; only cover $-90^\circ < \text{HA} < +90^\circ$

- Limited HA kept costs down
- 12 h coverage suffices for a full synthesis: this limitation made sense
- But it can be annoying for anyone observing circumpolar sources
- And an important limitation for VLBI observing
One of the innovations at the beginning was to use epoxy glue to secure the mesh surface panels to the backing structure.

Unfortunately, by the mid-1970s, it became obvious that the mesh was pulling loose.

A campaign was organized to use self-tapping bolts (each with its own lead drill) to (re)attach the mesh (with 180,000 bolts).

Innovation can have its down side.
Concluding remarks

- Technical developments vastly enhanced WSRT capability (sensitivity, bands, etc.)
- Going from a collective management to a Director General was of benefit to WSRT
- ASTRON has generally enjoyed support of ministers, members of parliament, civil servants. Provincial support (including local pride in the WSRT) has been a basis for the observatory nationally
Thank you!