JUMPING JIVE

Project ID: 730884

# JJ WP5 Tasks 1 & 2 Report To TOG

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# Glossary

**cal diode** A noise diode emitting a known amount of signal. Used to calibrate an antenna/receiver system. 3

**core2 board** Part of the DBBC which contains samplers and oscillators and does the digital processing for a chunk of bandwidth. 3

**DBBC** Digital Baseband Converter. Tunes the receiver into the required chunks of bandwidth. 3

**Electron** A framework allowing html, javascript, and css applications to be packaged as stand-alone desktop applications. 6, 7

**fila10g** Part of the DBBC that sends the output stream of data with time stamps added to the recorder. 3

**Flexbuff** Recording equipment consisting of a rack mountable computer with a large amount of internal (non removable storage). 2

**fringe** spike in a lag plot resulting from successful cross-correlation of data. 3

**NME** Network Monitoring Experiment. An experiment used solely to check the performance of the EVN. 3

**SQL** Structured Query Language. A computing language mostly used to query databases. 6

**ToG** Technical Operations Group. Body responsible for the technical operations of the EVN. 1

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# 1 Introduction

The main goal of this work package consists in testing and evaluating the performance of new telescopes highlighting the calibration and quality control of their data. However, the activities of WP5 have more ambitious goals which also have useful and very important consequences on the current available EVN telescopes. These activities are summarized in the following three main tasks:

- Enhancements at existing EVN and affiliated telescopes.
  Being telescopes instruments for performing science, they do not keep their equipment unmodified. Constant upgrades are usual and the incorporation of new front-ends, back-ends and recorders (data interfaces) requires periodic testing to assure that the quality is kept or improved, and that the compliance of the requirements is achieved.

- Supporting new telescopes and creating an inventory of potential new facilities that could join the EVN in a short term period.
  New telescopes joining the EVN happens very rarely since these are complex, scarce, and very expensive instruments. Therefore the goal of this task is more oriented in exploring the potential of already existing antennas or already planned telescopes that could join the EVN. In the case that within the JUMPING JIVE project lifetime new telescopes become available, support should be given to these stations.

- Improving the station feedback from the pipeline and archive.
  This is possibly the most important task to ensure a high level of quality from EVN stations. It consists of renewing the feedback system to assess each telescope performance.

This work package has a deliverable on month 18 which consists of a short report on the activities performed (and presented to the ToG) so far on tasks 1 and 2. This document summarizes this work and is divided in two sections that address these two tasks independently.

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# 2 Task 1 Activities

## 2.1 Significant Enhancements at Existing EVN and Affiliated Stations

There have been several improvements to the hardware at station level, these are summarised here.

### 2.1.1 Flexbuff Usage

With the addition of 160 TB of Flexbuff storage at both Noto and Medicina, along with associated capacity at the correlator, 9 EVN stations now utilise a Flexbuff as summarised in table 2.1.1. This storage not only simplifies the distribution of Mark 5 modules for the whole EVN, but also aids the transition to regular 2 Gbps recording rates and increases the flexibility of the EVN for target of opportunity and other out of session observations.

| Station | Local Capacity | Capacity at Correlator |
|---|---|---|
| Effelsberg | 256 TB | 101 TB |
| Metsähovi | 95 TB | - |
| Hartebeesthoek | 110 TB | 202 TB |
| Onsala | 324 TB | 101 TB |
| Yebes | 216 TB | 252 TB |
| Medicina | 160 TB | 168 TB |
| Noto | 160 TB | 288 TB |
| Westerbork | - | 288 TB |
| Jodrell Bank | 144 TB | 202 TB |

Table 1: Flexbuff Storage at Stations

### 2.1.2 Hardware at EVN Stations

New receivers at Kunming and Urumqi (6 cm, 5 cm, and S/X at Kunming, and the return of K-band at Urumqi) have allowed these stations to regularly join in EVN observations. For example Urumqi joined more than half (55/101) of the EVN observations in 2017.

A new L-band receiver has been installed in the Tianma 65 m antenna, and (after initial issues with polarisation) it appears to be performing well. New K-band and Q-band receivers have also been installed. The K-band receiver is

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performing well and the Q-band receiver is awaiting testing. Effelsberg has also recently installed a new Q-band receiver which is awaiting testing along with Tianma.

Support for continuous calibration has been increasing. Effelsberg, Medicina, Metsähovi, Onsala, Yebes, Hartebeesthoek (15 m only) and Sardinia now all support continuous calibration at least partially. New DBBC firmware supports noise diode switching between 10−100 Hz. Jodrell Bank has all required hardware in place and testing is ongoing. Continuous calibration remains a priority for the EVN particularly at the slower stations as it both decreases time spent waiting for a slow antenna to slew to source and fire a cal diode, and improves the amplitude calibration of the EVN which has been suboptimal to date (especially at higher frequencies). Software for extracting these calibration signals has been developed both at JIVE (extracting from the data directly) and at Yebes (extracting from the field system log) and tests are ongoing to determine the best solution.

JIVE has been supporting Warkworth with their initial continuous calibration setup as well.

Improvements in network infrastructure have allowed the Kvazar stations to join in eVLBI observations for the first time. Jodrell bank also observed as part of eVLBI at 2 Gbps for the first time, and the addition of two core2 boards and a fila10g at Westerbork allows not only 2 Gbps disk observations but also eVLBI. This is supported by a significant expansion in capacity of the JIVE software correlator (SFXC) and local networking infrastructure at JIVE.

## 2.2 Incorporating New Stations

A major goal of the JUMPING JIVE project remains the addition of new stations into the EVN. Most of this goal is addressed as part of work package 5 task 2. However supporting the integration of these new telescopes and tests involving them are a part of task 1 and thus discussed here. In particular this applies to the (re)integration of eMERLIN into the EVN, as well as initial tests using MeerKAT and the new African VLBI Network (AVN) stations (which are also supported by work package 9).

There has been significant progress on eMERLIN. Fringes were seen to four eMERLIN outstations during the NME tests at C-band in session two 2017 . Initially these still had significant problems: Gain calibration was well outside ideals, resulting in poor quantisation at the sampling stage, and thus essentially one bit data (non-symmetric around 0). Improvements followed quickly though and by session one 2018 network monitoring experiments (NMEss) showed

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much better sampler statistics for all four outstations, as well as weak but definite fringes at K band. These were the first K-band fringes with eMERLIN in the EVN.

Fringes were also found to MeerKAT for the first time during the N18L1 fringe test. MeerKAT observed in multiple modes: phasing 16 dishes with the beamformer, single dish through the MeerKAT correlator, and single dish raw data. So far only the beamformed data have been correlated, however the detection of fringes is a major step in MeerKAT deployment.

The 32 m Kuntunse former communications station in Ghana is the first AVN telescope to undergo successful conversion, and fringes were observed in the NMEs N17C1 and N18C1. At present the telescope has not joined science observations as the rubidium frequency standard is not stable enough for good quality observations at C-band (the only receiver currently available). Kuntunse has put out a tender for a Hydrogen maser to be installed by the end of the year. Investigations into a possible cooled receiver are ongoing.

JUMPING JIVE has also supported the Ghana AVN station through training of local operators and expertise and support in running both a local SFXC correlator for testing and the JIVE correlator for single baseline tests between Hartebeesthoek and Kuntunse.

There have been several successful observations with the Australian Long Baseline Array (LBA) observing alongside the EVN (GS039 and GG084A) which have been correlated at JIVE.

As part of WP 5, JIVE correlated the first VLBI observation of the new 13.2 m VGOS antenna in Santa Maria. Fringes were found in some bands and subsequent observations showed strong fringes. Santa Maria is available for EVN observations at X-band in the short term until IVS observations increase in cadence there.

## 2.3 Support Enhancements

In addition to supporting new hardware and stations in the EVN, support activities as part of JUMPING JIVE work package 5 have also been ongoing. The JUMPING JIVE support scientist acts as a point of contact for stations to report (and ask for help with) problems, as well as new ideas for improvements in the feedback system between stations and JIVE. The activities described below are to be considered part of task 1 and task 3.

There were three urgent requests:

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### 2.3.1 Amplitude Calibration Feedback

The amplitude calibration performance of the EVN has been reported back to EVN stations at the technical operations group (ToG) meetings roughly every 8 months. This results in often long delays between observations and feedback to stations on the quality of their amplitude calibration, and thus an inability to correct issues on reasonable time-frames. As such the back-end producing these feedback values has been completely overhauled and automated as much as possible, minimising the length of time between correlation and amplitude calibration quality feedback.

In addition these values are now stored in a database, and a new front-end using Grafana has been developed and released to stations. The Grafana powered front-end provides not only default graphs and values, but also exposes the database and tools, allowing stations to make their own custom graphs, tables and other products. This gives stations an idea of their performance throughout the previous sessions as soon as possible after correlation, and hopefully a chance to improve any problems in time for the next EVN session.

### 2.3.2 Station Feedback Database

The second major improvement requested by stations involves the station feedback system. This differs from the amplitude calibration feedback as it is submitted by the VLBI friends at EVN stations and is used to report issues occurring at station level. This has in the past been a single text file per experiment powering an independent website per experiment listing all feedback submitted by the station personnel. This sort of schema is great for a PI or support scientist at JIVE to quickly check if any issues were reported during their experiment.

Unfortunately this format is not very conducive for a station to examine their performance throughout a session or year, as it is not possible to easily search or order this feedback by station, session, or time. To that end a new database has been implemented to hold station feedback. The front-end for inputing feedback has not been changed and the new system runs in parallel to the old system. This means that new feedback is compatible with the old system and the existing webpage structure continues to exist, requiring no workflow changes for PIs or support scientists. All existing feedback has been converted (where possible) into the new database and any future feedback submitted gets added to both the original text format and the new database. Some data before 2002 differed in structure too much to be imported into the new database but almost all feedback since 2002 is included.

In order to provide more feedback to stations, PI letters (which contain a summary of any problems detected by JIVE) are automatically parsed and any

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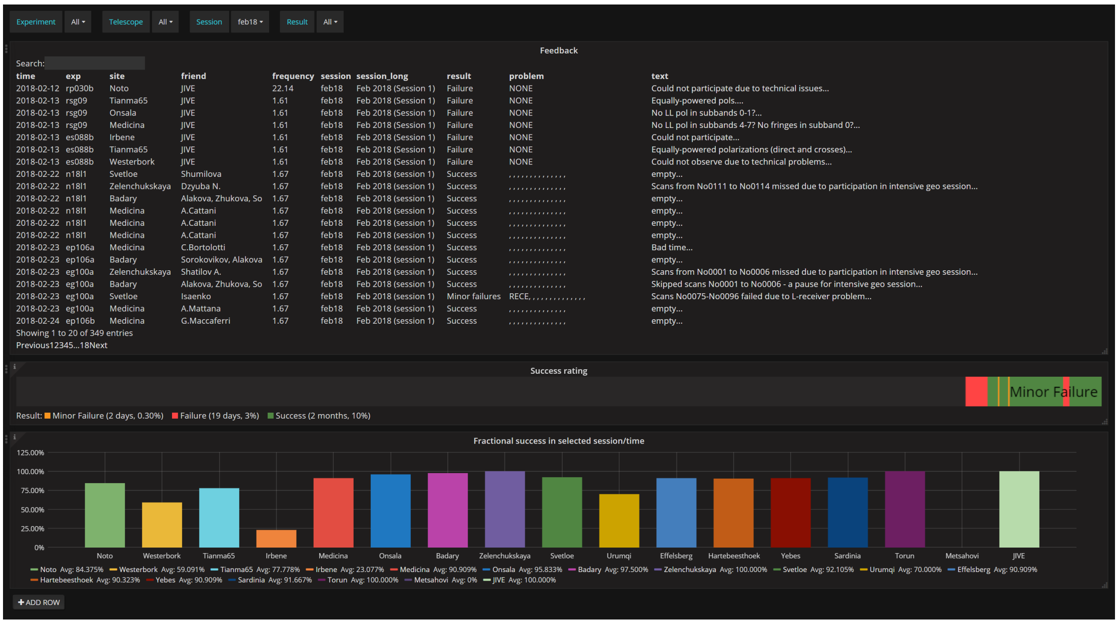


Figure 1: Grafana showing the feedback table and per session success rate for stations.

problems detected during post correlation analysis are also added to the new database. The database is accessible using the same Grafana front-end as for the amplitude calibration feedback, and provides a search-able table that can also be sorted by time, experiment, telescope, VLBI friend, frequency, session, and result type (e.g. Failure or Success). A graph of the average success rate per telescope can also easily be generated for each session.

Again the Grafana front end exposes the database directly, so custom SQL can be written by station personnel directly if more detailed access is required.

Both the new amplitude calibrations and station feedback systems are continuing to be developed as feedback is given by stations as to how they are being utilised.

### 2.3.3 EVN Communications

For each network monitoring experiment (NME) and eVLBI observation an EVN-wide chat is set up in order to coordinate observations, report any problems both from stations and from JIVE, and discuss results. This has been done using Skype. Unfortunately over the last few years the quality of the Linux Skype client has diminished as Microsoft stopped maintaining it. A new alpha client was then released which was an Electron wrapper around the Skype web client. At this time the old Skpye client was no longer usable as Skype changed the underlying

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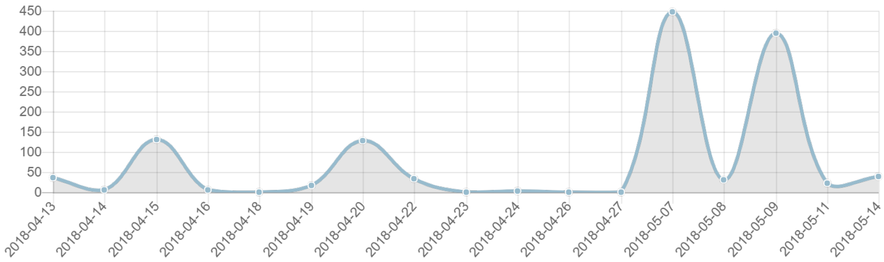


Figure 2: Total posts per day on EVN Mattermost in April and May.

communications system from peer to peer to cloud based. As such the only working Skype client on Linux was the alpha Electron build which was unstable and required updating every week or so as older builds would no longer allow log in. The change to cloud based communication also resulted in conversation history only being available for 30 days.

For this reason Slack was tested as a new communications tool. Unfortunately while the test went generally quite well it was discovered that Slack is blocked in China making it unusable for the EVN. Additionally the free version of Slack only stores 10,000 posts of history and some concerns were expressed about EVN communications being stored on external servers/the cloud (although this is now also the case for Skype).

For these reasons an open source Slack clone called Mattermost has been installed at JIVE and has now been adopted for all EVN communications during NMEs, eVLBI and tests. So far this seems to have been well received and has operated smoothly. It appears to be seeing use even outside of EVN sessions (see Figure 2). It is worth noting that over 7000 posts have been made in the EVN Mattermost since its 'launch' ath the end of January 2018.

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# 3 Task 2 Activities

This deliverable, due month 18, is an inventory of potential telescopes that can join the EVN or take part in EVN observations in the future. An increase of radio telescopes as part of the EVN would benefit it for two reasons: sensitivity and UV coverage, which results in an increase of the fidelity of images of sources. It also benefits the interested stations since a radio telescope taking part in an international collaboration acts as a pole of attraction for technological work and development that yields a very positive feedback to the country where it is located. This task has some overlap with WP 3, building new partnerships.

Although the EVN stands for European VLBI Network, Euro-Asiatic VLBI Network would be a more precise name, the EVN is truly a global network with stations and institutes currently in Europe, Asia, Africa and even an associated member in America. New additions to the EVN include therefore stations not only located in Europe.

Below we provide a table of radio telescopes that in the short-term and mid-term future could possibly join the EVN. We have classified this list in three distinct types: new telescopes, geodetic ones and old antennas conveniently modified to operate as radio telescopes. Some of the telescopes listed below will probably join other networks but will ultimately take part in EVN observations.

| Type | Name | Diameter | Frequency range | Location |
|---|---|---|---|---|
| New | NARIT | 40 m | L, K bands | Thailand |
| New | UAE 40m | 30m-40m | | UAE |
| New | FAST (CVN and EAVN) | 500 m | L band | China |
| New | QTT (CVN and EAVN) | 110 m | 150 MHz - 115 GHz | China |
| Geodetic | VGOS-RAEGE | 13.2m | 2-14 GHz | Portugal |
| Geodetic | VGOS-BKG | 13.2m | 2-14 GHz | Germany |
| Geodetic | VGOS-NMA | 13.2m | 2-14 GHz | Norway |
| Upgradeable | Goonhilly | 26m | | UK |
| Upgradeable | Sao Miguel | 32 m | | Portugal |
| Upgradeable | EISCAT | 32 m | L band | Finland |
| Upgradeable | Kuntunse | 32 m | C band | Ghana |
| Upgradeable | Hellenic | 30 m | L, C band | Greece |

Table 2: Potential telescopes that could join the EVN in the short-term, mid-term future

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## 3.1 New telescopes

Within this category four telescopes have been identified: NARIT 40m, UAE 40m, QTT and FAST.

**NARIT 40m** radio telescope is an already running project project which is currently progressing well and within its timetable. The construction of the infrastructure will start by the end of 2018 and the antenna is planned to be completed one year later. The telescope will be located about 40 km away from Chiang Mai, Thailand. The design is heavily based on the 40m Yebes antenna. NARIT has signed several Memorandum of Understanding with different institutes like IGN, MPIfR and the University of Manchester. The MOU with IGN allows collaboration in all technical levels but it will start on software control, operators and software engineers training and holography works. The MOU with MPIfR will be devoted to the construction of receivers at L and K bands.

The location has a limitation: the high water vapour content which will probably limit the higher observing frequency to K band. Observations at Q band may be restricted to some short periods along the year.

This telescope, being at a latitude of 19 degrees, provides an extension of the EVN towards the south which is now only covered by Hartebeesthoek. It is also relatively close to Kunming Chinese telescope and it would provide mid length baselines (1000 to 3000 km) with Chinese telescopes and long baselines above 6000 km to most of the telescopes in Europe.

The telescope will be equipped with an L band and a K band receiver for the commissioning phase.

A recent The presentation by the current project manager, Phrudth Jaroenjittichai1, with the current status is attached to this report as an independent file.

**FAST** radio telescope is a 500 m radio telescope in China. It belongs to NAOC and it is currently in the commissioning phase. The telescope is equipped with a 19 multibeam L-band receiver. Operations are foreseen to start by 2019 after the commissioning phase between 2016 and 2018. FAST would boost the sensitivity of the EVN at L-band and become a reference antenna in the network.

A recent presentation by Prof. Di Li with the current status is attached as an independent document.

**QTT** is a project for a 110 m radio-telescope in Urumqi, China. It is managed by Xinjiang Astronomical Observatory. The telescope will be equipped with receivers from 150 MHz to 115 GHz at both, the primary and secondary focus. The first receivers to be installed will be at 2 cm, 5 cm and 13/3.6 cm wavelengths.

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The project already has a funding of 700 M and works have already start at the site. The construction phase will take a 6 year period followed by 3 years devoted to testing.

This telescope will be probably integrated in the CVN, Chinese VBI Network in the future and it is expected to also take part in the EVN since Urumqi is already a member of the EVN.

A recent presentation by Na Wang with the current status of the project is attached as an independent document.

**UAE 40m**. The United Arab Emirates radio telescope is a project supported by Prof. Gendalf who contacted JIVE in 2016 requesting information for VLBI capabilities. The current status of the project is unknown. The UAE is sending a probe to Mars in 2021 and the UAE Space agency considers that a radio-telescope would be beneficial for the space program and for the science of the country. A workshop held in March 25 and 26, 2018 at New York University Abu Dhabi Institute addressed these matters. The suggested size ranges between 30 m and 40 m diameter. Such project is still to be considered by the government and hence it is still in the project phase. No observing frequencies have been decided yet.

Some exchange of emails between JIVE and the TOG chair with Prof. Gendalf happened and may be attached if required to this report.

## 3.2 Geodetic telescopes

These telescopes are already part of the new VGOS network or they will be part in the next years. They are usually 13 m diameter size with high speed azimuth and elevation drives above 10 degrees/s and 5 degrees/s respectively and they are equipped with very wide band receivers between 2 and 14 GHz. Receivers yield four 1 GHz bands in two linear polarizations with low system temperatures. The wide frequency coverage guarantees a common frequency setup with one of the most used EVN bands: 4.5 to 6.6 GHz and with a less used band centered around 8.4 GHz. However the higher frequencies guarantee an additional compatibility since the EVN is already planning extending its traditional C band up to 15 GHz. There is currently a big activity within Radionet BRAND project to reach this goal in 2020 with a prototype to be installed at Effelsberg 100 m radio telescope.

One apparent drawback would be the mismatch between the linear (VGOS telescopes) and the circular (EVN telescopes) polarizations. However it has already been proved that correlation is possible both types of polarizations using ad-hoc software written by Martí-Vidal in the last two years. Furthermore, the new wide band low frequency receivers for the EVN, BRAND type, will possibly

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use linear polarizations. There is also a hardware solution recently proposed by the Observatory of Yebes to the International VLBI Service (IVS) for VGOS stations within the RAND project that allows to convert the linear polarization into circular polarization using cryogenic hybrids in front of the low noise amplifiers. This solution needs still to be evaluated both at BRAND and the VGOS Technical Committee. If accepted it would imply that geodetic stations could seamless be integrated into EVN observations.

We have identified two main drawbacks for the usage of these telescopes within the EVN:

- VGOS will require in its final configuration 24h operations 7 days per week. Therefore it may be not possible to find observation time with the EVN. However this may not be an insolvable obstacle since an agreement between the EVN and the IVS could encompass some time for common astronomy observations.

- VGOS telescopes are small sized and their sensitivity is limited, however this can be partially compensated by wide bandwidths that in a 5 year time will be common both at the EVN and the IVS.

There are VGOS telescopes at the following sites in Europe: two twin telescopes at Wettzell (Germany), two twin telescopes at Onsala (Sweden), two twin telescopes at Ny Alesund (Norway) and one telescope at Yebes (Spain). The most interesting antennas are those located at stations which do not share the site with an already EVN telescope like Yebes and Onsala. Therefore these two sites should possible be disregarded. The distance between VGOS telescopes and the Onsala 18 m EVN antenna is roughly 1 km, whereas the distance between Yebes VGOS and the 40 m antennas is 400 m. Unless there is a very strong interest in very short baselines to recover wide emission these VGOS telescopes should be discarded. Besides such short distances allow RFI to be present in both antennas and very difficult to remove and avoid.

Wettzell and Ny Alesund however are excellent locations since they would provide between several hundred to a few thousand kilometers baselines. Their small size could be compensated by phasing up both telescopes.

The EVN is currently favouring the usage of data storage locally and at the correlator and this requires high speed Internet connections between both. VGOS telescopes fulfill this requirement since they produce vast amounts of data and would therefore be easily integrated into the EVN.

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## 3.3 Old re-purposed telescopes

Within this category fall the telescopes from Ghana, also to be included in WP9 (Capacity for VLBI in Africa), Sao Miguel, EISCAT from Finland, Goonhilly and the Hellenic telescope. Other potential candidates are: Usuda decommissioned 50m radiotelescope and ROT54/2.6 in Armenia.

Most of these telescopes are old communication antennas which should be overhauled and require a big investment to provide them with new gearboxes, faster motors, cooled receivers, a backend and a frequency standard and if possible, a high speed Internet connection. A reference article about such investment and transformation is the description of conversion of the New Zealand 30m telecommunications antenna into a radio telescope by Woodburn (2015).

**Kuntunse** telescope is an old Mitsubishi communications antenna 32 m diameter located in Ghana. It is currently equipped with narrow band warm receivers at 5 and 6.7 GHz. The antenna is still undertaking improvements with a new cable-wrap currently being employed (the current one limits the azimuth range the station can observe). A new hydrogen maser has also been ordered to allow for science operations (the current rubidium standard is not sufficient at C-band).

The maximum speed of the antenna is 0.29 deg/s which allows tracking but prevents fast slews between sources. Ideally this antenna should have newer motors and gearboxes to increase the slewing speeds and reduce the time between scans.

Jumping JIVE has already provided support to the staff who have attended several meetings for training. The scientist devoted to this work package has also travelled to Kuntunse to provide assistance and experience and train the staff at the site.

We attached the presentation with the current status of the Kuntunse radio telescope as an independent document.

**Sao Miguel** telescope is also an old Mitsubishi 32 m diameter antenna similar to the one in Ghana and located in the Azores Islands in the Sao Miguel island. The antenna was decommissioned by the telecommunications company and it could be used for radioastronomy observations. The antenna is very degraded because of the high humidity of the island, mostly the structure is full of rust. The investment required to clean the structure and implement the improvements required to make it work is high. MT-Mechatronics has estimated the cost to be around 2-3 M €. However no funds are currently available although an application is being written to ask for European economic support. The existence of the RAEGE telescope in the Santa Maria island can help in the

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operations and upgrade of the antenna since technical experience is available close to the site.

A small presentation with data from this antenna is also attached as an independent document.

**EISCAT** 32m telescope in Kiruna, Finland is an old 32 m antenna of the same type as Medicina and Noto which is no longer in use since 2015. Prior to that date it was used for telecommunication purposes. Two more telescopes of the same type are available in Tromso, Norway and Sodankylä, Sweden. The Kiruna antenna is currently equipped with a narrow band (8 MHz) L band receiver. The possibility to upgrade this antenna for radio astronomy has been considered and there is some support from Metsähovi. However there have been no news since the last months neither on the antenna upgrade nor on potential receivers or funds and this antenna is improbable to be upgraded in the short or midterm future.

We also attached an old presentation with information on this antenna as an independent document.

**Hellenic** 32m telescope is an old antenna devoted to telecommunication owned by the Hellenic Telecommunication Company OTE which is being decommissioned. A memorandum of understanding has been signed between the owner and the School of Sciences and Technology (SST) of the Hellenic Open University and the Telecommunication Systems Applications Research Laboratory. The antenna is located in Skarfeia, Lokrida. It is equipped with a C band receiver and works to upgrade the antenna are foreseen. Plans are being developed to install an L band receiver at 1.2-1.45 GH and 1.6-1.7 GHz.

Contacts will be established with the University to assess the feasiblity of an upgrade.

**Goonhilly** site. Two telescopes are available:

- Goonhilly-1 'Arthur' with a diameter of 25.9 m. This is an old telescope that was orginally used for the first transatlantic satelite communications. This dish will be fitted with an L-band receiver system which is being provided by Jodrell Bank and eMERLIN. Some works are underway at the moment.

- Goonhilly-3 'Guinevere' with a diametet of 29.6 m. This is a newer telescope with a better surface than the first one. This telescope will be equipped with a relatively broad-band C-band system. This receiver is being is being built by Oxford University from a modified version of the receiver designed for the CBASS projects SKA band-5a/b.

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Both telescopes are owned by 'Goonhilly Earth Station Ltd - GES-Ltd'. For the conversion and operations of Radio astronomy on the Goonhilly site there is a UK university consortia which have all individually provided funding with the motivation of converting these antennas and operating them for Radio astronomy. The consortia for Goonhilly Astronomy (CUGA) is made up of: Leeds, Manchester (JBCA), Oxford, Hertfordshire, Durham, UCLAN, Southampton, Bristol - Chaired by Melvin Hoare (Leeds).

### 3.3.1 Other re-purposed telescopes

At the time of this report some telescopes have appeared in the horizon but we have decided not to include them due a lack of concrete information. These telescopes are: Usuda-64, an old space communication antenna used by JAXA Japan) and soon to be decomissioned, Xi'an 40 m telescope at China, with an L and C band receiver compatible with the EVN and ROT/54/2.6 located in Armenia with a very odd geometry.

### 3.3.2 Effects of new telescopes on the EVN

Figure 3 (top) shows the existing EVN with potential new additions in red. We have not considered the VGOS antennas for this analysis due to the negatives described above. For a 'standard' EVN observation at C-band (5 cm) the following telescopes can be considered a likely 'EVN' array: Effelsberg, Hartebeesthoek, Irbene, Jodrell Bank (Lovell), Medicina, Noto, Onsala, Tianma, Torun, Yebes, Westerbork, Baday, Svetloe, Zelenchuckskaya. For two hours on source time this array results in an image noise of 6.9 $\mu$Jy/beam.

Adding in the potential 'new' telescopes: NARIT, UAE40m, QTT, Sao Miguel, EISCAT, Kuntunse, and Hellenic, this would decrease to 3.9 $\mu$Jy/beam. Note this does not include FAST as FAST has only an L-band receiver (at least at this stage). The effect of adding the new (again not including VGOS) antennas to the EVN on UV coverage is shown in figure 3 (bottom). In this example we consider the UV coverage at L-band for the first half of the N18L2 L-band NME with and without the possible new stations.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730884

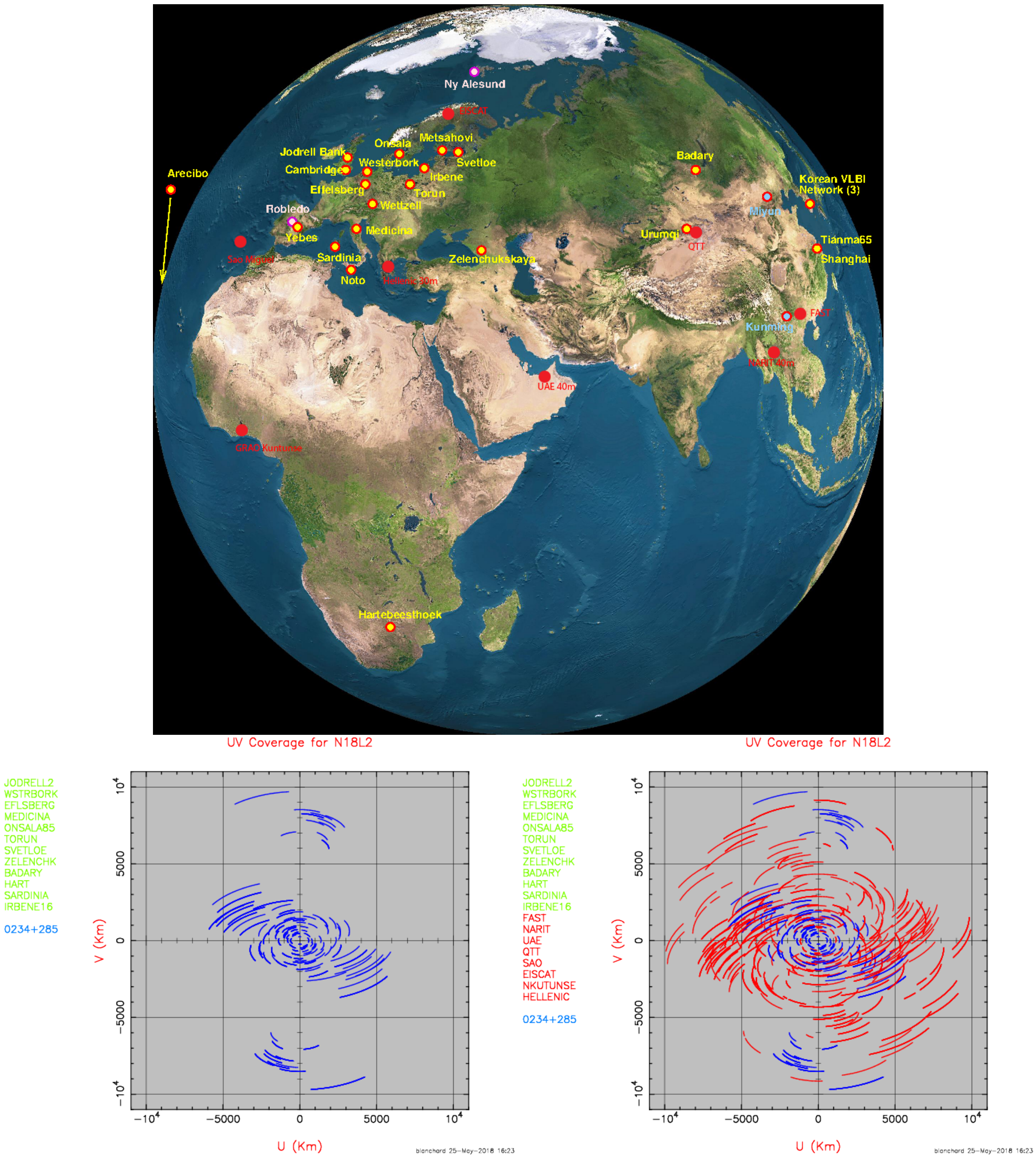


Figure 3: Top: Map of existing and possible new telescopes (in red). VGOS dishes are not included due to the decreased likelihood of being included. Bottom: UV coverage benefit of possible new telescopes. Left: With existing telescopes scheduled for N18L2. Right: with addition of possible new telescopes (in red). VGOS dishes are not included due to the decreased likelihood of being included.

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# ONLINE PRESENTATIONS

The slides presented at the ToG reporting the current status of the following potential stations are available on the JUMPING JIVE wiki pages[1].

- Sodankylä 32-meter
- Sao Miguel 32-meter
- Fast 500-m
- SmART / QTT project
- Ghana 32-m
- Thai National Radio Observatory

[1] http://www.jive.eu/jumpingjive/doku.php?id=new_elements:presentations

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