Organizational Review EGO and Virgo

by
EGO/Virgo Organizational Review Committee
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1. Context & Long-term goal

While the Virgo Collaboration has contributed to the 'gravitational-wave revolution' and produced stunning discoveries with the LIGO Scientific Collaboration and the Advanced LIGO detectors, the Advanced Virgo detector has not yet reached its planned sensitivity goals, typically running at only 30-40% of LIGO's best sensitivity in the O2 and O3 Observing runs. Critically, Virgo failed to join the O4a run, significantly compromising the ability to do multi-messenger astronomy, one of the primary science goals of the gravitational-wave and transient astronomy communities.

To make meaningful contributions in the future, the Virgo detector must be operating at sensitivities greater than 50% of LIGO's, and ideally approaching the 75% limit imposed by Virgo's shorter arm lengths of 3 km, as opposed to 4 km for each LIGO detector, determining the baseline over which the gravitational-wave strain is measured. With the next generation Einstein Telescope (ET) coming in the late 2030s or early 2040s, Virgo has a 20 year lifetime in which it can carry out a vibrant scientific program as part of the ground-based observatory network, but only provided that the many issues that have continually compromised Virgo's performance are identified, acknowledged, and addressed. These include organizational/structural/funding deficits as well as technical challenges.

Our review report responds to the charge provided to us in the 'EGO/Virgo Organizational Review' (see Appendix B), examining the management structures of Virgo, EGO, and their interaction. Based on our review, we make a series of observations and recommendations intended to improve how EGO and the Virgo Collaboration function. While not the purview of this report, we believe that the technical issues (not reviewed here) in addition to the organizational/structural/funding issues will need to be addressed to enable Virgo and EGO to succeed. It should be clear that the success of EGO/Virgo in the coming decades will also critically depend on the successes of future upgrades of the instrument and the timely availability of the necessary capital-investment funding.

We believe that implementing all our recommendations gradually, but as soon as possible, is mandatory, not only to resolve the current difficulties but also to ensure efficient and successful functioning of EGO and Virgo for the decades to come.

2. Background information and general remarks

2.1 Background information on Virgo

The Virgo observatory in Europe and the two LIGO observatories in the USA form the basis of the worldwide gravitational-wave research-infrastructure network which –following the revolutionary first direct observation of gravitational waves, GW150914, in 2015 during Observing Run O1– has opened an entirely new window upon the universe. Notably, it allowed for detailed studies of the dynamics of the least understood fundamental force of nature –gravity– in a regime with extremely strongly curved space-time and velocities approaching the speed of light. While Virgo only joined the network during its second Observing Run O2 in 2017, the much-improved sky-localization with three as opposed to two observatories, proved crucial in pinpointing the source of the first observed binary-neutron star merger (GW170817) with an accuracy which allowed 'standard' (electromagnetic) observatories to study the accompanying short gamma-ray burst (GRB) and optical afterglow, and its thermal aftermath ('kilonova'). This event marked the birth of a new and exciting research field: multi-messenger astronomy. Groundbreaking results have included for example: a complementary and basically systematic error free determination of the rate of expansion (Hubble constant) of the universe; limits on the mass of the graviton (the postulated quantum that is thought to be the carrier of the gravitational field); the origin of heavy elements in the universe; and better understanding of the structure of neutron stars.

Virgo also participated in Observation Run O3 (2019-2020) which ended prematurely by the COVID-19 pandemic. In O2 and O3, Virgo has operated at typically 30-40 % of LIGO sensitivity, which has allowed it to only contribute significantly for a small fraction of events, notably exceptional events like GW170817, but with a sensitivity insufficient for significant contributions to most observations. During the upgrade period prior to the start of Observing Run O4, Virgo installed advanced detector subsystems such as a frequency-dependent squeezer to reduce quantum noise and signal recycling to further increase its sensitivity. Despite a long commissioning period, Virgo failed to achieve the minimum required sensitivity –surpassing 50% of the sensitivity of a single LIGO observatory– to be able to seriously improve the stand-alone performance, and notably the important sky-localization power, of the two LIGO observatories before the start of Observation Run O4 (May 2023). Today's understanding is that Virgo will join O4 in April 2024 with a sensitivity approximately 55 Mpc for binary neutron star mergers, compared to the present sensitivities of 150-165 Mpc and 165-180 Mpc of LIGO Livingston and LIGO Hanford, respectively.

2.2 Working method of the Committee

The Organizational Review Committee was initiated by the EGO Council in response to the failure of Virgo to join O4, with the goal of revealing issues and problems that contributed to the failure and may have been present in EGO and Virgo going further back, probably even before the O3 data taking. Additionally, there is a clear lack of competitiveness with LIGO's sensitivity. For O5 and post-O5 (the so-called Virgo_nEXT upgrade), EGO/Virgo needs to improve many aspects. It is clear that well before the next generation of GW facilities take over around 2040, Virgo must become more competitive in the field. This review aims to scrutinize the organizational aspects of EGO and of the Virgo collaboration. The goal is to improve the functioning of EGO and Virgo, and to address the

underlying organizational shortcomings. A review focusing on the technical issues will be conducted in parallel by another committee.

The mandate given to the Committee by the EGO Council can be found in Appendix B. The Committee consists of Rosemarie Aben (Deputy Chair), Ursula Bassler, Federico Ferrini, Frank Linde, David Reitze, Laurent Serin (Chair) and Peter Wolf.

The Committee conducted interviews with individuals of the Virgo Collaboration, both from Member states and Observer states, EGO staff, and representatives of ET (see Appendix C for a list of all the interviews conducted by the Committee). The Committee visited the EGO site on January 18 and 19 and spoke to many of the EGO staff and Virgo Members who are involved in the day-to-day operation of the detector. Additionally, Committee members had discussions at a national level with key members of the Virgo Collaboration. The Committee extracted the key observations and findings from all the interviews and discussions, resulting in the observations and findings in Chapter 3, and finally formulating the recommendations, which are listed in Chapter 4.

The Committee has done its utmost to be careful and comprehensive, and firmly believes that the implementation of the recommendations, together with the technical adjustments that are imminent, will lead to a positive long-term future for Virgo.

3. Observations & Findings

3.1 Organization and governance

As originally implemented in the early 2000s, EGO is a legal entity charged with managing logistics, finance, procurement, human resources/personnel recruitment, and observatory maintenance and upkeep on the site of the Virgo interferometer. The Virgo Collaboration is charged with managing the scientific and technical direction; EGO has no major role in making scientific or technical decisions. EGO is designed to be scientifically junior to Virgo.

In recent times, however, EGO has taken on more technical responsibilities, nonetheless Virgo continues to maintain a dominant role in leading the detector and its upgrades. This is in contrast to LIGO and CERN's accelerator complex, both of which operate under strong central laboratory models. A stronger central laboratory, particularly for managing the overall detector, could be very beneficial if properly implemented. The role that people and personalities play cannot be overstated here. It is critical that everyone in the EGO Directorate and Virgo Collaboration leadership (Spokesperson, Project Upgrade Coordinator, Commissioning Coordinator, …) cooperates and works constructively and collectively to achieve the scientific mission. There are excellent examples of such collaborations in the past, however it is clear that the collective leadership of EGO/Virgo did not work effectively in the past few years while preparing for O4.

The shared management of the detector and its upgrades, between the Virgo Collaboration on one hand and the EGO on-site management on the other, leads to a "dilution" of responsibility with no clear ownership of success or failure, and more importantly no clear decisional chain for technical and operational decisions concerning the detector itself. Such decisions should not be taken at the Collaboration level in the Virgo Steering Committee (VSC), with around 40 members, of which many lack expertise on technical matters.

Historically, the present organizational situation is the result of Virgo being built in an "R&D mindset" throughout the first two decades of the 21st century. In some sense it was as much an exploration of new exciting technological possibilities as an endeavor for an operational observatory of the universe. The less centralized structure has served well in the early development of the detector and its upgrades, with cutting edge results on e.g. seismic isolation, quantum noise reduction and thermal control of optics. However, with the increasing complexity of the detector, and the international context of the LVK Collaboration requiring a minimum sensitivity for meaningful contributions to observations and the resulting science, this organizational structure has become increasingly obsolete. While not the sole cause of past and present difficulties (in particular, Virgo has consistently fallen short of its targets), it has certainly contributed to inefficient and often problematic installation, commissioning and operation of the detector. This in turn can lead to an unpleasant work environment on site, making it less attractive to visitors and young researchers.

Our recommendations are aimed at moving away from the "distributed" organizational structure, towards a "strong central laboratory" model with clear responsibilities and decisional powers for all aspects of the integration, commissioning and running of the detector. This central laboratory, which

we will designate as Virgo-Lab, should be a common effort of the Virgo Collaboration and EGO, with key positions being staffed by the best qualified person, irrespective of whether they are EGO-staff or members of a Virgo group, and regardless of whether they come from a historical or a new Virgo group. Another aspect of the reorganization is a better and more continuous oversight by the EGO Council, with an improved flow of information between EGO/Virgo and the funding agencies represented in the EGO Council, which was found to be insufficient, for instance in the run-up to O4.

3.2 Project management

Project management is a central aspect in allowing large, international collaborations to build complex scientific instruments. During this review, deficits in project management have been identified: some at an organizational level, some in the way the technical contributions and work between Collaboration members has historically grown. The current project management in place should be substantially improved.

A first observation is that many of the detector subsystems are solely developed within a single group. Even though this reduces organizational overload and favors a sense of ownership, this situation has some essential drawbacks:

- expertise on subsystems is only available in a single group, sometimes even a single person;
- there is no cross-development, which would allow experts from different groups to critically and constructively review details;
- documentation that allows exchanges among different groups is not produced nor provided.

In a Collaboration that has grown rapidly and is operating a detector of increased complexity, it is essential for new groups to properly contribute to the instrumentation effort. Adequate project management, as well as readily available and centrally managed documentation and training, enable new groups to participate effectively in the technical efforts. Even though an initial investment of resources will be needed to put the project structures in place, to provide and to curate the documentation, and to train new contributors, a positive effect on the medium and long term performance of the Collaboration will be realized. Cross training between EGO staff and Virgo Collaboration members is also necessary: EGO staff are more efficient if they are not solely seen as executors of instructions for groups not on site. The needs of off-site Virgo Collaboration members will be taken into account in the on-site planning with a better understanding by the on-site staff for the reasons behind a specific instruction or request.

A second observation concerns the review process, which does not appear well-structured and is mostly carried out internally by the Collaboration. In the past, this has led to important technical decisions being made too quickly and without sufficient critical evaluation. This may result in substantial cost overruns, lack of necessary expertise and human resources, and risks which have not been identified and mitigated adequately. Funding agencies are more inclined to invest in a project if rigorous review processes are in place, giving them the best possible assurance of a successful instrument being built and operated.

Finally, another key observation is that a workflow for rigorous project management – Research and Development (R&D), Technical Design Reports (TDR), reviews, funding proposals, quality assurance/quality control (QA/QC), documentation and realistic planning – is lacking within Virgo.

This has substantially hampered progress, with subsystems being delivered that did not meet the specifications, or with the interfaces to other subsystems that did not fit. Currently, the EGO System Engineer also functions as the QA/QC lead, illustrating the lack of the necessary resources for effective project management.

3.3 EGO Council and finances

According to the EGO statutes, the EGO consortium is composed of its Founding Members (CNRS, INFN) and Associate Members (Nikhef). The EGO Council, composed of Member representatives, is in charge, amongst other responsibilities, of appointing the EGO Director, the annual budget forecast, and the medium and long term financial estimates, including the staff plan. It is also in charge of the admission of new Associate Members and assigning and managing the annual contributions of the Associate Members.

A particular concern is the overall funding level of EGO/Virgo, in particular compared to LIGO. In absolute numbers the LIGO average annual expenses per LIGO site are estimated to be about 3 times the EGO/Virgo expenses. This relative EGO/Virgo funding shortfall becomes even more serious considering that at present Virgo's sensitivity falls short compared to the LIGO sensitivities. As a result, it seems e.g. unavoidable that Virgo will have to replace its marginally stable recycling cavities by stable recycling cavities which will almost certainly require an extra investment of 10-20 million Euros. Taking everything into account this probably means that EGO/Virgo will –at least for the coming few years– require a significantly higher funding level than has been provided to date. Likewise, structural strengthening of the on-site services mentioned elsewhere in this report, will warrant a structural increase of EGO/Virgo's funding level. This can partly come via common funds (as is already the case). In addition, the Council also has the power to fix annual contributions of founding and Associate Members. To become an Associate Member, the annual contribution to the ordinary budget should exceed the common funds.

A more transparent and better focused financial organization is highly desirable. The Committee found that contributions from the individual institutions/countries are difficult to estimate precisely, because some funds are used for direct support of national research centers and only "transit" through EGO. Also in-kind contributions are not always properly accounted for or, if they are, not in a sufficiently transparent manner. The financial and in-kind annual contribution of each Member institution/country (founding or associate) should be made available in a clear and transparent manner. The same is valid for common fund contributions. Accounting of upgrade budgets should be distinct from the annual funds, but must follow the same rules of transparency in order to have clear visibility of the efforts of each contributor.

The EGO Council currently has little influence on the definition of the participation of new scientific teams in the Virgo Collaboration and on the collaborative agreement between LIGO, Virgo and KAGRA. We observe that the EGO Council could play a stronger role in defining the path towards a future International Gravitational-Wave Network.

Finally, a recurring comment made to the Committee was that the rules and procedures for procurements at EGO have become much more cumbersome than in the past. The council and the

Administration and Finance Committee (AFC) are invited to, if possible, find measures to mitigate this further managerial complexity.

3.4 EGO staffing

A predominant finding from our review is that the number of on-site staff in Cascina is insufficient and must be increased to effectively support EGO operations. The EGO staffing level, at 62 FTEs in 2023, has been essentially constant for the past 18 years: 60 FTEs in 2006 with a peak of 64.5 in 2010. During this time, the Advanced Virgo interferometer has become significantly more complex with additional new subsystems (such as signal recycling cavity and frequency-dependent squeezing) and corresponding supporting infrastructure for those subsystems. It is therefore not surprising that the Virgo interferometer has struggled to reach its sensitivity goals in recent years. Furthermore, the aging EGO observatory facilities require more personnel to maintain them at adequate operational levels.

The Committee believes that the current staffing level is wholly inadequate for the scale of EGO operations. This conclusion is supported by a number of examples:

- The Optics Group has lost 65% of its staff, going from 7 FTEs ten years ago now down to 2.5, due to loss of staff or reassignment to other groups;
- Some detector subsystems have no on-site staff expertise to support/maintain those subsystems, and must rely on off-site Virgo members for expert support, a highly inefficient mode of operation;
- The current Deputy Director also serves as the on-site System Engineering Group Leader as well as the EGO Computing Group Leader. Each of these roles typically requires a full-time position;
- The Information Technology Group had people reassigned to work as detector operators in the control room;
- The number of operators trained for managing the detectors/runs was reduced from 7, the minimum required to run the shifts, to 5.

These are just some of the examples that we heard about during the course of our interviews. For comparative purposes, the LIGO Laboratory with its two sites has increased its operations staff from 150 FTEs (averaged over the 2007-2013 period) to 190 in 2023, driven by the increased complexity of the Advanced LIGO/A+ detector and by the need to maintain the observatory buildings and vacuum system in good condition. If LIGO was a single detector, the total personnel required for its operation is roughly estimated to be about 125 FTEs (on site and at MIT+Caltech). This is much in excess of the 62 FTEs at EGO plus additional support from Virgo Collaboration labs that we found difficult to quantify. Increasing the personpower for detector operations (on-site, off-site, EGO, Virgo collaboration) is mandatory. Many more Virgo Collaboration groups should contribute to the running of the detector.

The Committee estimates that an increase of *at least* 10 FTEs and likely more than 20 will be needed to bring the Virgo detector and EGO to a viable staffing level, either by hiring new staff or by long-term secondments from the Virgo collaboration. This is an urgent need, exacerbated by the fact that a number of long time EGO staff members are approaching retirement age. As they retire,

‘corporate memory’ will be lost, resulting in additional inefficiencies as new staff have to reinvent existing processes and procedures. Attempts should be made to prioritize hiring new staff in time to allow sufficient overlap with existing staff who might be retiring in the next 2-3 years. Recruitments should be made at an international level and strive to increase cultural diversity on-site, in order to also make the EGO/Virgo site more attractive to international visitors and long term secondments (see also section 3.6 on site attractiveness).

3.5 Virgo Collaboration

Several areas are crucial for ensuring a well-performing interferometer. These include detector operations, both inside and outside the control room; commissioning; data resource management, detector characterization, and detector calibration.

During the Committee’s visit to the EGO site, it became apparent that many of these tasks, especially the on-site tasks, are primarily handled by EGO staff. The hands-on involvement of the Collaboration is limited, with only few dedicated individuals involved in these essential activities.

Many areas report a lack of personpower, even though the Collaboration has significantly grown and various groups are willing or should be willing to contribute to the instrument: the entire Collaboration needs to be engaged and motivated to produce the best possible data with a fully operational instrument meeting its design performances.

The fact that the EGO site is scientifically not very attractive has been reported as a reason for the lack of engagement of the Collaboration. Nevertheless, one should expect an intrinsic motivation from the Collaboration to contribute to a machine that operates effectively and takes data with the desired sensitivity. This engagement includes taking on the necessary duties, engaging with EGO personnel on operations, and spending significant time on-site.

The current conditional authorship system is in place to encourage Collaboration members to contribute to the detector. However, it appears that the core program of tasks that qualify for authorship and maintaining authorship (as assessed annually) is quite broad, including long-term future R&D and data analysis. Many Collaboration members are involved in these latter two. While these are in fact important endeavors, they do not directly contribute to the current performance of the machine. One possibility to incentivize groups to focus more on detector-related tasks is to institute a two-tiered common fund fee structure, whereby groups who choose not to participate in instrument activities (at a well-defined and adequate level) are charged a higher “per author” contribution. Alternatively or in parallel, the introduction of a system similar to that used in particle physics experiments, where each group has to perform a certain number of service tasks per year to maintain authorship, could also act as a strong incentive to increase the commitment of the collaboration.

3.6 Site attractiveness

Partially triggered by the COVID-19 pandemic and the thereby premature end of Observing Run O3 in March 2020, the presence on the EGO site near Cascina has gradually reduced to a level that is

basically the EGO-employed personnel. On-site training capacity and supervision (notably regarding commissioning and noise hunting activities) of junior scientists has almost entirely disappeared. As a result, the daily presence at the EGO site risks now to fall below the minimal critical mass to maintain a lively and thereby stimulating environment. Also, a large majority of the resident staff speak Italian, making it the default language on site. This presents a barrier to meaningful participation of visiting scientists of the Virgo Collaboration who don't speak Italian. A critical mass of on-site personnel who speak English may lead to a more inclusive work environment for Virgo Collaboration members and other visitors.

Unlike e.g. CERN, EGO/Virgo does not have a fellowship and/or an associateship program. Such programs, stimulating and facilitating extended (e.g. 1-3 year) on-site stays and attracting international top-level researchers, possibly even from the LIGO/KAGRA communities, would boost the attractiveness of the EGO site. It would also help to increase the on-site critical mass and to get more experts on-site, alleviating the pressure on the EGO personnel who manage repairs/interventions when the experts are unavailable i.e. at their home institute.

To welcome Virgo Collaboration members, students and postdocs and their families on-site, in particular for long-term stays, a User's Office should be established to help with administrative and practical aspects of settling close to Cascina. The User's Office should also act as a liaison between the visitors and their home institutions and maintain a record of the necessary safety and security training.

Regarding education and outreach, the EGO site could benefit from a professional Visitor Center such as those that exist at CERN and the LIGO Livingston and Hanford sites. This will attract many youngsters from high-school and even elementary schools and will certainly lift the liveliness at the site. Similarly, an annual on-site (Summer) school for Masters and PhD students would be worthwhile to consider, as well as a year round academic training/seminar program.

The communication and outreach activities of Virgo and EGO appear from the outside as separate efforts (distinct web-pages, photo galleries, etc.). As these activities often suffer from limited person power, an integrated effort between the Virgo Collaboration and EGO would help gain efficiency and continuous/coordinated/coherent maintenance of the content.

Another area where an integrated effort of EGO and the Virgo Collaboration is mandatory concerns Diversity, Equity and Inclusion. Measures to increase diversity on all levels (gender, nationality…) need to be coherently put in place for EGO and Virgo. In the case of misconduct, inappropriate behavior or harassment, the authority in charge of support, investigation or disciplinary measures is the employer of the person involved. However, a common resource, such as an ombudsperson, who advises and orients the concerned persons and oversees the follow-up should be established.

None of the possibilities to increase the presence on the EGO site given above come for free. Nevertheless, it should be crystal clear that EGO/Virgo needs more people on-site. It is not efficient to rely on key experts that work remotely. A research infrastructure such as EGO/Virgo cannot be operated efficiently with key people only being able to be on-site on, e.g. a week's notice. Notably during commissioning, experts and critical staff must be on-site. Most notably, the EGO and Virgo

leadership should be on site on a regular basis, typically a few days per week, and more when the situation requires it.

3.7 Virgo and Einstein Telescope

Even though Virgo and ET are at a first glance similar –both (will) rely on laser interferometry to study gravitational waves emitted by expected and unexpected cataclysmic events in the universe– their scope of activities is very different given the phase –using the ESFRI nomenclature– they are in: Virgo is a running observatory i.e. in the ***Operation*** phase whereas ET is somewhere in the ***Design & Preparation*** phase and is not expected to commence its Operation phase before the late 2030s or early 2040s. Also, even though many teams are involved in both Virgo and ET, from a governance perspective the two collaborations differ significantly: Virgo is historically a French-Italian project and is still very much governed as such, whereas ET is from its inception a truly European endeavor with all participating countries represented equally.

Virgo's activities are focused on noise hunting, commissioning, observing, and detector upgrade scenarios (AdV+ phase II, stable cavities, Virgo_nEXT). Ideally, these activities must comply with the overarching schedule of alternating Observing Runs and detector upgrades agreed upon between the LIGO, Virgo and KAGRA collaborations.

ET is focused on site qualification/selection and civil engineering (i.e. research focused on the subsurface geology and hydrology), a risk inventory, the optimal detector concept (notably the 'Δ versus L' layout issue), a costbook, organizational matters –including a legal model–, and of course funding. Regarding ET's instrumentation: its high-frequency (HF) interferometers will build upon and profit from the Virgo and LIGO experience. For example, high intra-cavity power, large mirrors, low-loss coatings are all technologies to be developed, tested and operated at Virgo and LIGO, but are also required for ET. Its much more challenging low-frequency interferometers (cryogenically operated, novel mirror substrates and coatings, different wavelength, etc.) are, not surprisingly, the main focus of ET's detector-related R&D activities with dedicated R&D laboratories and have less synergy with Virgo. Nevertheless, ET relies on Virgo (and LIGO) for qualified personpower and training, de-risking certain technologies and most importantly: credibility. Virgo failing to be at the forefront of gravitational-wave research while the European funding agencies are consulted to commit major funds for a European next generation gravitational-waves infrastructure will not help to realize the ET project.

In spite of the differences described above, EGO/Virgo and ET are the two main ground based GW projects in Europe for the decades to come, and as such clearly interact, both positively and negatively. On the positive side we have e.g. ET as a "great attractor" for GW science and technology in Europe and EGO/Virgo as a provider of expertise and training for personnel and R&D. On the negative side there is increased competition for expert personpower and funding, and conflicting management structures and policies. For the short and medium term Virgo clearly needs to be the priority. It is the operating detector and the place where expertise is built and much of the R&D essential for de-risking some of ET's challenges is carried out. We believe that EGO/Virgo and ET have the potential to mutually benefit from each other and prosper together. However, that requires careful and common management of both projects, with priorities well planned and enforced, as a

function of the development phase of each project, and funding and personpower wisely shared across the two projects. This is not the case at present, which is detrimental in the short and medium term, to both projects.

4. Recommendations

In this section, we present a series of recommendations (unranked) based on the observations and findings presented above. Our primary recommendations are presented in **bold**, with more details and implementation strategies provided in the bulleted text. We emphasize that these recommendations are essential for the further success of EGO/Virgo.

ORGANIZATION AND GOVERNANCE

The current organization of EGO and Virgo, their links and relative responsibilities must be modified, and the role of EGO in detector construction, integration and operation should be strengthened. Below we give three recommendations that are a stepping stone towards a more transparent and efficient organization. In Appendix A we provide more detail and suggestions for a possible implementation.

EGO must play a much stronger role in detector construction, operation and integration after acceptance of detector (sub)systems at the EGO site.

- The EGO Director is responsible for all activities at the EGO site and is the final authority for all decisions concerning the functioning of the Virgo interferometer on site. Therefore, it is mandatory that the recruitment of future EGO Directors is carried out through an international call and evaluated by a search committee. He/she should be selected for his/her management skills as well as for his/her expertise in the field of GW and interferometry. The Virgo Collaboration should be closely involved in the selection of the EGO Director.
- We propose the creation of a “Virgo-Lab”, which is the joint structure between EGO and the Virgo Collaboration to run the detector at the EGO site (see Appendix A for the proposed organization).

All (technical) decisions regarding operations and upgrades are made by the Executive Board (EB).

- An EB should be established, consisting of 6-8 members: the EGO Director, the Virgo Spokesperson, the Virgo Deputy Spokesperson, the Head of Systems Engineering, and for example, the Upgrade Coordinator, the Commissioning Coordinator and the Run Coordinator. The board is chaired by the EGO Director and should strive for consensus. In case of disagreement within the EB, the final decision shall be made by the EGO Director.
- The EB is advised and supported by a Technical Committee (TC), which consists of all technical department heads, the head of general infrastructure, and additional subsystem technical experts when necessary.
- As a consequence, the Virgo Collaboration Board (VCB, replacing the current VSC) is responsible for managing Virgo Collaboration matters, such as the election of the Virgo Spokesperson. The VCB formally acknowledges the EB composition, but does not have a role in technical decisions related to the detector.

Oversight by the EGO Council should be strengthened by appointing a program officer, who is the liaison between the EGO Council and the EGO Director.

- This role is to ensure regular and efficient oversight and exchange of information between the EGO Director and the EGO Council (for example, by having weekly exchanges with the EGO Director). The role of the program officer is particularly important in implementing these recommendations.

PROJECT MANAGEMENT

EGO and Virgo must adopt a rigorous project management structure that utilizes modern tools and procedures for detector operations and Observing Runs, similar to any large-scale (international) research infrastructure.

- Rigorous reviews with external reviewers should be carried out for all subsystems. These include, for example, external critical design reviews, external technical design reviews, QA/QC requirements and assembly/test procedures.
- *All* documentation for the Virgo detector should be centrally curated and available to *all* EGO staff and Virgo Collaboration members.
- Major technical decisions should only be made after a thorough risk analysis and a holistic cost and human resource estimation.
- A rigorous workflow should be adopted for the following activities: *R&D, TDRs, reviews, funding proposals, QA/QC, documentation and realistic planning.*
- When carrying out reviews and evaluating funding proposals, staffing needs and required expertise should be critically assessed to ensure that institutes share adequate responsibilities for subsystems.
- Regular training should be provided by experts to Virgo Collaboration members and EGO scientists, engineers and technicians to increase the pool of experts for all subsystems. Collaboration members must take responsibility for attending these training sessions and being available to become experts.

EGO COUNCIL AND FINANCES

Additional financial resources are essential for the future of EGO/Virgo.

- Additional funding is mandatory for the required detector developments and staffing support that is necessary to reach the desired sensitivity.
- It is advised that *all* members of the Virgo Collaboration contribute to the running of the instrument through a common fund.
- To join the EGO Council, new Member countries/institutes must contribute to the ordinary budget beyond the common fund.

The financial budget of EGO and the financial flows between EGO and Virgo have to be reviewed and clarified accordingly.

- The total financial picture, consisting of ordinary budget, extraordinary budget (upgrades) and common fund should be presented to the EGO Council in a more transparent manner.
- The ordinary budget should not be redistributed to external institutes as is the case today (support for R&D, missions of national laboratories, etc.). Instead those institutes should be funded directly and/or by other sources.
- All the contributions to the instrument should be properly accounted for, meaning both cash contributions and in-kind contributions.

EGO PERMANENT STAFFING

A careful assessment of the EGO staffing needs should be carried out as soon as possible, with the goals of i) identifying critical staffing shortfalls, and ii) identifying (with the EGO Council) a means for increasing (funding for) EGO staff and closing the staffing shortfall gap.

- EGO should carry out a detailed analysis of the overall staffing needs, considering as priorities a well-staffed central engineering team (including a project office or similar structure), detector commissioning team, and a well-trained crew for carrying out Observing Runs. A preliminary estimate is that an increase of at least 10 FTE and more likely 20 at the EGO site will be needed for a viable staffing level.
- As part of this analysis, EGO should conduct a critical review of the internal EGO organization, and revise it as appropriate, distributing tasks to the functional groups in a more efficient and balanced way.
- Particular attention should go to attracting and recruitment of international staff.
- Staffing could be increased either by funding permanent positions in EGO or by long-term secondments or a combination thereof.

VIRGO COLLABORATION

The Virgo Collaboration must have an increased engagement in (on-site) detector related activities and tasks of common interest.

- Virgo members should take up their detector responsibilities, both on-site and off-site (and be supported by EGO staff in doing so): assuming responsibilities in the operations and commissioning, increasing their presence on-site, and engaging in formal and informal collaboration with EGO staff.
- Currently Virgo authorship is conditioned on contributions to activities defined in the Virgo Collaboration core program. In the core program most activities (instrument, data analysis, service tasks, R&D, …) are placed on an equal footing. This should be modified, with weight given to instrument activities and service tasks that concern the on-site installation, commissioning and operation of the detector.

SITE ATTRACTIVENESS

The EGO site should be made more attractive and scientifically vibrant for the EGO staff as well as for the Virgo Collaboration members and the wider international gravitational-wave community.

- The EGO and Virgo leadership should be based and present on site.
- The presence on-site should be increased by initiating postdoctoral fellowships and secondments for other long-term stays.
- A vibrant scientific culture should be developed within EGO with seminars, lectures, (summer) schools and internships for students. It would be beneficial to involve the nearby universities.
- EGO should establish a User's Office on site to assist visiting scientists and engineers with anything that they may need for an extended visit to the site.
- More international and cultural diversity should be ensured on site in order to increase the attractiveness of EGO as a workplace for non-Italian staff and visitors.

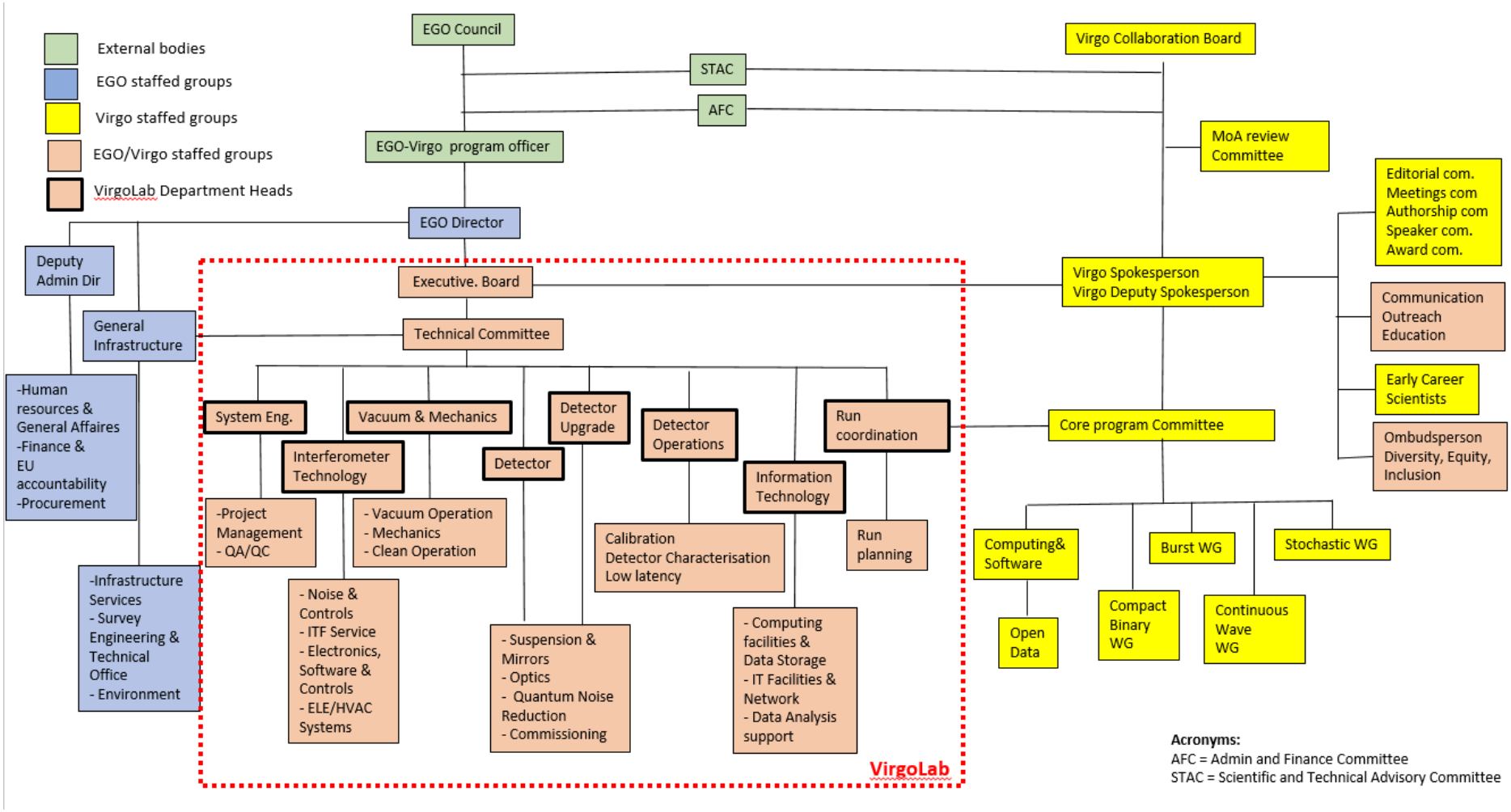
VIRGO AND EINSTEIN TELESCOPE

The impact of the prospect of the Einstein Telescope (ET) project on Virgo should be carefully managed.

- The funding agencies, and the Virgo and ET collaborations, should keep Virgo as a priority and ensure that expertise is shared among Virgo and ET for mutual benefit.
- Opportunities should be explored to redirect existing ET R&D funding to Virgo to increase Virgo's sensitivity, while potentially de-risking some of ET's technical challenges.
- A high level European gravitational-waves coordination board should be initiated, that evaluates and discusses the strategic developments of both Virgo and ET.

Appendix A

This appendix provides suggestions for a possible implementation of our recommendations on “Organization and Governance”. It consists of a suggested high-level Organigram and a description of the key roles and responsibilities, in addition to the brief description given in the recommendations. It draws heavily on the existing organizational structures, but with the aim of grouping all detector activities in a single entity and under clear responsibility.


External bodies
EGO staffed groups
Virgo staffed groups
EGO/Virgo staffed groups
VirgoLab Department Heads
EGO Council
STAC
AFC
EGO-Virgo program officer
EGO Director
Deputy Admin Dir
General Infrastructure
-Human resources & General Affaires -Finance & EU accountability -Procurement
-Infrastructure Services - Survey Engineering & Technical Office - Environment
Executive. Board
Technical Committee
System Eng.
Vacuum & Mechanics
Interferometer Technology
Detector
Detector Upgrade
Detector Operations
Run coordination
Information Technology
-Project Management - QA/QC
- Vacuum Operation - Mechanics - Clean Operation
- Noise & Controls - ITF Service - Electronics, Software & Controls - ELE/HVAC Systems
- Suspension & Mirrors - Optics - Quantum Noise Reduction - Commissioning
Calibration Detector Characterisation Low latency
Run planning
- Computing facilities & Data Storage - IT Facilities & Network - Data Analysis support
VirgoLab
Virgo Collaboration Board
MoA review Committee
Virgo Spokesperson Virgo Deputy Spokesperson
Core program Committee
Editorial com. Meetings com Authorship com Speaker com. Award com.
Communication Outreach Education
Early Career Scientists
Ombudsperson Diversity, Equity, Inclusion
Computing& Software
Burst WG
Stochastic WG
Open Data
Compact Binary WG
Continuous Wave WG
Acronyms:
AFC = Admin and Finance Committee
STAC = Scientific and Technical Advisory Committee

Description of roles and responsibilities:

General:

- EGO is the legal entity responsible for the operation, maintenance and improvement of the Virgo detector, together with the site maintenance and the administration of EGO and Virgo on-site resources.
- Virgo-Lab designates an internal organization including both EGO Staff and Virgo Collaboration members who operate, maintain and improve the Virgo detector, organize the data taking, and ensure data quality and data handling.

EGO Director:

- The EGO Director is responsible for all activities at the EGO site and is the final authority for all decisions relating to the operation of the Virgo interferometer on site. He/she takes final responsibility for the success or failure of Virgo in meeting its operational and technological objectives.
- The EGO Director is appointed by the EGO Council, recruited through an international call and evaluated by a search committee. Selection criteria for the EGO Director include management skills and competence in the field of GW and interferometry. The Virgo Collaboration is closely involved in the selection process (e.g. Virgo members in the search committee).
- The EGO Director is a fixed term position renewable once. The EGO Council and the Virgo Collaboration should be involved in the renewal decision.
- The EGO Director appoints EGO staff members, in particular the Deputy Administrative Director and the Head of General infrastructure, who are EGO staff.

Executive Board (EB):

- All decisions with respect to the operation and upgrade of Virgo are taken by the EB, typically on a weekly basis.
- The EB should consist of 6-8 members: the EGO Director, the Virgo Spokesperson and Deputy Spokesperson, the Head of System Engineering and, for example, the Upgrade Coordinator, the Commissioning Coordinator and the Run Coordinator.
- The EGO Director chairs the EB.
- The EB should strive for consensus, in case of disagreement the final decision shall be made by the EGO Director.

Technical Committee (TC):

- The TC advises the EB on technical matters.
- It is composed of all Virgo-Lab technical department heads (as indicated in the organigram), the head of general infrastructure, and other subsystem technical experts as required.

VIRGO Collaboration Board (VCB):

- The VCB is responsible for managing the Virgo Collaboration matters and electing the Virgo Spokesperson, and meets typically a few times per year.
- The VCB formally acknowledges the EB and TC composition.
- The VCB Chair, and the Virgo Spokesperson are observers in the EGO Council.

EGO-Virgo Program Officer:

- The program officer is the liaison officer between the EGO Council and the EGO Director.
- His/her role is to ensure an efficient and smooth oversight and information flux between the EGO Director and the EGO Council.

- He/she meets with the EGO Director on a regular basis (e.g. weekly). He/she or the EGO Director may invite the Deputy Administrative Director, members of the TC or members of the EB to any of those meetings as necessary.
- He/she reports back to the EGO council at EGO-council meetings and at any time in between as required.
- The EGO Council appoints the Program Officer.

Communication and Outreach:

- To give a coherent picture of the Virgo Collaboration and EGO, and to make efficient use of limited resources, communication and outreach should be an integrated effort of EGO and the Virgo Collaboration.

Diversity, Equity and Inclusion:

- A common ombudsperson for the Virgo Collaboration and EGO could provide support, guidance and oversight of follow-up actions in cases of misconduct, inappropriate behavior and harassment.

Appendix B

The charge for the EGO/Virgo organizational review provided by Stan Bentvelsen, Marco Pallavicini and Vincent Poireau on behalf of the EGO council, October 2023

1. Introduction and general context of the review

1.1 General context

The O3 data taking in 2019/2020 was a real success for Virgo with a strong contribution to the physics case, with 90 events recorded by the LIGO/Virgo/KAGRA collaboration. However, Virgo did not succeed the join until now (Oct 2023) the O4 data taking that started in May 2023. The EGO and Virgo teams are now working hard to try to fix the interferometer and join 04 no later than March 2024 (after the commissioning break of LIGO).

The Virgo Collaboration is composed of 829 members (including engineers) with 554 authors for the publications. The main countries in decreasing order of authors are Italy, France, Netherlands, Spain, Belgium, Poland, … The Collaboration has more than doubled since July 2019. The Spokesperson of the Collaborationis Gianluca Gemme (gianluca.gemme@ge.infn.it), in place since May 2023. Previous Spokesperson was Giovanni Losurdo (losurdo@pi.infn.it).

EGO (European Gravitational Observatory, https://www.ego-gw.it/) is a consortium following Italian civil code, founded by CNRS and INFN more than 20 years ago. Since 2022, NIKHEF joined EGO as an associate member. The consortium is open to new admissions, and institutes from Belgium, Poland, and Spain showed a recent interest to join EGO (since July 2023, they are now observers). About 60 persons are employed on the EGO site at Cascina near Pisa. Since December 2022, the Director of EGO is Massimo Carpinelli (massimo.carpinelli@ego-gw.it). The previous Director, now deceased, was Stavros Katsanevas. The ordinary EGO budget is about 11 M€ per year, coming mainly from the contributions of its members. Recently, the budget has been increased to cope for the inflation and cover some necessary reparations or upgrades. For the preparation of O4 and O5, a specific founding was added to the EGO budget (of the order of 20 M€ in cash).

EGO is advised by a council whose members are from the funding agencies CNRS/INFN/NIKHEF. Since January 2023, the president is Vincent Poireau (vincent.poireau@in2p3.fr) and the vice-president is Marco Pallavicini (marco.pallavicini@ge.infn.it). Other council members are: for CNRS, Susanna Vergani (susanna.vergani@obspm.fr) and Saîda Guellati-Khelifa (saida.guellati-khelifa@cnrs.fr); for INFN Oliviero Cremonesi (oliviero.cremonesi@mib.infn.it) and Marco Grassi (marco.grassi@pi.infn.it); for NIKHEF Stan Bentvelsen (s.bentvelsen@nikhef.nl) and Job de Kleuver (j.dekleuver@nwo.nl).

The EGO council sets up a Scientific and Technical Advisory Committee (STAC), composed of scientific personalities. The role of the STAC is to advice the EGO Council. Since 2023, the Chair of the STAC is Peter Wolf (Peter.Wolf@obspm.fr), the previous Chairbeing David Shoemaker (dhs@ligo.mit.edu). The members of the STAC are listed in Appendix A.

1.2 Review

This failure of joining O4 reveals issues and problems that are possibly present in EGO and Virgo since a few years, even probably before the O3 data taking. There is also a clear lack of competitiveness with LIGO. With O5 and post-O5 (the so-called Virgo_nEXT), EGO/Virgo needs to improve on many aspects. It is clear that before the next generation of GW facilities take over around 2040, Virgo must become more competitive in the field.

All these issues led to a decision by the EGO council to conduct an international review on EGO and Virgo. This high-level review aims at scrutinizing the organizational aspects of EGO and of the Virgo collaboration. The goal is to improve the functioning of EGO and Virgo, find and fix the organizational issues. It has to be noted that this is not a technical review. Such a technical review will be conducted in parallel (about the current technical failures and the proposal for stable cavities), with hopefully some bridges between the two panels of experts.

The reviewers are: Rosemarie Aben (scientific secretary), Ursula Bassler, Frederico Ferrini, Frank Linde, David Reitze, Laurent Serin (chair), Peter Wolf.

The charges for the panel are the following:

- Review and recommend on the organizational structure of Virgo
- Review and recommend on the organizational structure of EGO
- Review and recommend on the interaction between EGO and Virgo

Of course, the panel is an advisory board, and has no authority by itself. Its role is to propose recommendations that the EGO council will be free to apply to EGO/Virgo.

2. Detail of the review

2.1 Timeline

The review should aim for a document with recommendations to the EGO/Virgo management, before the end of the first 2024 trimester. The anticipated timeline is the following:

- Kick-off meeting with three representatives of the council: 3rd of October 2023
- First meeting of the panel: 17th of October
- Meeting between the panel and the EGO/Virgo management: October-November
- Interviews with individuals: October-December
- Panel invited to the EGO council of December at EGO: 18/19 December. Preliminary thoughts could be shared by the panel at this occasion
- Full day of review at EGO: January 2024
- Written report with recommendations: first trimester 2024

2.2 Deliverables

The panel is expected to write a (possibly short) report by the first trimester 2024. The first part of the report could be confidential and only transmitted to the council. The report should contain recommendations that will be transmitted to the EGO and Virgo management.

2.3 Available documents

Several documents are available to the panel:

- EGO statutes
- Virgo bylaws
- Virgo organigram / Advanced+ organigram
- STAC composition (see Appendix A)
- Any other documents the panel would find useful

2.4 Interviews

We suggest the panel to interview people to have an inside and diverse opinion on the issues with EGO/Virgo. These people should not be only from the management, but also from the Collaboration or from EGO. We suggest to aim for a large diversity: people with a long experience of EGO/Virgo, newcomers, young researchers, etc. For some of these people, we recommend to have individual interview in a private context for the freedom of speech, sharing the interviews between the different panel members.

The council or the national representatives could help to give a list of names.

2.5 Technical review

In parallel of this review, the EGO council will set up a technical review with a different panel. The goal of this review is to understand the root of the technical problems that prevent Virgo of joining O4. In addition, the Virgo Collaboration will propose an upgrade of the interferometer at the council of December 2023 with the aim to install stable cavities. The role of this technical review will be to assess that plan as soon as it is available.

Strong interaction between the two panels is expected, with ideally at least one member in common.

2.6 Specific questions

As a starter for the panel, here is a list of questions that the review may address.

About EGO:

- Are there aspects that can be improved in the organization of EGO?
- Attractiveness of EGO for its personnel, role of EGO personnel
- Strategy of EGO with respect to other activities (European project, scientific activity, …)

- Despite the top responsibilities of EGO in commissioning and AdV+, only technicians and engineers are employed by EGO up to now: is there a need to have researchers employed by EGO?
- Lack of FTE at EGO? Lack of specific expertise on the site (QA/AC, …)? Need for secondments?
- Share and turnover of responsibilities at EGO
- Fellowship program and visiting scientist
- Life in the EGO control room (spoken language, atmosphere for collaborators, …)
- Organize regular school in Cascina to gain in attractiveness?

About Virgo:

- Are there aspects that can be improved in the organization of Virgo? In the organization of AdV+?
- Share of expertise between laboratories, between individuals. Is it possible for new laboratories to take over an expertise? Is it possible to contribute on a given topic if the expertise lies in another lab? What should be changed in the current model?
- Responsibilities of upgrade coordinator versus commissioning coordinator, etc...
- Long-term aim for Virgo and its competitiveness

About EGO and Virgo interactions:

- Interaction between EGO and Virgo, decision making process between EGO and Virgo (clarify the chain of command and identify key persons who have the final word, in each domain)
- Responsibilities of EGO Director versus Virgo Spokesperson
- The Virgo Collaboration has more than doubled since a few years. Are there difficulties for newcomers to integrate into EGO/Virgo? What could be improved in this respect?
- Training of newcomers and of the young generation
- Attractiveness of EGO for collaborators
- Do the EGO/Virgo Collaboration and laboratories have all the needed competences and skill? (not a real technical request but an evaluation of the completeness of the team)
- New recruit at EGO: need to have Virgo members (or outside members) in the recruiting committee?
- Membership in EGO and Virgo

About the interaction with Einstein Telescope:

- Interaction/interference/synergies with the Einstein Telescope project
- Have a better interaction between ET and Virgo, ET and EGO? Official strategic partnership? (at the level of the Collaboration or of the project)
- Better ET/Virgo interactions at the level of the funding agencies? Sharing of funding and person power?

APPENDIX: STAC composition

Name	First name	Institution	Expertise	Appointed by Council in	End of appointment (3/6 years from 1st meeting attended)
Barsotti	Lisa	MIT	GW detection and technology	April 2023	May 2026
Biagi	Simone	LNS/INFN	Fundamental physics	December 2021	May 2025
Cavalier	Fabien	IN2P3	GW interferometry	December 2022	May 2026
Lindsey-Clark	Miles	IN2P3	Technology, tools, organization	September 2023	November 2026
Delfino	Manuel	IFAE	Computing	December 2021	May 2025
Dolesi	Rita	University of Trento	Astroparticle physics	July 2019	July 2025
De Jong	Maarten	Nikhef	Organization, gravitation physics	September 2023	November 2026
Markoff	Sera	University of Amsterdam	Astrophysics	December 2021	May 2025
Shoemaker	Deirdre	CGP/University of Texas-Austin	Gravitational physics	December 2021	May 2025
Smartt	Stephen	Queen's University Belfast	Multimessenger astrophysics	July 2019	July 2025
Tomaru	Takayuki	KEK	Interferometer operation	November 2019	November 2025
Wolf	**Peter**	Observatoire de Paris	Fundamental physics	July 2016	July 2025

Appendix C

The following interviews were conducted.

Date of interview	**Name interviewee**	**Considered role**
7 November 2023	Jo van den Brand	Former Spokesperson
17 November 2023	Gianluca Gemme	Current Spokesperson
11 December 2023	Massimo Carpinelli	Current EGO Director
10 January 2024	Giovanni Losurdo	Former Spokesperson
10 January 2024	Mario Martinez	Spanish Observer in the EGO Council
18 January 2024	Raffaele Flaminio	Former Project Leader / Upgrade Coordinator
18 January 2024	Alessio Rocchi	Current Upgrade Coordinator
18 January 2024	Fiodor Sorrentino	Commissioning Coordinator
19 January 2024	Vincent Poireau	President EGO Council / French Representative
19 January 2024	Marco Pallavicini	Italian Representative in the EGO Council
19 January 2024	Michele Punturo	Spokesperson Einstein Telescope
24 January 2024	Andreas Freise	Co-Director ET Organization
24 January 2024	Stan Bentvelsen	Dutch Representative in EGO Council
30 January 2024	Andrzej Królak and Tomasz Bulik	Polish Observers in the EGO Council
30 January 2024	Tjonnie Li and Giacomo Bruno	Belgian Observers in the EGO Council

In addition, there were group discussions with staff from the various departments of EGO, during the site visit on 18 January.

EGO department
Infrastructure Services
Vacuum & Mechanics
ITF technology Dpt: Electronics
IFT technology Dpt: Noises & controls
IFT technology Dpt: Optics team
Elec&HVAC + ITF services team
Information technology team
Administration team

Finally, there have been national discussions between Committee members and the respective Virgo Collaboration members from Italy, France and the Netherlands, resulting in three additional written contributions.