JUMPING JIVE

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Final report on JIV-ERIC memberships

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Contents

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1 Introduction

VLBI is collaborative and international by its very nature. Since the first VLBI demonstration experiments in 1967, the technique firmly occupies the leading position in high angular resolution studies of celestial objects. The European VLBI Network (EVN, Fig. 1) was established in the mid-1970s by combining the efforts of several European institutes and observatories, established primarily for activities other than VLBI. With the scientific achievements of astrophysical, astrometric and geodetic research by means of VLBI studies for more than four decades, the science case for prospective VLBI necessitates true globalisation. On a European scale, it means involving new partners and connecting them to top-level science by integrating them with EVN and JIVE activities. As members of a VLBI network that one day will include the SKA, European VLBI facilities can participate in the ongoing transformational advancement in radio astronomy.

JIVE was established first in 1993 as a Foundation under the Dutch law representing the core institutes and observatories of the EVN. It was transformed into the European Research Infrastructure Consortium (ERIC) in 2015. The multi-level partnership between JIVE and its members and associated organisations is the key component of the JIVE existence and main operational activities. Thus, JIVE always maintained partnership relations with its members as well as EVN organisations. However, it was the JUMPING JIVE project which provided new momentum for enhancing existing partnerships and establishing new ones.

The aim of JUMPING JIVE WP3 was to communicate the incentives to contribute to JIVE and EVN to relevant national research organisations and policymakers. These incentives are:

- Involvement in cutting-edge scientific research in cooperation with world-leading teams and organisations;
- Direct access to the intellectual property of the Europe-wide VLBI collaboration;
- Joint exploitation of science potential of VLBI for national-specific scientific schools and priorities;
- Joint exploitation of educational and public outreach potential of EVN and JIVE.

The main task of WP3 was to generate interest among potential new partners to participate in JIVE and EVN. While this WP had only a single task, its implementation was adapted for the specific status of readiness and other domestic circumstances of many new potential partners. The Work Package was implemented in three tiers, that differed by those specific domestic parameters:

- **Tier 1:** countries and organisations already involved in one or another way into EVN, JIVE and/or JIVE-related Horizon-2020 or other joint activities, not members of the JIV-ERIC, but with a well-established path toward membership. This involved consultations on local policy roadmaps and funding proposals, as well as drafting collaborative agreements. In specific cases, it could have entailed the implementation of joint science, educational, R&D and PO activities in these countries in close collaboration with the EVN.

- **Tier 2:** countries/organisations with existing “seed” VLBI groups and/or facilities that are not or only minimally involved in JIV-ERIC activities, but move toward establishing

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or enhancing cooperation with EVN and JIVE. This Tier encompassed establishing mechanisms to involve scientists, engineers and students in JIVE and EVN activities.

- **Tier 3:** countries/organisations, which possess existing radio astronomy facilities with new VLBI potential but so far are marginally or not involved in EVN and JIV-ERIC activities.

All three Tiers included similar forms of joint actions with local contacts, e.g., assisting them in creating a case to the respective national authorities on radio astronomy and VLBI developments. It also carried educational components and nationally oriented PR actions.

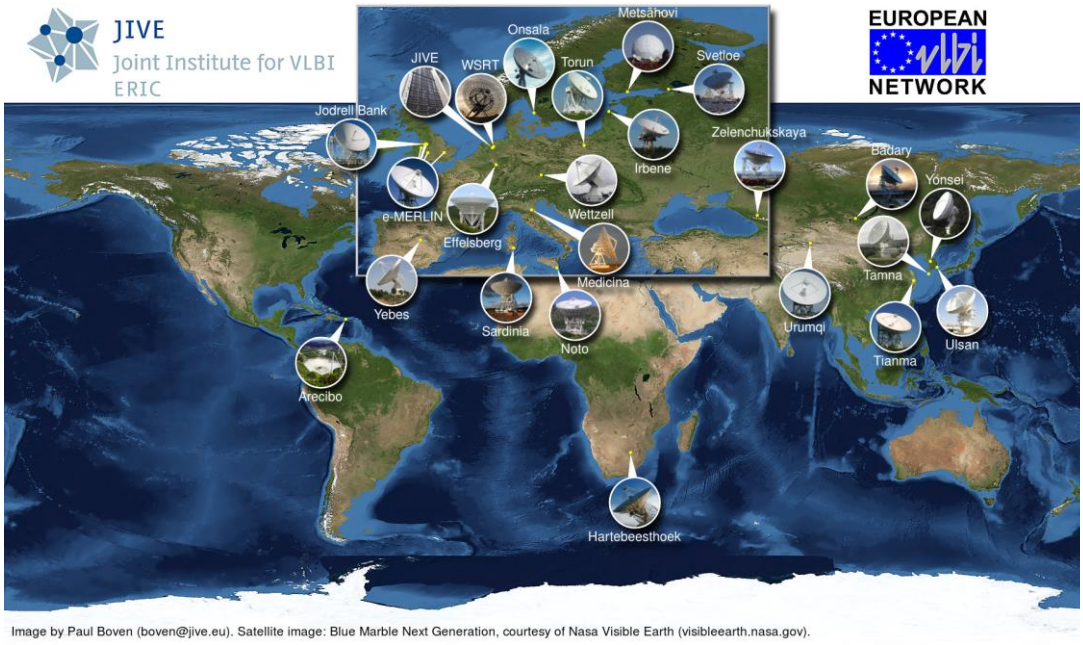

Fig. 1. Map of the European VLBI Network as of July 2020

2 WP3 implementation

The JUMPING JIVE WP3 was highly synergistic to a number of other JJ project Work Packages, in particular WP5 “Integrating new VLBI elements”, JJ WP6 "Geodetic capabilities", JJ WP9 “Capacity for VLBI in Africa” and JJ WP10 “VLBI with the SKA”. Thus, the implementation of WP3 involved many instances of joint actions with other JJ WPs.

Due to a broad variety of potential new JIVE and EVN partners, which are either prospective ERIC members (countries) or cooperating organisations, as well as new organisations participating in EVN activities, the implementation of JJ WP3 required different approaches, adjusted for specific circumstances in different countries and/or different research environments.

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The current document provides an inventory of all JJ WP3 counterparts and a brief description per organisation relevant to the scope of the JUMPING JIVE project.

3 Tier 1: Toward JIV-ERIC membership and membership support

The Joint Institute for VLBI in Europe has been established as a Foundation under Dutch Law in 1993. In 2015, JIV-ERIC has substituted JIVE Foundation as the core organisation of the EVN. At the time of the JUMPING JIVE initiation, JIVE had five members (France, The Netherlands, Spain, Sweden and the UK), with Latvia joining JIV-ERIC from 2016. At present (May 2021), JIV-ERIC has seven members, including the latest addition, Italy. Three organisations, National Astronomical Observatories (NAOC, PR China), Max Planck Institute for Radio Astronomy (MPIfR, Germany), and National Research Foundation and South African Radio Astronomy Observatory (NRF and SARAO, respectively, South Africa) have the status of JIVE Participating Research Institutes.

Below country-specific activities at new or prospective JIV-ERIC members (countries) are summarised.

3.1 Finland

The Metsähovi Radio Observatory (MRO), a division of the Aalto University (Finland) is involved in VLBI activities in the context of EVN and IVS for several decades. Besides participation in VLBI observations with its 14-m radio telescope, MRO excels in developments of VLBI-specific hard- and software. MRO is an associated member of the EVN Consortium. The MRO and Aalto were not members of the JIVE Foundation. Given a high level of expertise in VLBI, accumulated at the MRO, as well as the active involvement of several research groups at Aalto University, Turku University and Finnish Geospatial Research Institute (the latter being a subject of the Finnish Ministry of Agriculture and Forestry), full membership of Finland in JIV-ERIC appears to be very natural.

Specific incentives for the Finnish membership in JIV-ERIC are also related to the well-established involvement of the Aalto University and other Finnish organisations in high-profile space science projects, including several ESA planetary and space science missions. Worth exploring is a potential transfer to radio astronomy operations of an EISCAT 32-m parabolic antenna in Sodankyä in northern Finland, which almost certainly will require the involvement of the MRO and JIVE expertise. In addition, the technology-oriented synergy between EVN and IVS is a strong factor for the continuation of advanced VLBI R&D projects in Finland. This might be linked with the prospective collaboration between EVN/JIVE and IVS.

All the topics above have been incorporated in the draft National Roadmap for Astronomy prepared at the Aalto University during the JJ WP3 implementation in close cooperation with the representatives of the JIVE management. By the time of the JJ Project completion (May 2021), the outcome of the Roadmap evaluation by the Finnish authorities was not been announced. However, the JIV-ERIC Council invited a representative of the Aalto University in

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the Observer capacity (as stipulated in the JIV-ERIC Statute) to attend JIVE Council meetings starting from May 2021.

3.2 Italy

The Italian National Research Council (CNR), later substituted by INAF as the prime national agency for radio astronomy collaborations, has been among the founding members of the JIVE Foundation since 1993. The Italian representation in the JIVE Foundation has been entrusted to the Institute of Radio Astronomy (IRA, Bologna). The INAF owns and operates three VLBI antennas (Medicina, Noto and Sardinia), which are key components of the EVN. In the process of JIV-ERIC formation in the period 2011–2015, INAF consistently expressed support to the creation of JIV-ERIC. However, due to massive management reorganisation and change of leadership within IRA, INAF and at a larger national scale in the period 2014-2019, Italy has not become a member of JIV-ERIC in the first (founding) group of countries. Since 2015, INAF has participated in the JIV-ERIC on the basis of annual MoA's.

The JIV-ERIC Council and JIVE management continued active engagement with appropriate authorities in Italy over the entire period of JIV-ERIC existence. This included multiple meetings with the representatives of INAF, presentations of the case at several national and international meetings, a special presentation at the Accademia Nazionale dei Lincei (Rome, December 2017), a special meeting of representatives of the JIVE Council and INAF in Bologna in May 2019.

At the beginning of 2021, all these efforts concluded with the formal adoption of Italy as a JIV-ERIC member. This marks a fulfilment of the respective JJ WP3 task.

3.3 Latvia

Radio astronomy research began in Latvia in the 1960s by conducting Solar observations with a 10-m antenna in Baldone. After becoming a sovereign state in 1991, Latvia inherited, among other former Soviet military assets, a facility with two parabolic antennas of 32 and 16 m in Irbene, near Ventspils (Fig. 2). After 20 years of intensive reconstruction, the radio astronomy facility in Irbene has become operational. These major achievements enabled the Ventspils International Radio Astronomy Center (VIRAC), the owner and operator of the Irbene radio telescopes to become a member of EVN in 2016. In the wake of this milestone, Latvia has become a member of JIV-ERIC also in 2016.

While Latvian membership in both EVN and JIV-ERIC is a remarkable achievement (especially taking into account the size of the country with a population of about 2 million people), further support of the young VLBI school in Latvia is very topical. This is consistent with several JJ WPs, including WP3. In particular, the ongoing work construction of the Baltic LOFAR/ILT station in Irbene is the topic relevant to the JJ WP4.

After formal admission into the JIV-ERIC and EVN, JIVE continued providing support to VIRAC in various forms. In particular, JIVE supported the implementation of the EC ERA project 1.1.1.5/18/A/019 VIRAC Institutional and Scientific Capacity (LATSPACE). Representatives of JIVE participated in organising committees of several editions of the Baltic conference on Astroinformatics and Space Data Processing (BAASP) at the VUAS/VIRAC in Ventspils.

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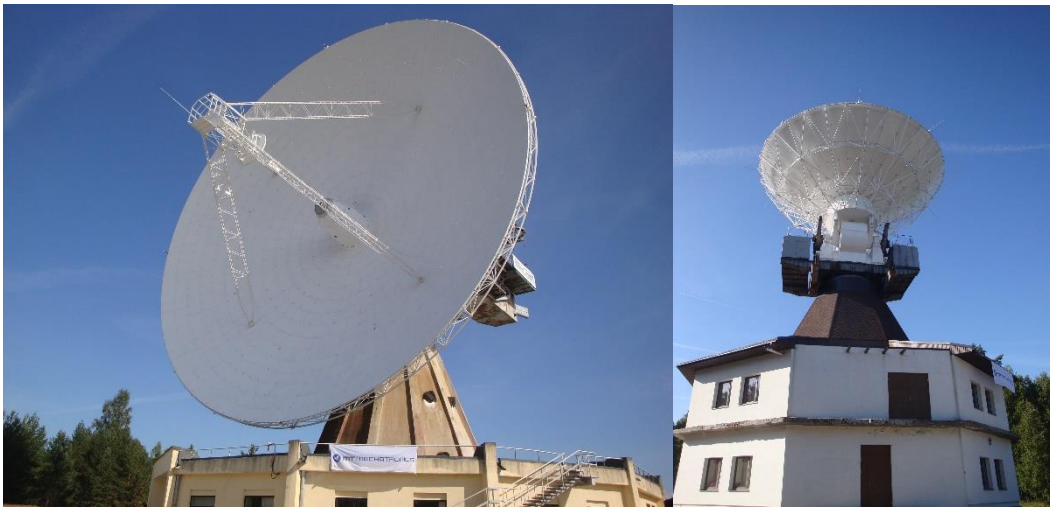

Fig. 2. VIRAC radio telescopes in Irbene, Latvia: 32 m (left) and 16 m (right).

JIVE also supported multiple public outreach activities in Latvia in the form of TV, radio interviews and publications in national and domestic newspapers. in 2020–21, JIVE through the JJ WP3 provided advisory support to the international evaluation of the VUAS and VIRAC.

It is reasonable to expect that while Latvia will remain a member of JIV-ERIC, and VIRAC will remain a member of EVN, continuing international assistance in the development of VLBI in Latvia will remain topical for the coming years. It will be conducted as an extension of the WP3 activities beyond the completion of the JJ project.

3.4 Poland

The Centre of Astronomy (CA) at Nicolaus Copernicus University (Toruń) is the major VLBI facility in Poland. Currently, its Department of Radio Astronomy operates a 32-m radio telescope located in Piwnice. The Piwnice group is active in VLBI research for more than four decades. The CA is a member of EVN. However, the CA never was a member of the JIVE Foundation and currently, Poland is not a member of JIV-ERIC. In the early years of JIVE existence, Polish participation in JIVE (and EVN) has been severely limited by economic conditions in the country that was in the socialist block until 1990. Since Poland's admittance in the EU in 2004, the situation has changed significantly, all political and economic hurdles for Polish participation in European scientific endeavours have been removed.

In 2010, under the guidance of the JIVE Foundation Board and leadership of the Nicolaus Copernicus University, JIVE began consultations with the Polish Ministry of Science and Higher Education on Polish participation in the JIVE Foundation. Although these consultations indicated positive perspectives for the eventual involvement of the Nicolaus Copernicus University in the JIVE Foundation, the process did not develop further due to domestic reasons in Poland.

Since 2015, the domestic situation for Poland becoming a member of JIV-ERIC has become more favourable. This is evident from several recent major steps undertaken by Polish authorities in joining major European scientific endeavours (eg. ILT, major ESA science

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missions). However, a “bottom-up” initiative aiming at eventual Polish admission into JIV-ERIC proved to be difficult.

In 2019, a new round of preparatory work for prospective Polish admission to JIV-ERIC has started from preparing a motivated case, which would be considered at the appropriate admirative level. In 2021, the CA got an offer to become an Observer in the JIV-ERIC structure, and a representative of the Center of Astronomy was invited to attend JIVE Council meetings starting from May 2021.

3.5 South Africa

VLBI research in South Africa has been centred at the Hartebeesthoek Radio Astronomy Observatory (HartRAO) since the mid-1970s. HartRAO is a member of EVN as well as the LBA and IVS. The HartRAO’s staff was actively engaged in advanced VLBI technology developments. Over the past decade, all radio astronomy activities in South Africa have been aligning with the SKA process. An important milestone on the road toward SKA-1 is the full deployment of the SKA’s precursor, the MeerKAT radio telescope. The latter is on the way to becoming VLBI-compatible in the coming year or so. The eventual participation of the SKA-mid in VLBI research is “on the books” too.

In 2018-2019, as a part of the preparation for the roll-out of the SKA-mid facility in the Karoo plateau, a major reorganisation resulted in establishing a new entity, the South African Radio Astronomy Observatory (SARAO). SARAO has become a "home" for both the HartRAO and MeerKAT.

The well-established radio astronomy groups in Africa (SARAO, SKA Office) provide extensive assistance to other African countries in founding operational radio telescopes. The flagship example of this activity is the radio telescope in Nkutunse, Ghana, inaugurated in 2017. Eventually, a network of such telescopes distributed over the continent will form the African VLBI Network (AVN). JIVE provided support to the first VLBI tests with the Nkutunse radio telescope and will continue doing so at other prospective African VLBI stations.

A brief review of South African interfaces to EVN and JIVE above is fully consistent with the JJ Work Packages 3, 5, 9 and 10.

Since 2011, NRF has been participating in the JIVE Foundation and has joined JIV-ERIC as a Participating Research organisation in 2015. The JIVE Management in cooperation with the EC and NWO is conducting negotiations with relevant South African authorities on full membership of South Africa in JIV-ERIC. This is done directly with the NRF, but also through the South African representation at the EC in Brussels. The case is different from other similar processes in the non-EU-membership status of South Africa. Nevertheless, in spite of difficulties of guiding the process toward JIV-ERIC membership in the unchartered legal circumstances, the prospect of South African membership in JIV-ERIC is positive. Obvious reciprocal incentives for both the South African (and wider, African) parties as well as EVN and JIVE community form around multi-facet joint activities.

The process of engaging South African partners in JIV-ERIC has been initiated under the JJ WP3 and will continue after the completion of the JJ project.

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4 Tier 2: Establishing and enhancing existing “seed” VLBI groups and/or facilities

The strength of EVN and JIVE foundations is in their user community concentrated in Europe but widely spread around the globe. In a number of countries in Europe and beyond, groups of scientists demonstrate an interest in pursuing VLBI research. These groups often become seeds for the formation of centres of excellence and/or founding operational components of EVN and related international collaborations (e.g., EC FP projects). Under the JJ WP3, widely diverse activities of such seed groups are supported aiming at the most efficient use and enhancement of the science services provided by the EVN and JIVE.

4.1 Hungary

VLBI science activities in Hungary concentrated originally (since the early-1980s) at the FÖMI Satellite Geodetic Observatory (Penc). Although small in membership, this group gained prominence as one of the most active EVN user groups unaffiliated with any EVN institute. In 2016, the group has been transferred to the major national astronomical establishment, the Konkoly Observatory in Budapest. Over the past 5–10 years, senior members of the group established working links with the leading universities in Hungary, including the Eötvös Loránd University in Budapest. Participation of this group in relevant JJ WP3 activities will aim at strengthening the user base of EVN and JIVE especially among young researchers in Hungary and other countries.

In 2019, a new collaboration between JIVE and the VLBI group at the Konkoly Observatory has been formalised in the form of an MoU between JIVE and the Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences. This MoU, negotiated under the WP3 umbrella, covers the involvement of the Hungarian VLBI group in the JIVE-led near-field VLBI experiment PRIDE of the ESA's Jupiter Icy Moons Explorer mission (JUICE). This new collaboration will strengthen the successful and long-standing collaboration between the Hungarian scientists with JIVE and EVN.

4.2 Ireland

The Irish involvement in VLBI research is associated mostly with the group at the Cork University College but involves also representatives of other Irish universities, e.g. in Dublin. In the period starting around 2005, this group consistently publishes results of its studies on properties of Active Galactic Nuclei based on VLBI polarimetry. Over the past decade, this group has been involved in several so far unsuccessful attempts to establish an operational VLBI station in Ireland. Although no specific path toward achieving this goal is identified at present, keeping an eye on relevant developments in Ireland appears to be useful. The Cork group intends to host the EVN Symposium, originally scheduled for the summer of 2020. However, the COVID restrictions resulted in the postponement of this important for the EVN event to the summer of 2022. Meanwhile, the Cork group in collaboration with JIVE initiated a very successful series of monthly online EVN science seminars which started in the middle of 2020.

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4.3 Israel

Israel has several well-established schools in theoretical astrophysics, optical and high-energy observational astronomy, planetary and space sciences. Yet, in spite of several attempts undertaken over the past four decades, no “hands-on” radio astronomy research has been conducted in Israel except for very few instances of co-authorship of Israeli-based researchers in large international collaborations. The latter included several VLBI studies, conducted in the early years of the JIVE existence.

In 2015, a new initiative to refurbish an existing satellite communication antenna into a VLBI radio telescope has been initiated at the Weizmann Institute of Science (Rehovot, Israel). This is a bottom-up initiative, which would require substantial support from the professional VLBI community from outside of Israel. The initiative is well within the scope of the JJ WP5 “Integrating new VLBI elements”, but seems to be reciprocally beneficial for JJ WP3 too. As of the time of the completion of the JJ project, no specific plan has been worked out for establishing a VLBI antenna in Israel. JIVE will continue monitoring the situation with the intention to extend possible assistance once the opportunity emerges.

4.4 Jordan

Since 2013 the management of the Royal Jordanian Geographic Center (Amman) conducts a preliminary feasibility study of establishing a radio astronomy facility on the basis of either a decommissioned satellite communication station near Amman or developing a new facility “from scratch”. In both cases, the prime task of the facility is to be VLBI-compatible. Just as in several other similar cases, the initiative would require substantial assistance in VLBI-specific know-how from abroad. The initiative might benefit significantly if pegged to similar activities in Africa, Portugal, Israel and other countries as well as the already established facilities in Latvia and New Zealand. JJ WP3, in cooperation with WP5 and WP9, is in the position to facilitate international support to the activity in Jordan. As of May 2021, the official project has not started yet. However, low-key contacts between JIVE and the initiative group in Jordan will be maintained within the scope of JJ WP3 and other relevant work packages.

4.5 Poland – Jagiellonian University, Krakow

The Astronomical Observatory of the Jagiellonian University (Krakow) is one of the leading astronomical educational and research establishments in Poland. It is involved in a number of high-profile international projects, such as CTA, H.E.S.S., Astro-H, LOFAR-ILT, SALT and several EC H-2020 projects. The Observatory has a Department of Radio Astronomy staffed by active researchers who are well known within the peer community. This latter department has the ambition to operate its own radio astronomy facility in the cm-dm wavelength domain, including eventual participation in the EVN. As of 2020, the Observatory was considering taking in possession a decommissioned satellite communication station “Orbita” equipped with a 16-m antenna and upgrade it to the status of an operational radio telescope. This work is obviously consistent with what is mentioned in the document in items 3.6, 3.8, 4.2, 4.5, 4.6 and the main scope of JJ WP5 and WP9. It is also complementary to the scope of JJ WP4. It appears that combining in one coherent package strategic ambitions of the N. Copernicus (Toruń) and Jagiellonian (Krakow) universities might create significant momentum for initiating a “top-down” initiative aiming at Polish membership in JIV-ERIC. The activity has slowed down under the pandemic conditions in 2020-2021 but would resume as the circumstances permit.

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4.6 Portugal, Autonomous Region of the Azores

Fig. 3. The 32-m antenna in Charco Madeira, Azores, Portugal

A 32-m satellite communication antenna in Charco Madeira, São Miguel, near Ponta Delgada (Fig. 3), the most populous city and home to the Regional Presidency and administration of the Autonomous Region of the Azores, has been decommissioned in 2014 and kept in a partially operational state as a backup communication facility. In 2016, the national telecommunication operator expressed interest in transferring the ownership and operational responsibility for this antenna to another party. The Regional administration expresses strong support for this initiative and considers this as an opportunity to establish a radio astronomy center on São Miguel, possibly – as a part of the Azores International Research Center (AIR Center) or other suitable arrangements. Additional favorable synergy for such a center comes from the presence of an already operational 12-m geodetic VLBI antenna on the Azorean island of Santa Maria – a joint Spanish-Portuguese project. The Azorean São Miguel VLBI initiative is also supported by the active group from the Institute of Telecommunications (University of Aveiro), which is involved in the promotion of the SKA cause in Portugal. Several other national astronomy organisations expressed their support to the São Miguel VLBI initiative. Finally, the Portuguese group that is involved in the SKA activities stays in close coordination with SKA South Africa Office and via this connection – to the AVN developments led by South Africa.

Altogether, the domestic developments and connections mentioned above create strong momentum for establishing a VLBI observatory in the middle of the Atlantic – a very favorable VLBI geographical location. Support to this initiative through the JJ project should be considered via WP3, WP5 in cooperation with WP9 and WP10. If successful, the São Miguel VLBI initiative would create a strong case for Portugal to become a JIV-ERIC member.

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4.7 Thailand

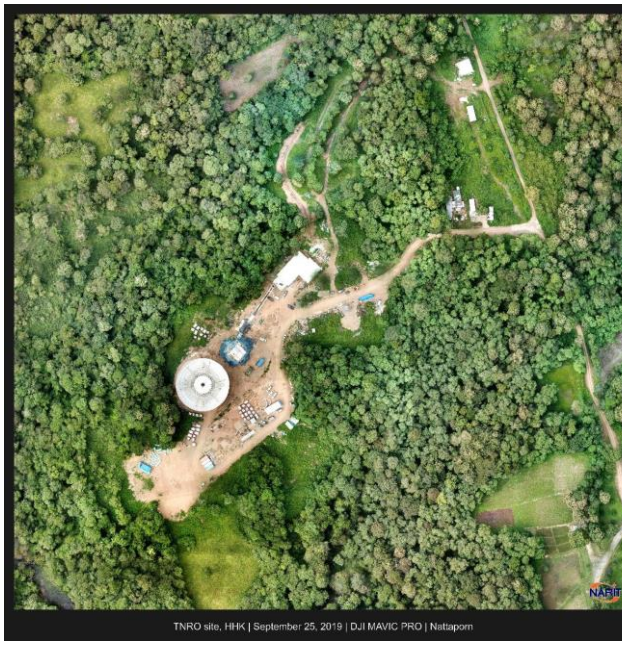

Fig. 4. Aerial view of the NARIT 40 radio telescope construction site, 2019.

In 2014, the National Astronomical Research Institute of Thailand (NARIT) initiated an investigation of a science and technology case for establishing a National Network for Radio Astronomy and Geodesy (NNRAG). The first two milestones of the NNRAG would include a 40-m radio telescope for (astrophysical) VLBI (Fig. 4) and a 13-m radio telescope for geodetic VLBI. The former is conceived as a potential EVN element. An international meeting with the participation of more than 50 experts dedicated to the NNRAG initiative has been held in Krabi in September 2016. The IGN’s 40-m radio telescope in Yebes, Spain, has been considered as the most relevant prototype of the large NNRAG antenna. MoUs on collaboration on the Thai 40-m telescope project between NARIT and IGN, and between NARIT and MPIfR, have been signed. It is foreseen that an international working group would pursue the project with the aim of hardware procurement and on-site activity in the coming five years. The 13-m geodetic VLBI antenna is to become a component of the IVS network.

The new Thai initiative clearly belongs to the scope of the JJ WP5. In addition, within the framework of the JJ WP3, it appears suitable to provide support to the establishment of the NNRAG especially in the training area, working toward the formation of a seed VLBI user community in Thailand. This task is synergistic to most JJ WP’s.

As of May 2021, the construction of the 40-m telescope is nearing its completion, with the "first noise" expected by fall 2021. In 2019, JIVE and NARIT signed an MoU on collaboration in VLBI research and technology with the aim for NARIT to become an Associated Organisation of JIV-ERIC once VLBI operations in Thailand commence.

4.8 Ukraine

Ukraine has a well-established school of low-frequency radio astronomy. The Institute of Radio Astronomy (RIAN, Kharkiv) of the Ukrainian National Academy of Sciences (NASU) operates one of the world’s largest low-frequency radio telescopes UTR-2, its VLBI extension URAN and aims to construct the next generation low-frequency radio telescope GURT. In several areas of low-frequency radio astronomy and related technologies, the RIAN team cooperates with LOFAR/ILT (a potentially synergistic topic for JJ WP4) and other large low-frequency astronomy facilities. Experimental radio astronomy programmes conducted in Ukraine are enhanced by solid support and active involvement of many representatives of the traditionally strong national school of theoretical astrophysics.

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Fig. 5. 32-m antenna in Zolochiv, Ukraine.

In the past, VLBI activities in Ukraine in the cm-dm wavelength domain involved the RT-22 radio telescope of the Crimean Astrophysical Observatory near Simeiz and the deep space communication RT-70 antenna of the Ukrainian National Space Agency in Evpatoria, Crimea. The former, operated by a RIAN team from Kharkiv, was involved in VLBI since the end of the 1960s, while the latter played an important role as a large Earth-based radio telescope during the in-orbit checkout and Early Science programme of the Russia-led Space VLBI mission RadioAstron, launched in July 2011. Since the annexation of Crimea by Russia, both Crimean radio telescopes stopped international VLBI activities, and the VLBI instrumentation at the RT-70 remained beyond reach for its owner, the RIAN.

In 2016, the RIAN in cooperation with the NASU began preparatory work for refurbishing the existing and fully operational 32-m deep space communication antenna near Zolochiv in Western Ukraine for radio astronomical observations (Fig. 5). In the course of this work, an exchange of several visits between the RIAN-NASU and JIVE took place in 2017–2019. In the second half of 2020, the first EVN VLBI test was conducted with the Zolochiv antenna. The work will continue in the coming years with a clearly formulated goal of RIAN becoming a member of EVN and, in a longer perspective, an Associated Organisation of JIV-ERIC.

4.9 United Arab Emirates

Informal contacts between JIVE and representatives of the United Arab Emirates Universities Al Ain and NYUAD (New York University of Abu Dhabi) conducted in 2017-2018 indicated an interest of the UAEU academics in pursuing radio astronomy research, including VLBI. The initiative is not mature enough to be formalised. However, a new momentum to this notion came with the successful launch of the first UAE Martian mission Misbar Al-Amal in July 2020. After the successful insertion of this mission in the areocentric orbit in February 2021, the appropriate UAE authorities commenced a pre-design study of a deep space network facility, which would have also radio astronomical single dish and VLBI functionalities. The initiative is closely monitored by JIVE via a well-established contact with the UAE groups. Activation of these contacts is expected in 2022-23.

4.10 United Kingdom – Goonhilly

The Goonhilly Earth Station, located at the south-eastern tip of Great Britain, is equipped with several parabolic satellite communication antennas which are about to be decommissioned. Potential upgrade of at least one of these antennas to a VLBI-compatible level has been on the discussion table since at least 2011. The progress in the implementation of this initiative has been rather slow over the past six years. However, the momentum is not lost and the

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initiative might get a new start, especially if supported within the UK and from abroad. A natural major “domestic” support to the initiative should come from the Jodrell Bank Centre for Astrophysics (JBCA) at the University of Manchester, the operator of the National e-MERLIN and VLBI Facility. Radio astronomy and VLBI developments at Goonhilly are highly synergistic to the JJ WP5 and WP9. Over the period of JJ project implementation, the progress at Goonhilly was very slow. However, the case is within the scope of the EVN forward look, and relevant know-how at EVN and JIVE could be invoked in support of the Goonhilly developments once the opportunity arises.

5 Tier 3: Existing radio astronomy facilities with new VLBI potential

A number of radio astronomy facilities around the world are technically (almost) capable of VLBI observations and might become involved in international VLBI research provided sufficient domestic support is created. As such, these facilities are of major interest for the JJ WP5, but also form a target group for JJ WP3. These facilities have the potential of supporting or creating the case for eventual JIV–ERIC membership or participation at the institutional level.

5.1 Armenia

Radio astronomy studies began in Armenia in the late 1950s. The domestic observational base consisted of relatively small fully steerable and fixed antennas for meter and decimeter wavelengths at the Byurakan Observatory. In the late 1980s, a novel facility, called ROT-54/2.6 (Fig. 6), combining a 54-m fixed radio telescope and a co-mounted 2.6-m optical telescope was constructed on the slopes of the Aragats mountain about 30 km north-west of Yerevan. The first single-dish observations were conducted with ROT-54/2.6 around 1989. However, for several decades, the facility was in a "dormant" state due to the natural disasters (a devasted earthquake in December 1988), economic hardship after the break-up of the USSR in 1991 and multiple military conflicts with neighbouring Azerbaijan over the past more than 30 years.

In recent years, an initiative group of the Yerevan Polytechnic University (YPU) in cooperation with the Jurisdiction Armenia Foundation initiated the resurrection of the ROT-54/2.6 facility. In 2018, the group approached JIVE with a request for assistance in transforming ROT-54/2.6 into an operational VLBI telescope. Its principle technical specifications are unique, especially the combination of the main reflector size (50 m in diameter) and high-precision geometry that enables observations at wavelengths down to several millimeters.

After reciprocal visits in 2018, JIVE and YPU representatives, in cooperation with the EVN Technical and Operations Group (TOG) established an International Advisory Group for ROT-54/2.6 and worked out a plan of joint actions. These included the inventory of the ROT-54/2.6 facility, determination of the overhaul strategy and plan for single dish and VLBI tests. The implementation of the plan began in 2020. Since 2019, representatives of the YPU group attend annual meetings of the EVN TOG and, as observers, participate in semi-annual EVN CBD meetings. The main goal of the joint activities is to make the ROT-54/2.6 fully EVN-

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compatible. This would facilitate the participation of the YPU in EVN and eventually in JIV-ERIC.

Fig. 6. Night sky seen from the opening of the telescope ROT-54/2.6, Armenia

5.2 Australia (UTas)

The radio astronomy group at the University of Tasmania in Hobart is active in radio astronomy for several decades. at present, it operates a 26-m antenna at Mount Pleasant near Hobart, a three-station network of 12-m geodetic VLBI antennas distributed over the Australian continent (the AuScope array) and a 30-m antenna in Ceduna, north of Adelaide. The UTas group is pursuing active research in VLBI using the LBA network and other world VLBI facilities, including the EVN. The group has a particular interest in conducting near-field VLBI studies in the interest of planetary science and diagnostics of the interplanetary plasma.

In 2019, JIVE and UTas signed an MoU on cooperation in the PRIDE-JUICE near-field VLBI studies. This MoU, supported through the JJ WP3 brings the long-standing collaboration between JIVE and EVN on one hand, and the UTas on the other hand, to a new level and creates a solid basis for its broadening in the future.

5.3 Canada (ARO)

The year 2017 marked the 50th anniversary of getting the first VLBI “fringes” (the first-ever successful VLBI experiment). The experiment conducted in 1967 involved two Canadian

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antennas, Algonquin in Ontario and Penticton in British Columbia. For about two decades after the first VLBI demonstration, the 46-m radio telescope of the Algonquin Radio Observatory (ARO) has been involved in North American and Global VLBI networks for various applications (astrophysics, astrometry, and geodesy). At present (May 2021), Thoth Technology Inc. operates ARO in the interests of the University of Toronto Canadian Institute for Theoretical Astrophysics. In 2017, the latter indicated an interest in restoring participation of the ARO 46-m radio telescope in international astrophysical VLBI programmes, especially at decimeter and meter wavelengths. That might require certain involvement by JJ WP5 and WP8. As of May 2021, JJ WP3 was involved in assessing perspectives of establishing cooperative relations between ARO and EVN/JIVE. This activity is likely to resume more actively after the COVID-related restrictions are lifted.

5.4 China

Chinese radio astronomy community has grown from the “entry” status in the early-1990s to one of the world-leading positions at present. This is clearly visibly in the VLBI area: as of 2021, the Chinese national VLBI network unifies 8 operational telescopes – a second position in the world shared with Australia, after the USA (16 operational VLBA telescopes). However, no less than 6 new Chinese radio telescopes, including the world largest fixed parabolic 500-m antenna FAST, and two largest moveable parabolic antennas exceeding 110 meters are on the way to joining VLBI networks in the coming 5–6 years.

Fig. 7. Haopin 40-m radio telescope, China.

Among these new VLBI facilities the 40-m parabolic antenna located in Haopin, Shaanxi Province, seemingly demonstrates the highest level of technological readiness (Fig. 7). The facility belongs to and is being operated by the National Time Service Center (NTSC, Xi’an) of the Chinese Academy of Sciences (CAS). The antenna is in a fully operational state. Its electro-mechanical specifications are fully consistent with VLBI operations at cm-dm wavelengths.

Preliminary contacts with the NTSC have been established in 2017 through JJ WP3, in cooperation with JJ WP5 and JJ WP8. If the Haopin facility becomes operationally compatible with EVN (possibly, with the assistance via JJ WP5 and WP8), it would strengthen the case for CAS to continue and enhance support to JIVE via bilateral MoA currently managed from the Chinese side by the NAOC.

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Further enhancement of the case for support of collaboration of the NAOC with JIVE could entail cooperation with the FAST, the new large (effective diameter ~120 m) IPS radio telescope for meter wavelengths in Inner Mongolia, the 110-m antenna in Xinjiang and a prospective 120–m antenna in Yunnan. These listed facilities are expected to begin VLBI operations in the period 2022–2027.

5.5 India (uGMRT)

The Giant Metrewave Radio Telescope (GMRT) near Khodad is owned by the Tata Institute of Fundamental Research (TIFR) and operated by the National Centre for Radio Astrophysics (NCRA) located in Pune (Fig. 8). After a recently completed upgrade, the facility got a new name uGMRT. It consists of 30 fully steerable 45-m parabolic antennas operating at frequency bands from 50 to 1420 MHz. The facility is practically not involved in VLBI studies (essentially – due to limited frequency compatibility with other VLBI radio telescopes and absence at GMRT modern VLBI backends). Nevertheless, VLBI observations with this ultra-sensitive facility at standard VLBI bands of 1400, 608 and 327 MHz are highly attractive for many scientific applications. JJ WP3 will investigate prospects of establishing VLBI collaboration with NCRA/GMRT.

Fig. 8. Five 45-m antennas of the uGMRT radio telescope, India.

In February 2021, the NCRA hosted an international online workshop to discuss the prospects of involving uGMRT in the international VLBI networks. JIVE and EVN were widely represented at this workshop. It concluded with a specific plan of actions aiming to test the uGMRT in the VLBI mode in 2021-2022. VLBI networks with the uGMRT involvement will occupy a unique scientific niche of high sensitivity VLBI studies at decimeter and meter wavelengths.

5.6 Japan (ISAS)

The Japanese radio astronomy school stands out in several areas, among which mm- and sub-mm- astronomy (e.g., Nobeyama, ALMA, EHT) and VLBI are most accomplished. In the

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latter domain of science activity, the primarily astrometric network VERA and its recent international extension KaVA (a joint Japanese-Korean endeavor), participation in the Global mm VLBI Array (GMVA) and Event Horizon Telescope (EHT), as well as active pursuit of international (via IVS) and several national geodetic VLBI initiatives make VLBI highly visible on the Japanese astronomy arena. Moreover, the Japan Aerospace Exploration Agency (JAXA) and its Institute of Space and Astronautical Sciences (ISAS) have launched in 1997 and operated for 6 years the first dedicated space VLBI mission, VSOP.

The major JAXA's ground-based deep space command, tracking and data acquisition canters are located at Usuda. Among other facilities, the center operates a 64-m steerable parabolic antenna. This antenna is fully equipped for cm-dm-wave VLBI observations. Its extensive participation in support of the Japanese and other space and planetary science missions limit the availability of this antenna for VLBI research. Recently JAXA has announced its intention to replace the 64-m Usuda antenna as its main "workhorse" for deep space operations with a new 50-m antenna. The latter has been completed and tested in 2020. This move will release the 64-m antenna for wider involvement in VLBI research, including cooperation with EVN. Investigations of potential collaboration between EVN/JIVE and ISAS has begun in 2018 under the JJ WP3 umbrella and will be continued after completion of the JJ project.

5.7 New Zealand (AUT)

VLBI activities in New Zealand are conducted by the Institute for Radio Astronomy and Space Research (IRASR) of the Auckland University of Technology (AUT). Its main observing facilities located at Warkworth (North Island) are a geodetic VLBI 12-m antenna and a 32-m antenna involved mostly in astrophysical observations since 2013, including VLBI. The latter antenna represents the most successful example of refurbishing a ~30-year-old satellite communication antenna into a modern VLBI radio telescope. In 2010, JIVE and IRASR signed an MoU on cooperation in VLBI research that helped to facilitate several joint research projects.

Given a very positive example of a "re-birth" of an old satellite communication antenna as a VLBI radio telescope, the IRASR/AUT's "know-how" seems to be an invaluable asset for similar work in Portugal (Azores, São Miguel), UK (Goonhilly), many AVN sites and antennas in Central and South America. In cooperation with JJ WP5 and JJ WP9, JJ WP3 has assisted in facilitating the transfer of the IRASR's expertise to the relevant partners listed above and will continue to do so after the completion of the JJ project.

5.8 Norway (Ny-Ålesund)

The VLBI facility in Ny-Ålesund (the island of Spitsbergen in Svalbard, Norway) consists of an operational 20-m parabolic antenna, built in 1994, and new twin VGOS antennas. The facility operated by the Norwegian Mapping Authority (NMA) is distinguished by its unique geographical position at the latitude ~79 degrees north.

While this facility is fully dedicated to geodetic VLBI, the co-existence of the old 20-m radio telescope and new twin VGOS antennas might allow operating the former in the interests of astrophysical VLBI as well as (eventual) participation in near-field VLBI tracking of space science missions. The case was under study by JJ WP3 in cooperation with JJ WP6 and will be pursued after the completion of the JJ project.

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5.9 Russia (RT-22, Pushchino Radio Astronomy Observatory)

Major VLBI research efforts in Russia are concentrated around the Quasar facility owned and operated by the Institute of Applied Astronomy (IAA, St. Petersburg) of the Russian Academy of Sciences (RAS) as well as the Astro Space Center (ASC) of the Lebedev Physical Institute of RAS. The latter is the leading organisation of the second dedicated Space VLBI mission RadioAstron, which was operational in the period 2011–2019.

The IAA is a member of the EVN, its three KVAZAR radio telescopes provide very important "filing" of uv–plane coverage on transcontinental VLBI baselines.

The ASC operated the RT-22 radio telescope in Pushchino (Moscow region) as the prime Earth data acquisition and tracking station of the RadioAstron mission. After completion of the RadioAstron mission, the RT-22 radio telescope might resume radio astronomy single dish and VLBI operations. Although not large in diameter, it would offer a useful uv-coverage extension for EVN. The case has been pursued by the ASC group starting from 2020.

Involvement of Russian entities in JIV-ERIC as members or participating organisations does not appear to be realistic at present. However active cooperation with the Quasar network and eventually the RT-22 in Pushchino remains an attractive perspective for EVN and JIVE.

6 Summary of WP3-specific synergies within JUMPING JIVE project

The inventory of potential JJ WP3 partners presented here involves radio astronomy organisations very different in their experience, expertise and field of activity, operational status and instrumentation compatibility with VLBI. JJ WP3 maintained contacts with these partners as deemed suitable in each individual case in view of its relevance to the main task of the work package – strengthening the JIV–ERIC and EVN basis. It was most efficient to exploit synergies with other JJ WPs over the course of the WP3 implementation adjusted to the specific interests of the parties involved.

Obvious synergies between JJ WP3 and other JJ Work Packages included:
WP4 "ERIC scope: the International LOFAR Telescope":

- Latvia, Ventspils International Radio Astronomy Center, Ventspils
- Poland, Jagiellonian University, Krakow
- Ukraine, Institute of Radio Astronomy, Kharkiv

WP5 "Integrating new VLBI elements":

- Armenia, Yerevan Polytechnic University and Jurisdiction Armenia Foundation
- China, National Time Service Center, Xi'an
- India, Giant Metrewave Radio Telescope, NCRA, Pune
- Ireland, Cork University College, Cork
- Israel, Weizmann Institute of Science, Rehovot
- Jordan, Royal Jordanian Geographic Center, Amman
- New Zealand, Auckland University of Technology (upgrade example)

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- Poland, Jagiellonian University, Krakow
- Portugal, Administration of the Autonomous Region of the Azores, Ponta Delgada, and University of Aveiro
- Thailand, National Astronomical Research Institute of Thailand, Bangkok
- UK, Goonhilly Satellite Station
- United Arab Emirates, Al Ain and NYUAD universities

WP6 “Geodetic capabilities”:

- Latvia, Ventspils International Radio Astronomy Center, Ventspils
- Norway, Norwegian Mapping Authority (NMA)
- Thailand, National Astronomical Research Institute of Thailand, Bangkok

WP9 “Capacity for VLBI in Africa”:

- New Zealand, Auckland University of Technology, Auckland (upgrade example)
- Portugal, Administration of the Autonomous Region of the Azores, Ponta Delgada, and University of Aveiro

WP10 “VLBI with the SKA”:

- India, Giant Metrewave Radio Telescope, NCRA, Pune
- Portugal, University of Aveiro
- South Africa, National Research Foundation and South African Radio Astronomy Observatory

In addition, a number of WP3 partners expressed interest in links and cooperation offered by WP2 “Outreach and advocacy”, WP7 “The VLBI future”, and WP8 “Global VLBI interfaces”. The list of potential synergies presented here is only indicative and is not intended to cover the entire internal synergistic link within the JJ project.

7 Conclusions

This document presents a condensed report on the JJ WP3 activities over the entire period of implementation of the JJ project. The highest priority in the JJ WP3 implementation was given to partners in Tier 1: they were solidly on the path toward membership in the JIV-ERIC. In fact, in the cases of two partners, Latvia and Italy, full membership in JIV-ERIC was attained after the submission of the initial JJ proposal.

Partners listed under the other two tiers have been kept within the scope of JJ WP3 activities as potentially important participants of future VLBI research involving EVN and JIVE.

VLBI is a mature and productive radio astronomy technique with advanced applications in astrophysics, astrometry, fundamental physics, geo- and planetary sciences. De facto, VLBI is already operating routinely with baselines comparable with the Earth diameter, thus constituting a global scientific instrument. This creates momentum for the formal establishment of a Global VLBI Alliance, GVA. Indeed, the GVA Working Group is being established by the International Astronomical Union in 2021 with support provided through joint activities under the WP3 umbrella. Worth mentioning in this respect is the Global VLBI Working Group (GVWG) established jointly by the IAU and URSI in 1993 with two specific tasks, (i) coordination of VLBI data recording standards, and (ii) coordination of global scheduling of Space VLBI missions

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VSOP and RadioAstron. The tasks have been accomplished by 2002, and the group stopped its activities in 2003. Another potential precursor of GVA appears to be the coordinated Global mm-VLBI Array, GMVA, which organises mm VLBI observations under the Open Sky policies for the past decade.

In the strategic perspective, while focusing on enhancing the base of JIV-ERIC, JJ WP3, as well as the entire JUMPING JIVE project, might serve as a stepping stone toward the formation of GVA. This would involve all the JJ WP3 partners listed in this document, as well as EVN member organisations, NRAO, GBO in the USA, CASS in Australia, and others.

The original goals of the JJ WP3 as formulated in the Grant Agreement and Work Package description appear to be achieved in full and create a solid basis for strengthening European and global cooperation in VLBI research with leading positions occupied by EVN and JIVE.

Within the framework of the JUMPING JIVE project, the WP7 "The VLBI Future" produced the strategic outlook for the development of VLBI in Europe and beyond in the period through 2030, the document entitled "VLBI20-30: a scientific roadmap for the next decade". Under the auspices of the presented here WP3, the existing JIVE partnerships have been enhanced and new ones established, all – with the goal of implementing the strategic outlook defined in the above document.

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List of acronyms

AIR Center	– Azores International Research Center, Portugal
ALMA	– Atacama Large Millimetre Array
ARO	– Algonquin Radio Observatory, Canada
ASTRON	– Netherlands Institute for Radio Astronomy
AUT	– Auckland University of Technology, New Zealand
AVN	– African VLBI Network
CA	– Centre of Astronomy at Nicolaus Copernicus University, Poland
CAS	– Chinese Academy of Sciences, China
CASS	– CSIRO Astronomy and Space Science, Australia
CNR	– National Research Council, Italy
CSIRO	– Commonwealth Scientific and Industrial Research Organisation, Australia
CTA	– Cherenkov Telescope Array
EC	– European Commission
EHT	– Event Horizon Telescope
EISCAT	– European Incoherent Scatter Scientific Association
e-MERLIN	– Multi-Element Radio-Linked Interferometer (enhanced), UK
ERIC	– European Research Infrastructure Consortium
ESA	– European Space Agency
EVN	– European VLBI Network
FAST	– Five hundred-meter Aperture Spherical Telescope, China
FÖMI	– Institute of Geodesy Cartography and Remote Sensing, Hungary
FP	– Framework Programme
GBO	– Green Bank Observatory, USA
GMRT	– Giant Metrewave Radio Telescope, India
GMVA	– Global mm VLBI Array
GURT	– Giant Ukrainian Radio Telescope, Ukraine
GVA	– Global VLBI Alliance
GVWG	– Global VLBI Working Group
H-2020	– EC Horizon 2020 Programme
HartRAO	– Hartebeesthoek Radio Astronomy Observatory, South Africa
H.E.S.S.	– High Energy Stereoscopic System
IAA	– Institute of Applied Astronomy of the Russian Academy of Sciences, Russia
IAU	– International Astronomical Union
IGN	– National Geographical Institute, Spain
ILT	– International LOFAR Telescope
INAF	– National Institute of Astrophysics, Italy
ISAS	– Institute of Space and Astronautical Sciences, Japan
IPS	– Inter-planetary scintillations
IRASR	– Institute for Radio Astronomy and Space Research, New Zealand
IVS	– International VLBI Service
JAXA	– Japan Aerospace Exploration Agency, Japan
JBCA	– Jodrell Bank Centre for Astrophysics, UK

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JIVE	– Joint Institute for VLBI ERIC (Joint Institute for VLBI in Europe until 2015)
JIV-ERIC	– Joint Institute for VLBI ERIC
JUICE	– Jupiter Icy Moons Explorer mission
JJ, JUMPING JIVE	– Joining up Users for Maximising the Profile, the Innovation and the Necessary Globalisation of JIVE
KaVA	– KVN and VERA Array
KVAZAR	– VLBI Coordinate and Time Maintenance System of Russia
KVN	– Korean VLBI Network, Korea
LBA	– Long Baseline Array (a Southern hemisphere VLBI array)
LOFAR	– Low-Frequency Array, The Netherlands
MeerKAT	– Karoo Array Telescope, South Africa
MoA	– Memorandum of agreement
MoU	– Memorandum of understanding
MPIfR	– Max Planck Institute for Radio Astronomy, Germany
NAOC	– National Astronomical Observatories of China
NARIT	– National Astronomical Research Institute of Thailand
NASU	– National Academy of Sciences of Ukraine
NCRA	– National Centre for Radio Astrophysics, India
NMA	– Norwegian Mapping Authority, Norway
NNRAG	– National Network for Radio Astronomy and Geodesy, Thailand
NRAO	– National Radio Astronomy Observatory, USA
NRF	– National Research Foundation, South Africa
NTSC	– National Time Services Center, China
NWO	– Netherlands Organisation for Scientific Research
PRIDE	– Planetary Radio Interferometry and Doppler Experiment
RIAN	– Institute of Radio Astronomy, Ukraine
RT-22	– Radio Telescope of 22-metre diameter, Russia and Ukraine
RT-70	– Radio Telescope of 70-metre diameter, Ukraine
SALT	– Southern African Large Telescope, South Africa
SARAO	– South African Radio Astronomy Observatory
SKA	– Square Kilometre Array
TOG	– Technical and Operations Group (of EVN)
TVN	– Thai VLBI Network, Thailand
UAEU	– United Arab Emirates University, UAE
URAN	– Ukrainian Radio interferometer of the Academy of Sciences, Ukraine
URSI	– International Radio Science Union
UTR-2	– Ukrainian T-shaped Radio telescope, second modification, Ukraine
VERA	– VLBI for the Earth Rotation study and Astrometry, Japan
VGOS	– VLBI Global Observing System
VIRAC	– Ventspils International Radio Astronomy Center, Latvia
VLBI	– Very Long Baseline Interferometry
VSOP	– VLBI Space Observatory Programme
VUAS	– Ventspils University of Applied Sciences
WP	– Work Package
WP2	– JJ WP “Outreach and advocacy”
WP3	– JJ WP “Building new partnerships”

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WP4	– JJ WP “ERIC scope: the International LOFAR Telescope”
WP5	– JJ WP “Integrating new VLBI elements”
WP6	– JJ WP “Geodetic capabilities”
WP7	– JJ WP “The VLBI future”
WP8	– JJ WP “Global VLBI interfaces”
WP9	– JJ WP “Capacity for VLBI in Africa”
WP10	– JJ WP “VLBI with the SKA”
YPU	– Yerevan Polytechnic University

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