Twenty-five years at Westerbork

This year we celebrate the 25th anniversary of the Westerbork Synthesis Radio Telescope with a workshop on 'Cold Gas at High Redshift' and a commemorative volume which is being prepared by Ernst Raimond. This signal year could not be passed without a celebration party for the telescope. On June 23rd almost 300 friends of the WSRT, coming from Westerbork, Dwingeloo, the universities and other institutes, celebrated this milestone. (photo: Harm Jan Stiepel)
Message from the Director

Harvey Butcher

This summer we celebrate a quarter century of operation of the Westerbork telescope. This celebration began with a birthday party -- held on 23 June, just one day short of precisely twenty-five years since the formal opening of the facility by Queen Juliana in 1970. e are also looking back over the quarter century in a book on the telescope to be published in the fall. Here our astronomers consider the role the WSRT has played in the history of radio astronomy and also how our subject is likely to evolve in the coming decades. And on 28 - 30 August we are holding a workshop entitled "Cold Gas at High Redshift" -- an international gathering in Dwingeloo and Hoogeveen to consider the state of play in the study of the early Universe and the role the WSRT and other facilities can play in such studies in the coming years.

But the summer also signals other major events for NFRA. The preliminaries to the planned upgrade and maintenance activities at the WSRT are essentially completed and implementation work on the telescope now begins in earnest. For the next couple of years, the technical status of the telescope and the kinds of observations that can effectively be carried out will be in a state of flux. More on this below.

Then, construction of a new home for our Institute in Dwingeloo begins this summer. In roughly a year's time we will move into spacious new quarters, where in various ways we will be able to play a more effective role in supporting the activities of our community.

And finally, the decision making process of the last two years in the community was formally completed during the spring, and we are now taking the first steps in an ambitious program that stretches well into the next century. This program foresees on the one hand that our community should gain access as soon as possible to a mm-wave synthesis array, and on the other that NFRA should spearhead the development of a very large decimeter-wave radio telescope for studying the early Universe.

Upgrade program.
The status of and planning for the WSRT upgrades may be summarised as follows.

New front-ends. The prototype multi-frequency front-end receiver system has completed its test program on telescope RT-2 and in the lab, and production of the final front-ends is well under way. The tunable UHF systems go into operation on the telescope in 15 months time, and the cryogenic and low frequency narrow band systems a year later.

New back-end. Our new, high performance, full-custom correlator chip has now been successfully produced and the prototype boards for the new correlator are under test in Dwingeloo. Phased implementation of the correlator system is also foreseen, with the last component -- the wide-band IF system -- coming on-line early in 1998.

Operations software. The new control and observing system (bundled in the software project TMS: Telescope Management System), necessary to make effective use of all the new hardware and new operational possibilities, has now been specified and planned. Implementation will start early in the fall and will be phased to occur on nearly the same time scale as the hardware upgrades.

Maintenance. Finally, during the coming two or more years (the time scale being determined by the availability of finance), we will also undertake a program of major maintenance on the telescope. This will include treatment of the dishes for corrosion and of the load-bearing structures of the (33 tonne) counterweights for metal fatigue.

Disrupted observing. All these activities will unavoidably cause fundamental telescopes to be removed from the array for varying periods of time. First, from September into November, and then from about March into next spring, the telescopes will sequentially be removed from service, each for a period of two to three weeks. During this period the front-end structures will be modified to accommodate the series multi-frequency front-ends. In parallel, as many as possible of the counter-weight structures will be strengthened by welding extra supports in place.

Then, when the front-end modifications are completed, pairs of telescopes will be removed sequentially from the array to treat the mesh and dish structures for corrosion. While it would clearly be preferable to speed this process up, the available financing does not allow us to treat more than four telescopes per year. Preliminary plans are to shuffle newly treated dishes among telescopes RT-0 to RT-4 so that telescopes RT-0 and RT-3, or RT-0 and RT-6, will be unavailable for long periods while the other telescopes are absent only for a week or two at a time. Final scheduling of this work will unfortunately depend to some extent on the availability of contract labour and of course also on the weather.

Observing with a partial array.
We have given much attention during the last two years to getting ready for this situation -- in particular, to providing new modes of using the telescope that do not require the whole array, or indeed do not put requirements on u-v coverage at all. These are, of course, also modes that can be scheduled at any time during gaps in the normal program of 12 hour synthesis measurements. Here let me summarise these modes and the status of their availability as of mid-1995.

Flexible filler bank. This instrument for observing pulsars has been described in detail in previous Newsletters. It makes possible searches for pulsed emission even for relatively high dispersion measures, and is now also set up for pulse arrival timing programs. It connects to the tied-array output of the array and can make use of as many or as few telescopes as are available. From this summer its operation is fully automated, so that observing programs do not require the presence of an observer. Michiel van de Klis (michiel@astro.uva.nl) is pro-
Tied array spectroscopy. Also called the compound interferometry mode, this new capability configures the array as two (individually coherently tied) sub-arrays to form a two element interferometer that feeds the spectral line back-end. Up to 5120 spectral channels of selectable width are thereby available for surveys in velocity/frequency space. Software for removal of the signals from interfering sources away from field center makes use of a fully sampled map of the region; for the 80 MHz bandwidth 92cm receiver system, WENSS data are available for much of the sky. Provision for unattended operation should take place during the coming fall. Jay Chengalur is project scientist (chengalur@nfra.nl).

Cluster-cluster VLBI. As reported last Newsletter, Leonid Gurvits (gurvits@nfra.nl) is spearheading implementation of a technique whereby two synthesis arrays -- in this case the WSRT and the VLA -- are each configured as four (or more) sub-arrays that combine to perform VLBI measurements simultaneously on three (or more) bright, point source calibrators (separated by up to several degrees on the sky) and on a (potentially very weak) nearby object source. In principle, phase errors due to the ionosphere and troposphere as well as instrumental errors can be continuously solved and removed, allowing long integration times on the object of interest without having to detect its fringes on the timescale of phase coherence. Astrometry of mJy sources at the sub-millarcsec level should be possible with the technique when the full arrays are both available. Incorporating the two telescopes working together in this mode in global VLBI sessions should permit high quality mapping of very faint sources (such as high redshift galaxies) with resolution at the milliarcsec level. Contact Leonid for the latest on these developments. Do note, however, that proposals for global VLBI go to both the EVN and US networks, whereas straight cluster-cluster observations must be proposed to the NFRA and VLA program committees.

NFRA gets a new building.

For almost a year now plans have been being made to have a new building constructed for the NFRA Institute in Dwinglee. This building will not only decrease our maintenance costs and bring the working environment into compliance with governmental health and safety regulations, but will also provide much needed additional floor space for JIVE personnel and visitors, for JIVE’s large new VLBI correlator and for the optics laboratory and office and lab space for the personnel and machines of the Kapteyn Observatory working group (KSW). In addition, we expect to have much more pleasant colloquium and meeting rooms, and to be able to accommodate up to ten or twelve visitors simultaneously instead of the current maximum of four or five.

Plans are to construct an entirely new building, that will extend across the current parking area along the boundary of our lease into the wooded area that leads back towards the 25-m radio telescope. The existing two story office wing (which dates from 1980) will be renovated and connected to the new building, but essentially all the existing single story structures will be razed.

During the summer the first hole was dug for the new building. Construction will continue through the winter and into next summer, so that JIVE’s correlator and processing facility can move into new quarters during next summer. As soon as the first phase of the multi-frequency front-ends (the UHF systems) leave for Westerbork, in September 1996, our technical laboratory, engineers, technicians, scientists and administration will move, to be joined by the technicians of the KSW. Finally, when the move has been completed, the then empty older buildings will be removed from the site.

Long term strategic planning.

In February, NFRA’s Board, after receipt of the report of last November’s visiting committee (AFEC-II) and following consultation with the National Committee for Astronomy, formally decided to pursue two lines of policy in the coming years with high priority.

First, priority on the short term will be given to gaining access to one of the currently planned submillimeter synthesis arrays. The required capital financing will be the subject of a formal proposal to our research council, the NWO, this fall. We expect our long term annual budgets to remain very constant, so financing of any operational contributions following a construction phase will have to be accompanied by stopping one or another of our current activities.

Second, policy cornerstone for the longer term at the NFRA Institute and technical laboratory will be a technology development effort, which should lead to an affordable design for and ultimately to construction of a telescope at decimeter wavelengths that will have very substantially increased collecting area over existing facilities -- the so-called Square Kilometer Array.

The latter effort has to be given concrete form within the recently formulated umbrella policy of NWO: even institutes dedicated to purely curiosity driven research should in future develop programs with identifiable elements of wealth creation and relevance to other sections of society. Our approach will initially be to focus on adaptive phased array antennas implemented using highly integrated Si-based technologies. We intend to collaborate with interested telecommunication companies and technology development organisations, with Dutch technical universities and with international groups able to bring new technology to bear on the program, to produce the necessary technical innovations, which can then also be exploited commercially. Such an approach is new to us and will likely require several years to effectuate. By that time the WSRT upgrade program will be nearing completion and our R&D lab can turn its attention to these exciting new developments.
Newsflash !!

Lightning causes a temporary setback in WSRT operations

A powerful thunderstorm has proved to be a major player in WSRT operations. On both July 14th and 27th lightning struck near telescopes 7 and 8, causing major damage to the telescope system. The first stroke on July 14th effected radio telescopes 6 to B, with the greatest damage done to RT8, the one closest to the actual hit. Fortunately the telescope system in the control building was partly shielded from the stroke. Still, the damage of this stroke even inside the systems was considerable.

After we had just recovered from the first stroke, a second one hit us even harder on the 27th. Surprisingly this stroke did not damage the telescope system as much as the previous one. Nevertheless several other systems, e.g. the fire alarm were completely destroyed and the ‘after-effects’ in the electronics are still noticeable and probably will be for some time longer. The ferocity of the hit could be seen by the effect it had on one of the relays. The copper of the relays itself was vaporised, but the plastic cover was still intact.

For over three weeks the WSRT was not able to observe at all. Thanks to the skilful efforts of the Westerbork staff however it was soon possible to return to the daily business of observing. A job very well done.

Announcement

The Committee on Radio Astronomy Frequencies announces:

The Committee on Radio Astronomy Frequencies of the European Science Foundation, CRAF, announces the publication of the CRAF Handbook for Radio Astronomy and the CRAF Newsletter:

The developments of technology which enabled all kinds of advanced astrophysical research, at the same time threatens to render it impossible from the surface of the Earth. Terrestrial, airborne and spaceborne transmissions are generated in ever increasing numbers for a multitude of purposes.

The pressure on authorities to make radiospectrum available for all newly developed tools, e.g. RDSS, MSS, HDTV, DBS, APC, is tremendous.

This Handbook for Radio Astronomy reviews the radio astronomical needs. It is conceptually based on the continuation of this service.

For the sake of the continuation and progress of the science of radio astronomy, CRAF takes the starting-point that frequency protection should be maintained at least to the level the Radio Astronomy Service has enjoyed until now.

The Handbook for Radio Astronomy is distributed among radio astronomical observatories in Europe and elsewhere, among bodies like the CEPT, and industry during August 1995. Institutes interested in a copy of this document should contact the CRAF secretary:

Dr. T.A.Th. Spoolstra
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P.O.Box 2
7990 AA Dwinglew.
The Netherlands
tel: (+31) 5219-7244
telefax (+31) 5219-7332
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The CRAF Newsletter is also available on the CRAF homepage at the address: http://www.nfra.nl/craf.
Square Kilometer Array Interferometer (SKAI) project

Kickoff Meeting on April 18, 1995

Harvey Butcher

At its February meeting, the NFRA Board took a formal decision concerning the long term future of NFRA’s Institute. That future will be predicated on a technology development program that should ultimately lead to the development of a very large radio synthesis array interferometer having a total collecting area of about a million square meters. We are now referring to this effort as the Square Kilometer Array Interferometer (SKAI) project.

To help get the project formally under way, a kick-off meeting was held on 18 April in Dwingeloo. Staff members from all the astronomical institutes in the country were present. The discussion focused mainly on the science of interest to the Dutch community, but consideration of the appropriate technical and political approaches to the project were also on the agenda.

Here I try to summarize the presentations as best I can (any mistakes are mine), also trying to provide enough background to allow readers to get a feel for how our thoughts on the project are developing.

Strawman design

A strawman design of the array has been proposed by Robert Braun (see figures), that will serve as the basis for at least our initial discussions and activities. This concept supposes 32 individual unit telescopes, each roughly 300 meters in diameter, with the array of units arranged in an core pattern of dimension 30 x 50 km (which choice assumes siting in northern Europe, the long dimension being N-S), and having a limited number of outlying element telescopes extending to at least 100 km from the center.
The total cost is a strong function of the highest frequency to be observed; assuming an instrument devoted to the study of neutral hydrogen to \( z < 6 \) - the range of cosmological epochs thought to be relevant to galaxy formation and evolution - a frequency coverage of 200 to 1500 or 2000 MHz is appropriate.

The unit telescopes are supposed to consist of many individual receiving elements, the signals from which are combined in phase and (weighted) amplitude to generate multiple, electronically steerable beams on the sky whose sidelobe structure can be controlled in real time to minimize sensitivity to external interference.

At one extreme, each unit telescope could consist of an Arecibo-like spherical dish sunk into the earth, and would then employ a movable, phased array of receivers near its focus. Or it could be an array of many small (6 to 25 m diameter) steerable paraboloidal dishes. And at the other extreme, each unit might consist of a field of a very large number of individual receiver elements (generalized dipoles) relying solely on electronic phasing for beam steerability.

The meeting was told that some variant of the latter design is the preferred option at the moment at NFRA, for three reasons.

- The advantages of having no moving parts, especially as regards maintenance costs during operation, seem considerable. The ease in this concept with which multiple beams on the sky can be created and pointed electronically, can be manipulated in shape to minimize the effects of interference, and can be used for calibration during observing, is very attractive.

- Adaptive phased array antenna technologies are also of intense current interest to the R&D groups of telecommunications companies. During the coming decade that industry will be converting the well developed relevant military technologies into affordable, silicon based systems for commercial exploitation. This approach then seems likely to have the best chances for proceeding in collaboration with industry and for generating commercially exploitable technical spin-off.

- Finally, although it cannot be predicted how man-made interference in the environment will evolve in the coming decades, it seems possible that the most intractable problems will involve satellite communications, in which case few if any places on earth will be immune. Northern Europe, and the northeastern Dutch provinces and Lower Saxony in particular, can in this case also provide candidate sites. Here environmental issues are taken very seriously, leading on the one hand to good control of unwanted activities in the region (e.g., interference generating activities), and on the other to a requirement for close cooperation with environmental groups when planning any new activities. Thirty-two 300 m structures spread over a couple of hundred of kilometers would only be a serious option if they would also contribute to other plans for the region (e.g., maintenance of nature reserves and eco-tourism) and if they are very inconspicuous - i.e., flat, such as a phased array of simple receiving elements would naturally be.

**Science case**

Discussion of current thinking on selected topics of particular interest to our community was lead by individual researchers.

*Tjerd van Albada* summarized the situation regarding the evolution of large scale structure over cosmic time. He especially emphasized two points:

- Redshifts of normal galaxies to \( z = 0.3 \) using the H I line will be trivial with the SKAI, but large scale structure to that limit should be known from other planned studies by the time the telescope goes into operation. The SKAI should plan to push the redshift limit for this study to beyond \( z = 2 \). But if the instrument is capable of integrating for roughly a hundred days, then it should be able to detect \( (5 \sigma) \times 10^5 \) to \( 10^6 \) galaxies with H I masses \( \geq 5 \times 10^7 \) M\(_\odot\) of H I per square degree in the interval \( 2.8 < z < 3.2 \).

A substantial fraction of a square degree should therefore be available instantaneously for observation, arguing for element telescope diameters not of 300-m but of more nearly 100-m. The strawman design would have to accommodate this need by employing multiple beams from its 300-m apertures or be modified to consist of a hundred elements each 100-m in diameter.

*Marijn Franz* underlined the importance in this regard of being able to study in some detail the "transition" in the universe that occurred at \( z = 2 \). That is, all studies of cosmological evolution must take into account the potential evolution of the probes used - usually galaxies - and at this redshift we know something major happened to many and probably most galaxies. As does its strawman concept, the SKAI should ensure that systems with H I masses on the order of \( 2 \times 10^9 \) M\(_\odot\) could be studied during and after this epoch.

*George Miley* carried this line of thought further, emphasizing that morphological information on systems in the range \( 1.5 < z < 3 \) will be essential to a successful interpretation of the processes governing evolution. Luckily, cosmology comes to our rescue here and angular sizes of individual systems are expected to vary rather little between \( z = 0.8 \) and \( z = 3 \). But baselines up to at least 150 km are of fundamental importance for this work, even if that means sacrificing brightness sensitivity. George also noted that optical follow-up will be necessary, so account must be taken of where the large optical telescopes will be to which Dutch researchers will have access. Given the advanced state of the ESO VLT, this may mean a southern hemisphere site is to be preferred.

*Frank Briggs* discussed the epochs before \( z = 3 \), pointing out that the spectra of QSO's show absorption lines to \( z \approx 5 \). One should therefore seriously consider trying to detect proto-galaxies and proto-clusters (H I masses \( 10^{12} \) M\(_\odot\) and greater) in the range \( 5 < z < 8 \), both for the study of galaxy formation and of large scale structure. The signature of such objects will
likely be diffuse line emission on one arcminute scales, arguing for as compact a configuration for the SKA1 as possible to maximize surface brightness sensitivity. The main question mark seems to be whether or not the inter-galactic medium re-ionized by these epochs, in which case one would want to optimize the SKA1 for detection of the Thomson scattering haloes around QSO’s, as proposed by Sholomitsky. The μJansky continuum sensitivities required are achievable with the strawman SKA1, but the detection of expected tangential linear polarization over scales up to a degree will be an observational challenge given the galactic foreground emission and Faraday rotation.

I pointed out a proposal by Dubrovich that it may be possible to open an observational window to even earlier cosmic epochs (100 z 300, say) if one can detect the fluorescence of early, rare molecules (LiH, HeH+, etc) at mm wavelengths with SKA1. Here one would also expect galaxy-sized condensations to be involved, so that arcminute resolution with the highest possible surface brightness is also indicated.

Renzo Sancisi discussed the prospects for substantial progress in understanding the nature of unseen matter around galaxies using H I rotation curves. Adequate maps of galaxies to z = 0.5 might be derived with a compact (30 km) configuration for the SKA1, but to learn about the evolution of unseen halos one wants to map systems to well beyond z = 1. This will require baselines of 100 km or more, which however then provide inadequate brightness sensitivity unless (as seems possible) most galaxies are substantially richer in H I than nearby systems. Also of great interest will be the study of the H I tails and bridges between galaxies in small groups over cosmic time. To what extent do the metal line absorption systems in QSO spectra come from such gas rather than from gas bound to and part of extended discs in spiral galaxies? Can we observe spiral discs forming over cosmic time?

Frank Verbunt told the gathering that exciting aspects of stellar research were hard to identify if one wants to avoid "more of the same (even if better)" science. That is, the ability of the SKA1 to detect a large range of normal stars would permit it, in the global VLBI network, to obtain distances and proper motions rather better than HIPPARCOS, but that this could not be expected radically to change our current ideas on anything. Similar arguments probably apply to most aspects of pulsar research, for which the SKA1 should otherwise be ideally suited. Possibly the most interesting possibility could be the use of pulsar timing observations to determine the gravitational accelerations of pulsars in globular clusters and in the general galactic potential - if enough suitably stable pulsars can be found such observations could provide information obtainable in no other way.

Development program

Arnold van Ardenne told the meeting that NFRA sees a timescale of ten years for the SKA1 development program. That is, in ten years we should be ready to start construction of the final SKA1. This program will comprise three areas of activity, each foreseen to take a good fraction of the allotted decade and each requiring its own project team: (i) generating in detail the science case, as discussed above; (ii) carrying out the R&D required to solve outstanding technical issues; and (iii) doing the politics required to involve sections of the broader community in the project.

The technical problems to be solved to turn the strawman concept into reality are formidable. Current designs for adaptive phased array antenna’s generally are efficient only over a small frequency bandwidth, for example, and their efficiency is usually a function of frequency. If one is to consider extremely large numbers of receiver units, it is unavoidable that highly integrated circuits must be employed – whole receiver systems on a single chip -- and that one must focus on silicon based chip technologies. And the amplifier systems must achieve noise figures close to current state of the art but without significant cooling below ambient temperatures. Finally, a major problem for phased array antenna’s is and will remain the extremely large numbers of connections and connectors required -- minimizing cost and maximizing reliability here will be a major challenge.

The development program envisaged includes laboratory prototyping on a several year timescale and a major working prototype that can be added as the fifteenth and possibly sixteenth element telescopes to the Westerbork radio telescope. The practical experience thereby gained would not only be valuable for the SKA1 but the step would also provide the WSRT with coverage of the southern sky as the ESO VLT comes on-line.

As regards politics, an inescapable fact of the current scene is the lack of an existing international organization in Europe to champion major projects in radio astronomy. While it is not clear whether this will ultimately prove an advantage or disadvantage, it is clear that the project will ultimately have to be internationally financed and run. Our strategy will be first to create support and commitment in the wider Dutch community, then turn to building an international consensus and formal organizational structure to carry out the final construction and operation of the facility.
### Allocations PC 95-01

**WSRT Allocations period July 1995 - December 1995**

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<th>WSRT No.</th>
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Note: Oversubscription rate: 275/165 = 1.67

### JCMT Allocations August 1995 - January 1996

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<td>N07</td>
<td>Sprans</td>
<td>Cool Star PDR’s</td>
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<td>Groenewegen</td>
<td>Mira Mass Loss</td>
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<td>N10</td>
<td>Hurley</td>
<td>Soft γ-ray Repeaters</td>
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<td>N13</td>
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<td>Outflow in M36</td>
<td>U/B/A</td>
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<tr>
<td>N15</td>
<td>Israel</td>
<td>Cl in Big Cold Bulges</td>
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Note: NL JCMT Oversubscription rate: 99/46 = 2.2
## WHT Allocations August 1995 - January 1996

<table>
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<tr>
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<td>Franx</td>
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<tr>
<td>N02</td>
<td>Bremer</td>
<td>Evolution Cluster Galaxies</td>
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<tr>
<td>N03</td>
<td>Kuijken</td>
<td>Bars in Bulges</td>
<td>1D</td>
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<tr>
<td>N07</td>
<td>Prins</td>
<td>Spectroscopy M31 SNR's</td>
<td>2G</td>
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<tr>
<td>N08</td>
<td>Kuijken</td>
<td>Kinematics Bulges Disk Galaxies</td>
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<td>Voors</td>
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<td>Fatava</td>
<td>Lithium in Stock 2</td>
<td>1B + 1B backup</td>
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<td>van Winckel</td>
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<td>van de Werf</td>
<td>ISM Cooling: Flow Galaxies</td>
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Note: Oversubscription rates:
- D: 12/7 = 1.7
- G: 9/5 = 1.8
- B: 25/9 = 2.8
- Overall: 46/21 = 2.2

## INT Allocations August 1995 - January 1996

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<td>N05</td>
<td>van Paradijs</td>
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<td>N06</td>
<td>de Bruyn</td>
<td>Spectroscopy Giant Radio Galaxies</td>
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<td>N07</td>
<td>Favata</td>
<td>X-Ray Hipparcos Stars</td>
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<td>N08</td>
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<td>Surface Photometry WHISP Galaxies</td>
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<td>van Hoof</td>
<td>CNO in PN's</td>
<td>2B + 2B backup</td>
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Note: Oversubscription rates:
- D: 17/8 = 2.1
- G: 20/6 = 3.3
- B: 11/8 = 1.4
- Overall: 48/22 = 2.2

## JKT Allocations August 1995 - January 1996

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<td>Spectroscopy OB Stars</td>
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Note: Oversubscription rates:
- D: 7/8 = 0.9
- G: 10/4 = 2.5
- B: 5/14 = 0.4
- Overall: 22/26 = 0.9
Multi Frequency Front End progress report

Gie Han Tan

General
Less than a year ago the successful Multi Frequency Front End (MFFE) design review was held at the Dwingeloo observatory. Since then good progress has been made in the project. Both on the improvement of the MFFE design and the prototype MFFE, which acts as a test vehicle for the design, as on the series production of the series project phase.

MFFE design and prototype
The general recommendation of last years design review was to freeze the presented design. However there were still some problems with the system temperatures at the 13 cm, 6 cm and 3.6 cm wavelengths which should be solved to achieve the specified goals. Next to that it was accepted that the design of the receiver-systems below 1200 MHz be improved for sensitivity. Last point made was that if possible without interrupting the pace of the series project it should be investigated what could be done to broaden the 49 cm receiver.

The problems with the high system temperatures were traced down to resonance effects in the waveguide structures for 6 cm and 3.6 cm. At the point where the waveguide enters the cryostat thermal gaps are introduced to avoid any heat transfer through conduction. These gaps together with the surrounding environment in which they are embedded produced a resonant structure causing RF energy transported by the waveguide leaking away. This loss resulted in extra thermal noise which gave a serious contribution to the overall system-temperature. A re-design of these waveguide gaps and there environment solved this problem. At 13 cm the situation was different, instead of waveguide coaxial lines are used to bring the signal from the feed into the cryostat. Here the problem was caused by these coaxial lines, which had very good thermal characteristics, but suffered from relatively high loss and matching problems. Again this resulted in an extra noise contribution to the total system temperature. This problem was solved by using another type of coaxial cable.

In February of this year the prototype MFFE was brought again on one of the WSRT telescopes for another test-run. Performance at 13 cm (fig. 1) and 6 cm (fig. 2) was much improved and matched well with the foreseen system-temperatures of 58 K at 13 cm and 55 K at 6 cm. Unfortunately the performance at 3.6 cm had improved but was not as low as was specified. More research has been spend on this problem since then and the, not totally completed, analysis has shown that the mesh leakage of the reflector is higher then had been assumed in the past. When the analysis has been completed, the results will be published in a this newsletter. But at this moment it is sure that the specified noise temperature at 3.6 cm has to be adjusted to a higher value since a replacement of the reflector mesh is not foreseen.

During this test-run also VLBI observations were made at 13 cm and 3.6 cm. The correlated results showed that the prototype MFFE performed very satisfactory for this observing mode. This conclusion is not only important to validate the new local oscillator system of the MFFE but is also a major milestone for the WSRT, since it is a new observing facility provided by the WSRT to the astronomical society.

A major effort has also been spend on the receiver systems below 1200 MHz (92 cm, 49 cm, UHFlow, UHFhigh). New LNA’s for all 4 wavelengths were designed which give very low noise (15 K - 30 K) at room-temperature. By placing these LNA’s directly at the feed the receiver temperature becomes almost the same as the noise temperature of the individual LNA.

A re-design of the RF- and IF-system now makes it possible to observe with a maximum instantaneous bandwidth of 80 MHz. The 10 MHz bandwidth is still available and must be used in situations where a lot of external interference is encountered. To achieve this new RF and IF modules had to be designed. The design of the RF-modules was done in house, while the IF module was designed in cooperation with the Central Electronic Department of Delft Technical University, the Netherlands. At the moment of writing (July 1995) prototypes of these modules are available and will be tested next.
Prototype MFFE / System temperatures 6 cm

Source: Cas. A = 701 Jy (Baars et al 1977), Tsource = 56 K, 10-2-1995

August in the WSRT to validate their performance. When these tests are completed the MFFE design for phase 1 of the series project will be completely frozen.

For the 49 cm receiver it has been identified which parts should be re-designed to achieve a larger tuning range. However it is not completely clear how much time it will cost and if it will be done. Later this year a decision will be made on this subject.

Series project

Last year also the production phase of the MFFE made a start. As was presented this phase is split up in two stages. Phase 1 will produce a series of 15 MFFE's equipped with the UHP low and UHP high receivers, while phase 2 will add all the remaining receivers.

The project-team has focused on phase 1 and completion is expected in December 1996. This relatively short production period for the complicated MFFE design is to a large extent caused by the approach that a large part of the construction of both mechanical and electrical parts is contracted out to industry. This approach, where just documentation of our designs is given to a manufacturer and the production is completely done by him, is a new to our institute. This meant that our organisation had to adjust with this new situation. Among others more time had to be spent on the quality of documentation and procedures for contracting out, handling documentation, testing and qualification had to be established. But at this moment we see that this initial investment in time is rapidly paying back and results in a good confidence that the project will be finished in time. Next to that this new way of working will be of benefit to future projects like the 1 km2 array. The R&D group of NFRA can spend more time on his core activity while leaving the production work to specialized industry.

Concerning phase 2 it has been decided that this should be ready by the end of 1997. Up to now it has been investigated how this can be achieved in a secure and cost effective way. At this moment the approach we have chosen is to cooperate with the various technical workshops of the Dutch universities to have them make the complicated mechanical systems which are needed for phase 2. Discussion is going on to get the necessary commitment from the involved parties to assure that the completion date in 1997 will be met. By September of this year this stage should be reached and a firm planning schedule will be available.
A new Telescope Management System for the WSRT

Marco de Vos

Most of you know about the construction of the Multi Frequency Front-Ends and the development of the new DZB backend. They will give a dramatic increase in the possibilities of the WSRT. They have been described and "advertised" at length in this Newsletter and in various reviews. Some of you may have wondered how we are going to fit all these nice new things in the current WSRT. Building a new device is one thing, connecting it to some existing hardware is something different, and controlling the two in a consistent and efficient way is yet another problem. This article is concerned with the latter problem.

Let me quote from a document produced in December 1994:

The WSRT is a complex instrument that can produce high quality radio-data on a wide range of astronomically interesting sources. In the forthcoming years, two major hardware upgrades will increase the quality of the instrument considerably. Those upgrades will also increase the complexity of the instrument, and thus demand for an improved system for operational control. This operational control system is referred to as the Telescope Management System (TMS).

In constructing the TMS we are confronted with the one hand with an existing system that has historically developed to a considerable complexity. It allows for functionality which will have to be available in the new system as well, but may also contain functions and choices that need to be reevaluated. On the other hand we face new hardware with new functions, new interfaces and new protocols. The new system should be able to make optimal use of the new possibilities thus offered. Finally we are facing a user group which has demands in terms of observing modes and service. These demands are taken very seriously, so the new system should be flexible enough to allow us to accommodate.

(from: Towards a Telescope Management System for the WSRT, NFRA Note 626, pg. 3).

It had by then become clear that we did not want to accommodate for the new hardware in the existing on-line/off-line system. We wanted to make a fresh analysis of the present situation, and a complete redesign using the state of the art in software technology. This choice was not made just for fun, or because we like to build nice software (although it is fun, and we do like to build nice software). The main driver was, and still is, that we need a reliable software system at Westerbork. It needs not be fancy, but it needs to be robust, flexible and extendible.

The TMS project started in January 1995 with a concept study in which the requirements were formulated and a global analysis was made. The resulting document was over 100 pages long, so I will save you the details (please contact me if you're interested). The figure shows the three domains with which the TMS is concerned. Operating the WSRT can well be compared to a production process. Such a process cycles over planning, manufacturing and evaluation. In our terms: specifying and scheduling observations, observing and post-processing. Post-processing obviously includes quality analysis of the data.

The concept study was followed by a feasibility study. In this phase a development plan was made, specifications were further consolidated and a project team was formed. We are now starting the actual development. The TMS will be built by a team of five people, most of them spending only part of their time on the TMS. We will use object oriented techniques for the analysis and design of the system, and implement it mostly in C++. Object oriented techniques turned out to be well suited for a system like the TMS. Verifying this was one of the goals.

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**Resource Management**
- Define Resources (devices, programs)
- Compose Instruments
- Specify Projects & Observations
- Plan a Schedule

**Post-Processing**
- Assess quality of Measurements
- Calibrate Resources
- Do Initial research processing

**Operational Control**
- Launch Instruments
- Adjust Resources at clock ticks
- Control Resources (in test mode)
- Monitor Resources

Astronomer's requirements

Research data + quality report
for the concept study, by the way, we are not just following the hype.

The TMS will be developed in several stages. First we will build the necessary backbone, allowing us to communicate with all computer systems involved, guaranteeing proper storage of information of the system etc., followed by a prototype for observation control (using dummy devices). Then the first production version will be build. In this version many of the existing programs will be used with a TMS-wrapper. In the second production version, the old software will be replaced by pure TMS programs. Finally a third sweep over the whole system will be made to improve performance and robustness.

Our main goal is to release a working version before the new hardware becomes available. This will allow us (and you) to make full use of the new possibilities of the WSRT as soon as possible. In this respect, I hope that TMS will not only mean "Telescope Management System" but also towards more science.

For more information on the TMS contact the author at devoscalnfra.nl or have a look at http://www.nfra.nl/nfra/tms.

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The EVN-MarkIV processor

Jean Casse

The EVN-MarkIV processor is being designed, built and tested at different locations and by different Institutes: the Playback Units and the Station Units (SU) have been contracted to Penny & Giles Data Systems Ltd (P&G) in the UK, the Correlator hardware is primarily a task for the Haystack Observatory with a contribution from NFRA (system design and input board).

The realisation of a custom correlator chip has been contracted out to the NASA Space Engineering Research Center (SERC) for VLSI System Design at the University of New Mexico. The high level processor software has been granted to the Nuffield Radio Astronomy Laboratories (NRAL) at Jodrell Bank. The Station Unit Interface Module (SUIM) linking the SU to the correlator, the Clock module and the Test, Synchronisation and Pulsar gating Unit (TSPU) are the responsibility of JIVE in Dwingeloo with part of the work subcontracted to the Institute of Radio Astronomy at Bologna. The Data Distributor which links the Station Units to the Correlator module is the responsibility of NFRA. The cooperation between JIVE, NFRA and NASA (representing itself, the Haystack Observatory, the Smithsonian Center for Astrophysics (CFA) and UNM) has been formalised with the creation of the International Advanced Correlator Consortium (IACC).

The processor consists of 16 Playback Units feeding 16 Station Units in which the track data is decoded and reformatted prior to correlation. Between the Station Units and the Correlator is the Data Distributor (part of the Correlator subsystem) which allows a great variety of configurations but also provides a recirculation mode by which the efficiency of the Correlator in the case of spectral line observations is greatly enhanced. Timing is provided by a central timing system (TSPU/Clock) which also provides the gating of pulsar signals. The data transfer between subsystems are to take place via high-speed Serial Links. The whole correlator is controlled in semi real time (all subsystems have intelligence) by a Correlator Control Computer (CCC).

Correlator subsystem

The basic building block of the correlator subsystem is the Haystack correlator chip. The logical design has been carried out at Haystack. The physical design, production and testing of prototypes has been contracted to SERC. A condition for letting the contract was the demonstration of a working correlator chip initially designed for the Arecibo telescope. After a second iteration this chip was demonstrated to work at a clock rate of 130 Mhz, well above the specification.

The first 12 wafers yielding over 1300 Haystack chips have been delivered from the Hewlett Packard (HP) foundry to the University of New Mexico (UNM) in December 1994. A number of correlator chips were still being packaged at the end of the year when the chip designer J. Canaris from UNM, started the testing procedures. In parallel to these developments, the correlator chip has undergone extensive simulation testing in correlation modes at both Haystack and UNM. A limited amount of VLBI data has been fed to the virtual correlator chip and later to the prototype correlator board and "first IACC correlator fringes", in good agreement with the expectations, have been obtained.

This first batch, unfortunately, has an important flaw: the built-in phase rotators are not working as a result of a design fault. This means that a second iteration is required which began in the middle of June. For this operation 3 of the 16 masks have to be redesigned and the new layout re-simulated. The chip yield of the first batch has been depressingly low as a result of chip damage during testing and packaging. The
present yield is only 19% (vs 12 % for the Arecibo chip) but measures are being taken to improve it in the next batches.

In the meantime a correlator crate with backplane, control board and one correlator board populated with chips from the first batch (see photo) has been delivered to Dwingeloo so that the testing in-house can be started. The Data Distributor is presently still in the design phase. It is not intended to use it in the prototype phase. The present status for this item is that the functional description was released in April of this year. The design team is now occupied with the detailed design.

**Station units**

The contract with P&G concerning the Station Units (SU) involves the design of four prototype units, including full documentation and full rights for reproduction by companies outside P&G. This project is the responsibility of Bryan Anderson at Jodrell Bank who set the specification and takes care of the "daily" monitoring.

These four prototype Station Units should have been delivered in the course of March of 1995. The manufacturer, unfortunately, met with serious design problems so that delivery had to be postponed until about September of this year. The problems are concentrated in the so-called TRM (Track Recovery Module) which serves to recover the signals from the tracks on the tapes regardless of the format, the operating mode, the data rate, etc. This module produces decoded and synchronous signals which are then rebuilt into channels, have the proper delays applied to them, etc. The designers use FPGA's (Field Programmable Gate Arrays) for these operations extensively. These chips simplify greatly the overall design but as a result of their complexity, are quite difficult to route, especially if a large fraction of the available functionality of the chip is to be used (95%) in order to reduce the costs and while in addition the data rate is set at the limit of the specification.

**Playback units**

A contract was let in 1994 to P&G for 16 Playback Units. These units have been specified to operate at the standard MarkIII A, MarkIV and VLBA speeds with thin and thick tapes. P&G demonstrated for JIVE and MPIFR (David Graham) visitors on a prototype recorder that it could read the tracks written by a Metrum Data Acquisition System and hence meet the specification. According to the current plan, the Playback Units will be delivered to Dwingeloo from July 1995 to February 1996. A document from P&G specifying the procedure for the acceptance of the Playback Units has been
prepared and sent to JIVE for comments. To be comprehensive, the performance tests will include all possible configurations.

The delivery of the first Playback Unit was scheduled for the beginning of February. It appeared at the time that the unit did not meet the specification; the parity error rate was far too large. A test of a P&G headstack at Haystack indicated that the performance (SNR test) was at least 4 to 6 dB inferior to that of the Metrum Headstack. This is most probably the cause of the problems with the high error rate. An R&D program has been started at P&G to improve the performance of the heads.

**SUIM/TSPU**
The SUIM interfaces the Station Unit and the Data Distributor. It is housed into one of the slots of the Station Units backplane. It has many other functions like the gating of the signals (for instance for pulsar work), the injection of test signals, etc. The Test-Synchronisation-Pulsargate-Unit (TSPU) feeds the whole correlator with the appropriate clock and gating waveforms. Both are being designed at JIVE by Sergei Pogrebko. Pogrebko is being assisted in this by Gino Tuccari and Stelio Montebugnoli from the Institute for Radio Astronomy at Bologna. Broadly speaking, the XILINX design has been done in Noto while the board design was taken care of by the team in Medicina. At this moment a working SUIM has been delivered while the design of the TSPU is in the final design phase.

**Processor control software**
The control software for the Correlator Control Computer is the responsibility of a team at the Jodrell Bank Observatory working with R. Noble as project leader. The last quarter of 1994 was the first with the Control Software team up to its final strength of four.

It is intended that the Correlator Control Computer will be a Unix workstation. This workstation is not a real-time system and hence each subsystem has its own intelligence for handling time-critical operations. The CCC passes ahead of time to the various subsystems the necessary instructions in the form of "messages" via a suitable Local Area Network (LAN). The "grand design" for the processor software which is being developed using the Object-Oriented Modeling and Design technique was practically ready by the end of 1994.

The availability of the various hardware subsystems governs the planning of the software tasks. At this stage, unfortunately, as a result of delays with the hardware projects practically no tests have been performed using the software already available for instance the Playback and Station Units software. The final software interface specification for the remaining subsystems (correlator, TSPU, tape handling system) have been laid down only recently. The processor software will also include the necessary tools for diagnostic purposes. The use of HOPS (Haystack Observatory Postprocessing Software) for that purpose is being investigated. Selection of the type of Data Base has not yet been made. The software team is striving to adopt a system in common with NFRA for their new Westerbork correlator.

**Timeline**
The planning for the prototype processor has been carried out using the Super Project (SPJ from Computer Associates) planning methodology as much as possible. In the planning the delivery dates for the subcontracted subsystems are entered as milestones.

The planning of the prototype indicates that "first fringes" could be observed in the Spring of 1996. As a result of delays with the delivery of a number of items, the original slack in the planning has vanished. It can be concluded from the planning that the Station Units, the Serial Link modules, the software for the DSP's (Digital Signal Processors used for controlling the correlators) and the correlator chip are currently all on the critical path.

Planning information for the completion for the 16 station processor is also becoming available. The current planning which still needs refining/optimizing predicts a completion date of mid 1998.

The building extension in Dwingeloo have just started. It is expected that by the end of 1996 the new building will have been delivered.
Proposal deadlines

New proposal for the WSRT, the ING and the JCMT should be received before noon 15 September 1995 at the address below.

Dr. F.P. Israel
Sterrenwacht Leiden
P.O. Box 9513
2300 RA Leiden
The Netherlands

Proposal deadline for EVN is 1 October 1995