THE CANADIAN LONG BASELINE ARRAY[+]

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On 1983 May 31, the National Research Council of Canada
gave formal approval to a new national facility, the
'Canadian Long Baseline Array'. The instrument will be made
up of eight radio telescopes spaced across southern Canada,
with a ninth antenna, primarily for geophysics, in the
north. Though the project is still some way from being
funded, the NRC approval was an important and encouraging
step in a process that started five years ago.

The Canadian Long Baseline Array (CLBA) began in 1978 with
the submission of a proposal to a committee of the Canadian
Astronomical Society (CAS). Soon after, the CAS adopted an
expanded version of the proposal, with the recommendation
that the project be given the highest priority for a new
astronomical instrument for Canada. In the years following,
the CAS has continued its strong support for the project.

Since 1980, the array has been the work of the 'CLBA
Planning Committee' of the CAS. This committee has drawn
on the efforts of more than 45 radio and optical
astronomers, geophysicists, and engineers in producing a
design for the array. The work is summarized in a report
published in 1982*, which includes design, reliability and
cost studies done under contract by Canadian industry. The
description of the CLBA that follows is largely abstracted
from this report.

* The report: 'The Canadian Long Baseline Array', dated
1982 September 27, is to the Natural Sciences and
Engineering Research Council and the National Research
Council, from the Canadian Astronomical Society.

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1.   The Overall Telescope

Two features that are especially emphasized in the design of
the CLBA are (i) sensitivity, which is reflected in the
choice of the largest antenna affordable, and (ii) image
forming over as wide a range of angular scales as possible,
a feature discussed further under 'Configuration'.
Estimated sensitivities, with receivers attainable in 1982,
are shown in Table I, together with the frequencies covered.
The two sets of figures are for a single pair of antennas
(N=2), and for coherent operation of the linear array of
telescopes (N=8), which may be possible at the longer
wavelengths or with improved atmospheric measurements.

The beamwidths listed are for the $\sim$ 5000 km maximum
Canadian baseline. These figures would be reduced to 2/3
of their value with the addition of an antenna in France.
Considerable interest has been expressed amongst French
scientists, particularly those in the Groupe de Recherches
Géodésie Spatiale, in having their planned 32m antenna
used, as first priority, in cooperation with the CLBA. The
French site is essentially ideal from the point of view of
the U-V plane coverage.

TABLE I

Frequency (GHz)	N=2 (mJy)		N=8 (mJy)		Beamwidth marcsec
	1 sec	15 min	15 min	12 hours	
0.611	90	3.0	0.57	0.082	12.2
1.5	41	1.4	0.26	0.037	5.0
2.25	45	1.5	0.28	0.041	3.3
5.0	51	1.7	0.32	0.046	1.5
8.3	70	2.3	0.44	0.064	0.9
10.7	76	2.5	0.48	0.068	0.7
22.0	473	16.	3.0	0.43	0.34

2.   The Configuration

Eight of the CLBA antennas will form a nearly linear array,
running from Newfoundland to British Columbia, but slightly
tilted from an exact east-west line. The linear configura-
tion was chosen instead of a two-dimensional array only
after much weighing of relative advantages. Scientifically
the choice seemed evenly balanced between a wide field-of-
view (i.e. sensitivity to a wide range of angular scales) on
the one hand, and coverage of low declinations on the other.
The more economical maintenance of a line of southern
stations turned out to be the deciding factor.

In arriving at suitable configurations, the image forming
properties of different arrays were compared quantitatively
by simulating the observation of a number of test sources.
Two configurations selected in this way are shown in Fig. 1,
with corresponding U-V curves in Fig. 2 and an example of
the imaging tests in Fig. 3. Other test sources used were
an extragalactic source with jets, and multiple sources,
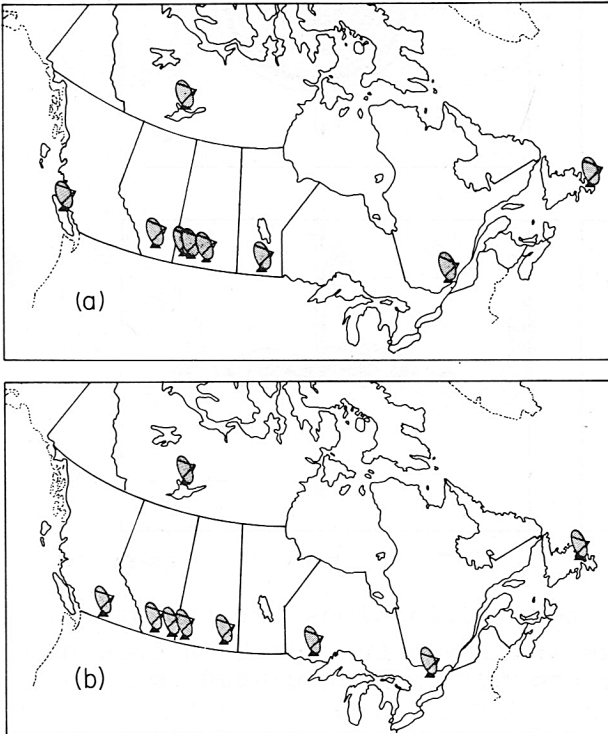for simultaneously testing the large and small scale imaging
properties of the arrays.

Fig. 1 - Two array
configurations desig-
nated (a) J3M and (b)
P10, that fulfill the
CLBA design aims.
Array P10 uses
existing radio
telescope sites (but
not the telescopes) at
Penticton, B.C. and in
Algonquin Park,
Ontario.

A primary aim of the imaging tests was an array with the
widest field-of-view consistent with good imaging. Confi-
gurations that best satisfied this aim were found to be
those with roughly an exponential distribution of baseline
lengths. The arrays of Fig. 1 are examples. These arrays
have minimum baselines of about 75 km, and are able to map
sources as large as 1.0 arcsec, at 2.2 GHz (0.1 arcsec at
22 GHz) with the dynamic range (peak brightness to peak
brightness error) remaining above 300.

Other advantages of exponential configurations are: geo-
metrically similar sampling of the visibilities of similar
sources of different angular scale, and a near uniform
'filling-in' of the U-V plane for a moderate (say $\sim$10%)

bandwidth. The tilt of the arrays of Fig. 1 from an east-
west line also slightly improves the filling-in of the U-V
plane. After the first 12 hours of observations, the U-V
tracks interleave instead of overlapping.

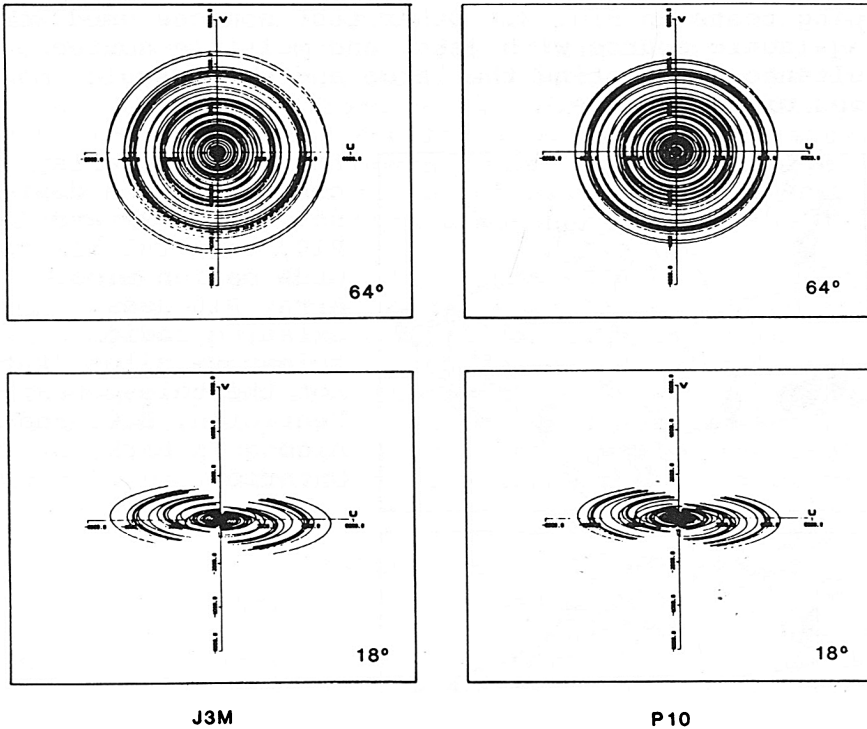   J3M   P10

Fig. 2 - The U-V tracks at two declinations for the arrays
of Fig. 1, excluding tracks involving the northern antenna.
The dimensional tick under the 'U' indicates 6000 km.

The eight southern antennas of the linear array will be
used primarily for astronomy, while the ninth antenna, at
Yellowknife, Northwest Territories, will provide north-
south baselines which are a priority of Canadian geo-
physicists. A second geophysical priority will be
satisfied by having baselines on, and close to, the geo-
logically stable Canadian shield.

3. Antennas

The 32m dia antennas of the CLBA will be upgraded versions
of a standard wheel-and-track communications antenna. The
antenna will have 'shaped' main and secondary reflectors to
give near uniform illumination (i.e. little apodization)
and, consequently, high efficiency ($\gtrsim$ 70%). At the time
of the CLBA report, the highest frequency considered was

22 GHz. Since then, the possibility of improved panels, to
give a useful collection area at 43 GHz, has been conside-
red. Any such improvements would have to be made, however,
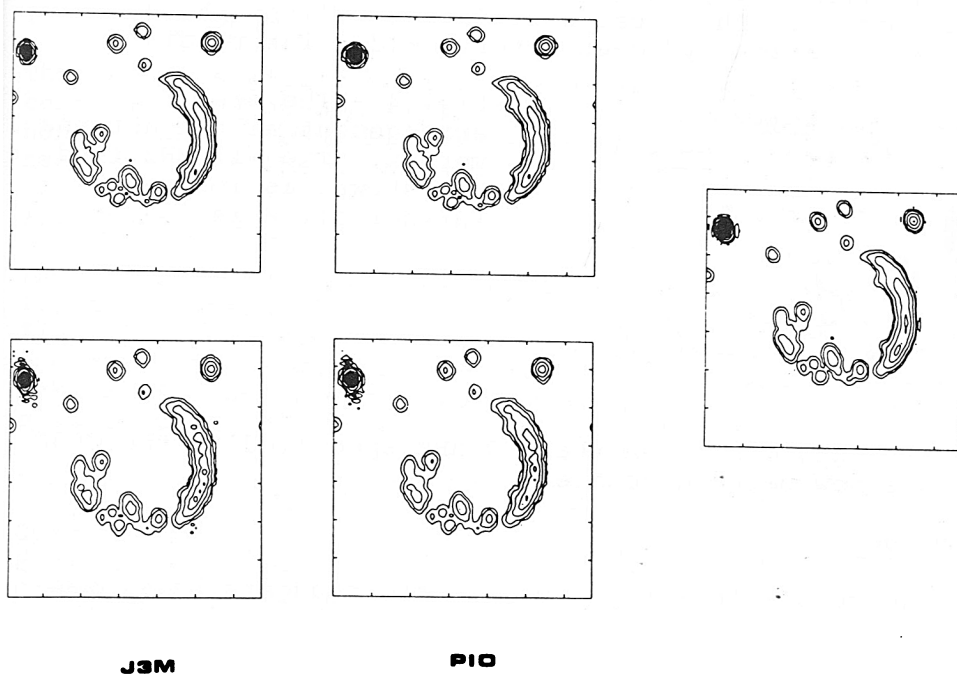to fit within the overall cost estimates of the 1982 CLBA
report.

J3M   P10

Fig. 3 - Reproduced images from simulated observations with
arrays J3M and P10, for declinations 64° (top) and 18°
(bottom). The original, a DRAO map of CTB1, is on the
right. The lowest contour level is 0.002 of the peak
brightness.

4.   Antenna Feeds

Dual polarized feeds for each of the frequencies listed in
Table I will be arranged at the vertex of the 32m antenna,
as shown in Fig. 4. The feed will be selected by appropri-
ately tilting the antenna subreflector. A dual frequency
feed will be used for the 2.25 and 8.3 GHz bands. The 611
MHz feed, not shown in Fig. 5, will be a large uncorrugated
horn of square aperture, placed to one side of the vertex.
The length of this horn is kept manageable by having a
flare angle that varies with distance from the throat.

5. Receivers

Dual GaAs FET amplifiers will be used at all of the
frequencies listed in Table I, and cooled (except at 611
MHz) to 20K. The development of such amplifiers is under-
way at the University of Alberta and the National Research
Council, Ottawa. The local oscillators will be phase-
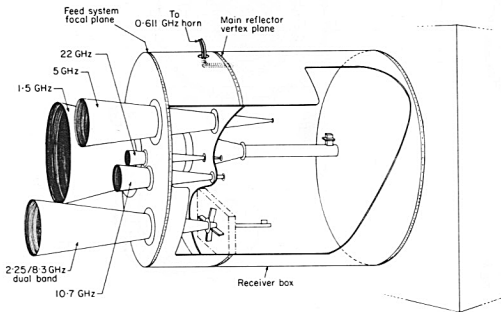locked to a station hydrogen maser. Wider intermediate

Fig. 4 - The feed
arrangement at the antenna
vertex. The 611 MHz feed,
not shown, is located
further off axis.

frequency bandwidths than the 200 MHz specified in the CLBA
report are now being discussed.

6. Recorders

Video recorders with automatic cassette changers have been
specified since the 1978 proposal. The 1982 design calls
for two channels, of 4 recorders each, recording a total of
96 M bits sec^{-1}. These would run unattended for 24 hours.
This bandwidth will possibly be increased as a result of
rapid advances in the recorder field. Reliability of the
cassette machines, which was already good, has been
improved by the development of automatic equalizers by
J.L. Yen at the University of Toronto.

7. Correlators

The correlators will receive data streams from up to 10
antennas. Normally, 32 lags will be produced for each of
four polarization products. Fractional-bit delay correc-
tion and three-level 'fringe rotation' schemes will be
incorporated. Up to 2048 spectral line channels will be
provided by recirculating the data to the correlators.

8. Image Processing

Image processing for the CLBA is designed to give the non-
expert user a source image, a spectrum, or geophysical data
without necessarily any direct intervention on his part.
The processing is divided into levels in which, typically:

(i) edited and calibrated correlation coefficients are produced; (ii) images are produced, and (iii) images are enhanced in various ways. The design centers upon a VAX 11/780 computer and three PDP 11/24 computers controlling array processors.

9. Operation

The antennas will be controlled over telephone lines from a central computer and will be unattended except for a few hours a day. Teams from the headquarters will undertake nearly all of the maintenance.

10. Staff and Costs

The staff of the CLBA will total 75, as indicated in Table II; and construction costs will total an estimated 70.1×10^6, distributed as shown in Table III. Yearly operating costs will be 7.7×10^6 of which salaries will make up 3×10^6 and the purchase of new receivers, or other equipment to upgrade the instrument, 1.5×10^6.

TABLE II
CLBA STAFF

Operations	31
Engineering support	6
Computer programming	8
Administration and services	9
Development	13
Scientists	8
TOTAL	75

TABLE III
ESTIMATED COSTS
(Millions of 1982 Canadian dollars)

Antennas and feeds	31.7
Receivers and electronics	10.2
Correlation and processing	6.4
Headquarters	5.2
Sites	4.4
Design, management, other	5.8
Contingency	6.4
TOTAL	70.1