6th Review of MAX IV´s Project Management

Report by the appointed review committee to the Swedish Research Council, November 2022

Dnr 2022-06714

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Preface

The Swedish Research Council (SRC) is a governmental agency supporting fundamental and applied research of the highest scientific quality in all academic disciplines. It is also part of SRC´s remit to evaluate the funded research and to assess its academic quality and impact. The Council for Research Infrastructure (RFI) at SRC has the overall responsibility to ensure that Swedish scientists have access to research infrastructures of the highest quality. Furthermore, RFI evaluates the needs for research infrastructures, launches calls and evaluates applications, participates in international research infrastructures and works on monitoring and assessments.

MAX IV is a synchrotron facility in Lund, Sweden, for which the Swedish Research Council/RFI is the largest funder. MAX IV builds on innovative accelerator physics and a strong soft x-ray researcher community.

This is the sixth review conducted since the summer of 2018. The reviews have primarily focused on the project management structure within MAX IV and on how the laboratory is transitioning into operation. Since 2019 the panel also has looked at scientific output and how the laboratory and its board are working with the long-term strategy. The expert members of the present review committee consisted of Thomas Allard, Wolfgang Drube, Carlo Bocchetta, Zahid Hussain, Britt Hedman, Lennart Bergström and Bettina Kuske – the Terms of Reference issued to the committee are attached as Appendix 1.

Since the start of this review series there has been immense progress in the build-up of the MAX IV accelerator and beamlines. The last two of the 16 funded beamlines are soon coming into user operations, thereby marking the end of the current construction phase.

I would like to take the opportunity to thank the review committee for their tireless and excellent work, which has resulted in this report. Furthermore, the efforts of the management and staff of MAX IV are highly appreciated, both for preparing background material for the review and being available for presentations, discussions and in-depth interviews, making our visit in Lund highly productive.

Stockholm, 5 december 2022

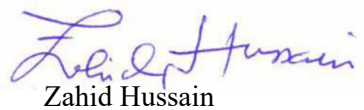
Lisbeth Olsson, Chair of review

Secretary General, Council for Research Infrastructures, Swedish Research Council

To the Swedish Research Council

The present document presents the views and assessments of the review committee members. By signing they take full responsibility for the report. The chair and her supporting staff confirm that the work was conducted in accordance with the statutes of the Swedish Research Council and that it was performed in an impartial manner.

Thomas Allard
Chair of Sub-Committee 1



Zahid Hussain
Chair of Sub-Committee 2

Wolfgang Drube
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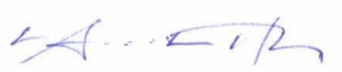

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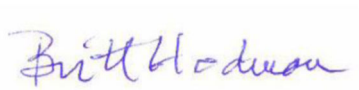

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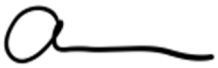

Maja Hellsing
Secretary

Lisbeth Olsson
Chair of review

Executive summary

The committee is deeply impressed by the profoundness and pace of the changes that MAX IV has accomplished since the last review in November 2021. These changes were initiated by the senior management team and especially by Olof Karis since he started as interim director in March 2022, but they would not be possible without the entire team's effort and support. MAX IV has gone to great lengths to properly react to each of the 12 recommendations put forward by the committee in 2020 and 2021.

The list of achievements is long; proper staff training has been established at different levels, required working procedures have been ironed out, roles and responsibilities have been clarified, the requested technical division has been set up and there has been progress in the finance tracking. Many people that the committee talked to expressed the view that this is still only the beginning of a long journey but that the organization is moving in the right direction. The staff morale is high and there is a sense that MAX IV is on the path to success, a view that the committee shares. Still, challenges remain until the newly decided changes turn into a daily routine and larger items still remain, e.g. the envisioned reorganization of the science division.

Despite all this success, the committee believes that MAX IV needs to increasingly keep an eye on external developments and competition. Other 4th generation light sources are on the horizon and MAX IV should as quickly as possible make sure to harvest the scientific success of their innovative accelerator design to the full extent. Opportunities exist for increased sustainability in the operation of accelerators, beamlines, and conducting experiments. Science directed towards sustainability is an urgent societal demand supported with much funding, where MAX IV needs to play an active role. Financial problems caused by rapidly increasing rent and energy prices must be dealt with more proactively and mitigation plans have to be established together with the MAX IV board and Lund University.

The committee commends the MAX IV staff for their technical and scientific achievements during 2022. The accelerator team keeps adding new features to the machines and thus defend its leading position in the community. In early 2023 the last two of the 16 funded beamlines will enter user operation, thereby marking the end of the current construction phase. There is a significant increase in MAX IV publications as compared to the previous year. While the quality of the publications is at par with other facilities, the absolute number is still a little low. However, the Committee feels comfortable predicting that the publication rate will continue to increase, driven by both the continued development of techniques and instrumentation and the support of user experiments.

1 Cost and Schedule

1.1 Findings

The construction of the last beamlines (BLs) of the 16 funded is essentially complete. By the beginning of 2023 all BLs will be in operation, the newest ones starting with baseline capabilities. As requested, overview information was provided on active and upcoming larger projects at BLs, accelerator and infrastructure, including some budget numbers, coarse milestone dates and the planned full scope of all beamlines. Currently, the Central Project Office (CPO) lists 25 BL projects, 17 ongoing and 8 upcoming, as well as 8 accelerator projects. 6 main BL projects have been identified (NanoMAX, CoSAXS, SoftiMAX, DanMAX, ForMAX, MicroMAX) aiming at adding further BL functionalities and capabilities. Budget and end dates for the individual projects were available to the Committee.

As requested, detailed figures for the complex operating costs of the entire laboratory were presented in the review, so it can be assumed that the financial systems are mature at top level and able to track project data properly and effectively. However, the breakdown of project costs and revenues between operations and investments was not clear.

1.2 Comments

The committee is reasonably confident that required information and planning is sufficiently in place at CPO and that the current projects therefore will be successfully completed within the targeted timeframes.

It is important that detailed breakdown of costs and revenues between operations and investments is transparent and consistent. Information was not provided on the financial tools utilized. Since last year there seems to be further progress on the work with reporting of staff hours related to projects. However, the committee is still uncertain of whether the final two phase-III beamlines are tracked in a way that (when they are completed in 2024) material costs and labour use, direct and indirect, can be effectively separated from operating costs. Such information is essential for the laboratory to make accurate cost planning for future beamlines, hence the appropriate methodology must be implemented. It is therefore recommended, if not used, that when MAX IV is setting up a new project the organization makes use of a method with a Work Breakdown Structure, with connected work packages that in turn is connected to the financial system through separate order numbers that can be tracked. The work packages should also incorporate the associated timelines, so that the staffing of the project is easy to follow. It would be good to see the planned start and end dates, the progress to date (Earned Value, etc.) and forecasted completion date, as well as forecasted budget including risks to complete. A table with all projects having such parameters would give a clear picture of the situation.

2 Technical

2.1 Findings

There is a new MAX IV web page that provides information on the beamline capabilities in a standardized way. Every beamline is presented with all its parameters, available techniques, staff, publications, and sometimes even movies. The web pages are updated before every new call for proposals in a systematic manner.

Accelerators

Delivery of beamtime in 2022 is back to the pre-pandemic levels for all three accelerators. The mean time between failures increases in the rings but remains at a low level for the linac. This is mainly attributed to very short interruptions due to RF trips, which have a limited impact on the overall uptime. A 'Linac Reliability Improvement Plan' including a timeline exists and is being worked on. The emphasis of the work in 2021 lay in the further development of the Soft X-ray Laser (SXL)/Short Pulse Facility (SPF) and the 1.5 GeV ring.

Short Pulse Facility, SPF

Due to improvements in the linac optics, including minor hardware changes, the emittance has been reduced to a third of its former value, i.e. 60 μm. Much work has been invested in the linac temporal stability, including new hardware (cavity-based beam arrival monitor) and increased theoretical understanding leading to a different operation of the bunch compression. This resulted in a 9-30 fs RMS timing jitter. A transverse deflecting cavity was installed and will be commissioned in December 2022. This will allow for a sliced analysis of the bunch, crucial for further optimizations.

1.5 GeV Ring

The installation of the Multipole Injection Kicker (MIK) is complete. Temperature tests were satisfactory for 500 mA (multi-bunch) and 20mA (single bunch) operations. Initial injection studies were performed the week after the review and demonstrated that injection with the upgraded system could be realized with higher injection rates than with the previously used dipole injection kickers and also that the perturbations to the stored beam were significantly reduced. As a by-product, this new injection system also significantly facilitates the compensation of the perturbations produced by insertion devices, since the stored beam no longer executes larger oscillations at top-ups. The compensation of the non-linear fields of the insertion devices for BLOCH and FinEst beamlines allowed for successful injection in the difficult 'universal mode', even at small gaps. Further development time was invested in the Transverse Resonance Island Orbits (TRIBs) operation mode. There are no current limitations. Tests with users also included top-up, and the response was very positive. The Fast Orbit Feedback system is in commissioning, showing very promising results for a strong attenuation of the ID perturbations.

3 GeV Ring

There was some progress shown in the development of the lower emittance optics for the 3 GeV ring, although it is not yet possible to accumulate the beam. The dynamic aperture apparently is much smaller than calculated. This is not yet understood. Lower beam emittance would allow for reduced current at the same brilliance, i.e. is a potential for energy savings. Optimization of the octupole settings led to a 19% increase in momentum acceptance.

Undulators

All 16 beamlines at MAX IV (1.5 GeV, and 3.0 GeV storage rings and the Linac), utilize insertion devices (IDs) for further increasing their brightness. Upgrades related to undulators include e.g. motion control upgrades, fast step scanning, and continuous scanning modes. There is a magnetic measurement laboratory equipped with various kinds of measurement tools within MAX IV. The undulator group is currently offering 24/7 on-call service. Benchmarking of the MAX IV undulators at e.g. DanMAX and ForMAX beamlines show that these IDs provide the highest brilliance as compared to IDs at any other facilities, which is result of the high brilliance of the MAX IV source and quality of the IDs.

Detectors

MAX IV has formed a new Detector-Scientific Software (DetSciSW) group in Nov 2021 that now includes the detector group along with the data acquisition/data processing group. Currently the detector group primarily focuses on supporting hard X-ray commercial detectors that include, photon-counting pixel detectors, CMOS cameras, and energy-resolving detectors.

Data and Software

MAX IV has developed an Experimental Data Policy that states that MAX IV acts as a custodian but does not have data ownership. This has defined how data are handled and stored. This development effort was supported by Knut and Alice Wallenberg foundation in the DataSTamP project. Data include raw and cured data as well as metadata (best effort). Data are maintained for 7 years minimum and are searchable online. MAX IV is a partner in the EU-funded ExPaNDS collaboration (see https://expands.eu/ for additional information), which provides a common standard that is evolving. A scientific infrastructure and data flow system is in place for 12 beamlines, of which 6 are actively using them. Data are transferred from the beamlines to a central storage cluster, with as of September 2022 includes a tape storage capability for the long-term archiving. Infrastructure hardware is provided for data analysis during beamtime and for off-site data analysis. Future challenges include gathering and storing contextual information (metadata) that would provide the scientific information for the stored data.

Two examples were provided of interaction between the KITS department within MAX IV and beamline staff for projects that enabled control and data

acquisition at CoSAXS (time-resolved measurements) and FlexPES/BioMAX (continuous scans), but data acquisition and analysis software were not described in detail during the review.

2.2 Comments

A direct comparison of the current beamline specifications to the originally intended specifications was not supplied to the Committee, but may not be relevant for the users at this point. The benchmarking of all the operational beamlines against some of the leading beamlines at other facilities, as was presented during the review, is an effective means to show that MAX IV beamlines are state-of-the-art as they currently stand. They are highly competitive with similar classes of word-leading beamlines. However, MAX IV needs to continue making improvements in the beamline performances as there is a danger that their competitiveness may diminish with the planned upgrades of other facilities. The upgraded facilities´ highly optimized beamlines might make better use of their upgraded diffraction-limited sources with high brightness and high power of coherence.

Accelerators

The MAX IV accelerator division works continuously on all 3 accelerators to improve their performance and understand their limitations. The level of competence and innovation is high and the Committee commends the team for their ongoing success. Due to the creation of the Technical Division within MAX IV (along the lines of recommendations given in the past), the complete engineering support has been moved away from the accelerator division. The Committee is eager to learn how far this changes the working conditions for the accelerator group. The new organizational structure should not result in a reduction of the accessible support for the ongoing projects on the accelerators, since they are needed to maintain and develop the systems to keep them compatible.

Undulators

Apple II-type undulators are used for MAX IV´s soft x-ray beamlines on both the 1.5 GeV and 3.0 GeV rings, which are designed and completely characterized in-house. In-vacuum hard x-ray beamline undulators are purchased from the commercial market but before installation, they are characterized using the facility´s magnetic measurement laboratory. It is highly encouraging to see that the low emittance of the 3.0 GeV ring results in world-leading high brilliance at DanMAX and ForMAX beamlines. The Committee commends MAX IV and the undulator group for this excellent performance.

The undulator group performs excellent R&D efforts in developing novel Apple II-type undulators that include for example prototyping of a compact, cost-effective Apple II with complete polarization control. The Committee encourages the group to take an additional step in carrying out a design study for the development of a soft x-ray undulator suitable for installation at the 3.0 GeV ring that could provide the highest possible coherent power with complete

polarization control and the possible capability of delivering orbital angular moment. Combining this ID with coherence-preserving beamline optics, and an advanced scattering chamber would fulfil the need of developing a MAX IV flagship beamline, making the best use of the low emittance and high coherence as provided by the pioneering and revolutionary MAX IV accelerator system.

Detectors

No benchmarking of the available detectors at MAX IV was presented to the committee but it appears that the hard x-ray detectors at the facility are state-of-the-art. The Committee commends KITS for recognizing that merging together the scientific software team and the informal detector group is an effective means to acquire state-of-the-art detectors with suitable characteristics. It is also effective for their installation at the beamlines, along with their maintenance, and troubleshooting.

Clearly the detector group needs to set their priorities and keep their R&D effort within the boundaries imposed by the number of their staff and available funding. However, it is important for them to pay attention to the development of some of the ultrafast (nanosecond to 100's of picosecond regime) soft x-ray detectors that would be required if and when MAX IV is ready to develop a flagship beamline with maximum possible coherent power as delivered by the low emittance 3 GeV storage ring (see new recommendation 4).

Data and Software

MAX IV has developed a system for short and long-term data storage that at present seems to meet the demand of the output of the beamlines. Collaboration with other facilities, and interaction within EU programs are good steps as they provide standardization, feedback and collaborations.

Progress has been made with the data acquisition and control software on the beamlines, although it appears that the stability and user-friendliness of some of the software components require further improvement when individual beamlines are put into operation. In particular, there seems to be a need for action with regard to the stability of SARDANA in measurement operation at the beamline. This should be addressed with high priority, as this is the direct interface of the user groups with the beamline control. If the control software hangs resulting in an interruption of the measurements, this is not a tolerable situation, especially if it happens outside core working hours. It appears that the local beamline scientists are not authorized to perform a reset/restart of the software and that this only can be done by a KITS specialist. This procedure should be reconsidered.

It would be helpful for the commissioning of beamlines if the software developers concerned would test/commission their programs intensively under real measuring conditions on-site in close cooperation with the beamline staff. The quality of the control and data acquisition software is essential for the success of a measurement series and thus also for the satisfaction of the user groups. Until the stability of SARDANA is resolved it will impact beamline

availability, in which case a risk analysis should be performed to examine the cost-benefits of having more extensive on-call capability outside normal working hours.

3 Management and Organization

3.1 Findings

MAX IV management has acted to restructure its organization. Much effort has been invested to bring the current management structure to a level where it can function in an appropriate way.

The formation of a new technical division was started during the summer by moving KITS from the science division, followed by the engineering groups moving from the accelerator division.

The new website clearly communicates the capabilities and performance of the beamlines. The benchmarking of all the beamlines against some of the leading beamlines at other facilities has been carried out and MAX IV management clearly states that such a comparison is difficult (like comparing “apples and oranges”). Staff interacts with the users in preparation for experiments and that provides a separate communications path at that stage. The interactions and dialogue with the users, in particular at Swedish universities, have been significantly improved and integrated with the restart of the work on the strategic plan.

Risk assessments and corresponding action plans were presented for the general work environment as well as information for managing risk on beamline projects.

The appointment of Olof Karis, as interim director, has resulted in a radically improved atmosphere at MAX IV where the morale of the staff now appears to be generally high. Communication at different levels has significantly improved. Particular attention has been paid to open communication between management and staff, and additional changes in the information approach and distribution have been made as needed. The restructuring of the science division, to be restarted next year, besides other aspects, aims at providing career paths to scientific staff.

3.2 Comments

The committee notes that with the restructuring work, undertaken by the new management, the organization is now in a good position to tackle present and future demands for full exploitation of MAX IV’s scientific potential. The management structure was fundamentally improved by the introduction of the technical division, which strengthens the ability to carry out projects and operations more effectively. It should be acknowledged that the new leadership places strong emphasis on teamwork within management and pays more attention to the quality of communication, which benefits project implementation and operational tasks.

The implementation of a technical division, in which resources provided by engineering groups and KITS are pooled, is well suited to carry out projects and operations more effectively and to relieve the scientific divisions so that they can focus on their core tasks. The incorporation of CPO into the new division seems reasonable at this point, as the major construction projects are largely completed – however, this structure might be less suitable if new large projects are initiated in the future. The foreseen restructuring within KITS, as outlined by management, is welcomed by the committee; this process is not yet complete, and the committee understands that it is still being optimized.

The information about current performance and status is well covered by the web information and staff-user interactions. However, there is work remaining before the needs of the user base and the capabilities of current and future beamlines are discussed and acted upon in a systematic, transparent and efficient manner, and that may be a process that is folded into the strategic plan development.

Project management methods seem to be matured to an acceptable level. Further improvements can be made by having periodic updates on the risks including associated contingencies, both for schedules and costs. As the project progresses the updates will show where risks occur and whether the remaining contingency is enough for project completion. The allocation of financial contingency based on comprehensive risk analysis will strengthen project success.

The leadership of Olof Karis and the senior management team has remarkably improved the morale level in a short time. From interviews with selected personnel, it appears that the morale is high. In particular, the roles and responsibilities of beamline managers are now clearly defined. Mandatory training for managers at MAX IV has been worked out in detail. Specific training courses will be implemented, partly in cooperation with LU. The restructuring of the science division, to be restarted next year, besides other aspects, aims at providing career paths to scientific staff – which the committee strongly supports.

4 Science

4.1 Findings

There is a rapid increase in the science productivity of MAX IV as compared to previous years (138 publications in 2021 as compared to 103 in 2020, an increase of 34%. During 2022, a total of 103 publications have been reported so far but this is an incomplete list.). As the beamlines continue to add capabilities and reach their target performance parameters it is projected that this positive trend will continue. A large fraction (around 30%) of the publications are published in high-impact journals.

The benchmarking of all beamlines shows that, as things stand today, MAX IV beamlines are highly competitive and state-of-the-art when the comparison is made with the completed scope.

4.2 Comments

While there is a rapid increase in science productivity, which is very encouraging, the Committee notices that the absolute number of publications from different beamlines remains somewhat low. The Committee is delighted to see that around 30% of the scientific papers are published in high-impact journals, which is competitive with other facilities.

The Committee stresses the need to continue improving the performance of the experimental setup to ensure that the scientific excellence enabled by the superb source and the new beamlines provides the desired return on investment. This is expected to happen as the beamline achieve their scope performance, and the user base becomes more familiar with the facility and its capabilities, resulting in performing experiments more effectively. In addition, the facility needs to find means of encouraging users to publish their results in a timely manner, make sure that the users acknowledge MAX IV and report their publications. As the beamlines continue to add capabilities and reach their intended performance parameters it is expected that the positive trend will continue.

MAX IV continues to make progress in completing the full scope of all the funded beamlines. The performance of the beamlines compares well with world-leading scientific programs. However, the Committee would like to continue encouraging MAX IV to make methodical effort by engaging their user base in developing a science case for near future beamlines that should include at least one beamline fully optimized for using the high brilliance of the MAX IV storage rings. This is essential for MAX IV to stay competitive far into the future.

5 Strategy

5.1 Findings

The work on MAX IV´s upcoming 10-year strategic plan is ongoing with some incremental improvements as compared to what the Committee saw during the previous review. The interim director, Olof Karis, has taken many steps to make progress by further improving the current draft of the plan instead of starting over. He has actively engaged with all member universities involved with the University Reference Group (URG) and has started meetings with internal staff as well as the user community to openly get their feedback. He is also seeking feedback from the MAX IV board, LU, and the laboratory´s advisory committees, including the Science Advisory Committee (SAC). The interim director has shown his attention to give high priority to completing the 10-year science strategy by early 2023.

The director showed a roadmap as a result of the first Expression of Interest (EOI) for future beamlines where Swedish researchers were heavily involved. A total of 13 EOI proposals were received and rated; a process that has given priority to future beamlines. However, it is still unclear how these beamlines could seek funding. MAX IV also presented a clear prioritization of the continuous work to improve and upgrade the capabilities of the existing beamlines. The improvement/upgrades were divided into three well-motivated phases.

The director stated that the funding situation for the development of future beamlines is uncertain in the immediate future (coming two years), as available funding will depend on the work with upcoming research bill in Sweden. Other urgent economic issues relating to rapidly increasing costs of electricity and rent were pointed out.

5.2 Comments

The strategy process that was described is reasonable considering the change of director in March 2022 and the need to deliver a strategic plan no later than early 2023, in light of the upcoming research bill.

The tentative roadmap for future beamlines is well motivated from a user perspective. Still, MAX IV is strongly encouraged to propose a flagship beamline that makes use of the coherence as delivered by the low emittance source in the best possible way (see new recommendation 4). Considering the fact that the 3 GeV ring is diffraction limited around 300 eV and below, it is clear that the sweet-spot energy range for such a flagship beamline is in the soft x-ray range (covering photon energies of ~0.1-2 keV). The use of soft x-rays with both high coherent power and high brightness is highly suited for studying a wide range of forefront scientific problems, such as: i) measuring spontaneous dynamical processes (in contrast to pump-probe studies) with relevant time

resolution down to nanoseconds (requiring ultrafast photon detectors), ii) the determination of electronic structures and the role played by inhomogeneities in quantum materials, iii) studies of functional materials which are relevant for new energy technologies, iv) studying devices *in operando* with relevant time and spatial resolution, v) investigation of emergent phenomena in strongly correlated quantum systems, and iv) measurements of time scales of coherence and decoherence of dynamical processes, and understanding of entanglement in quantum computing materials. These research areas include some science grand challenges and provide new opportunities for MAX IV to contribute at the forefront of science.[1] The Committee would like to re-emphasize the fact that an *incremental approach* that may provide renewal and upgrades of existing MAX IV beamlines will not allow for tackling the aforementioned forefront scientific challenges in an effective way.

Swedish researchers were heavily engaged during the EOI process and benchmark ranking of these proposals was done by the MAX IV staff, perhaps in consultation with SAC and the Board. Until the strategic plan is complete, it is difficult for the Committee to evaluate its impact and possibility of enabling world-leading research at MAX IV. However, it is clear from the presented benchmarking of the current beamlines, including a comparison with some of the leading beamlines at other facilities, that MAX IV beamlines, in many cases, are state-of-the-art and highly competitive. However, MAX IV needs to continue making improvements to the beamlines' performance to stay competitive. At the same time, there will be a need for a strong educational effort by MAX IV directed to Swedish researchers to not only appreciate and make use of the current capabilities but also be engaged in the development of future upgrades, sample environments, and construction of new cutting-edge technology beamlines.

The already funded phase of the MAX IV construction plan is near complete. The presented benchmarking has clearly shown that the operational beamlines with their current capabilities at MAX IV perform well compared to similar beamlines at other facilities. While the MAX IV has set up a prioritized plan for the completion of its remaining capabilities, the management presented convincing arguments why a reference to the full-scope characteristics given in the original proposal/description is less appropriate and the Committee has accepted these arguments. In addition, the Committee agrees with the director to give his highest priority towards completing of the 10-year science strategy by early 2023.

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[1] It is worthwhile to point out that the use of soft x-rays furthermore allows utilizing both spectroscopic features for measuring the electronic structure for understanding and control of functionality of materials whereas higher energy end of soft x-rays, in addition to tender/hard x-rays, allow utilizing diffraction techniques for measuring the atomic structural properties with chemical state specificity and thus deeper understanding of functionality of materials. The determination of both the electronic and atomic structure of materials is essential for developing new technology for the sustainable future.

Finally, regarding funding, the presentations shown to the Committee gave an idea of the foreseen difficulties regarding future funding. Many of the sources for funding for operations were not negotiated yet, and management is currently projecting a flat funding profile until 2026. The projected spending exceeds the listed revenues by ~100 million SEK/year for the next four years (summing up to a total shortfall of ~425 MSEK). How much of this amount is estimated as contingency was not indicated. Additionally, there is a very high risk for further increases in rental costs and the anticipated increase in prices for energy.

When estimates are made for future funding it is normal to separate the contingency funds allocated to projects and the funds needed for maintenance of existing equipment such as beamlines and buildings. It is important to have that separation for the funders to understand where the allocated funding is used.

6 Progress on previous recommendations

In the previous project review report of November 2021, the review committee gave eight recommendations. In addition to these, MAX this year addressed four of the recommendations from 2020 that were poorly addressed during the last review.

The eight recommendations from last year, as well as the IV four from the year before, have now been addressed in a systematic and convincing manner. The actions taken in response to these recommendations were presented in much detail. Although not everything is finalized, improvements have been significant, many ongoing processes have been started in all areas of recommendations. Time will tell if more adaptations are required but currently the actions are appropriate.

For this review, the committee is highly satisfied with what has been achieved within this short amount of time.

7 Recommendations

To conclude this report, the review committee would like to give the following five new recommendations, the order of which does not reflect any intended prioritization:

1. For projects in general, the financing area should make use of improved accounting methods for material but also staff spending profiles. Projects should report the planned start and end dates, the progress to date (Earned Value, etc.) and the forecasted completion date, as well as the forecasted budget to complete, etc. It is recommended to have periodic updates on the risks. Risks should be associated with contingency, both schedule and cost contingency. On project completion a final report shall be written with verification of the achieved scope. (Q4 2023)

2. MAX IV management should very quickly provide the board with a risk assessment and a mitigation plan with options for how costs can be reduced, and the implications of these different options. MAX IV management should ask their Board to address future budget problems and make all stakeholders and funding sources aware of the situation. (Q4 2022)

3. The restructuring of KITS should aim to ensure the best possible support for the beamlines in terms of stability and user-friendly functionality of the control system and data acquisition. It is recommended that during commissioning, software developers temporarily work directly at the beamlines concerned. (Q2 2023)

4. Develop a cohesive strategic plan with a roadmap list that contains a plan for at least one flagship beamline that goes beyond the current capabilities and makes the most use of coherence as provided by the pioneering MAX IV source. (Q3 2023)

5. Develop and adopt a sustainability policy and action plan to both promote sustainability research and reduce the carbon footprint. Communicate the policy and action plan to both employees and users. (Q3 2023)

APPENDIX 1: Terms of reference

Background

Since the summer of 2018 the Swedish Research Council, at the request of RFI, has conducted five larger reviews of the MAX IV project. Initially these reports revealed deficiencies in the project management methodology which have gradually been addressed and the workflow at the laboratory has significantly improved. Since the review in November of 2019, RFI has expressed the intention to continue with an annual review cycle of MAX IV in order to ensure that the funding from the Swedish Research Council is being used in an optimal way. MAX IV is now reaching what could be considered full operations with all beamlines receiving light – however not all initial specifications have yet been obtained.

Purpose, method and scope

The purpose of these reviews is two-fold: Firstly, the Swedish Research Council and other stakeholders need to monitor how MAX IV is progressing during operations and how the recommendations from the previous review are being implemented. Secondly, MAX IV should be given principle advice on how to deal with any potential problems identified during the review.

The review committee´s focus should be on whether the organization employs the right methodology to deliver the planned scope required for the intended user science cases. In order to do so the review team will be divided into two sub-committees, where each of the two sub-committees will be headed by a respective sub-committee chair person:

1) **Project Management (Chair: T. Allard):** This sub-committee will focus on the project management methodology employed to execute various projects at MAX IV, both relating to beamlines and accelerators. The sub-committee should focus on how the methodology might be further improved to deliver the projects according to planned scope, cost, and schedule. Comments on other processes closer to the operation of the facility are also welcome.
2) **Transition to operations (Chair: Z. Hussain):** This sub-committee will focus on how the various projects are being practically and technically implemented in relation to the planned scope and the scientific needs of the MAX IV user community. The sub-committee may comment on options on technical solutions within the intended scope but should not make recommendations that are in conflict with the plans described in funded applications. The sub-committee may suggest future scientifically impactful ways forward beyond the currently defined scopes.

The groups will also comment on how the organization works with strategic long-term matters primarily related to the scientific program and the funding of the laboratory.

The review will be chaired by prof. Lisbeth Olsson and will be conducted as a hybrid meeting, partially on location in Lund as well as via video link, on 7-8 of November of 2022 with a closeout session (via video link) on the 21 of November. The background material will consist of a document package that MAX IV will

be submitting upon the detailed request of the Swedish Research Council – this request will be sent no later than 4 weeks prior to the start of the review. The material will then be sent to the committee when available, but no later than one full week before the start of the review.

The work will be based on 1) plenary session which are jointly held for the whole review committee, 2) breakout sessions for the respective subcommittee and 3) interviews with individual people within the organization as the review committee sees fit. The main findings and the recommendations of each subcommittee will be presented at a concluding closeout session. The findings of the committee should further be formulated in a brief report to the Swedish Research Council, addressing the questions listed below, and be finished no later than two weeks after the review has been concluded. A detailed instruction of the desired format of the report will be provided by the Swedish Research Council to the reviewers before the review.

Charge questions

The following questions should be answered by the subcommittees from their respective perspectives:

1) **Cost and Schedule:**
    a. Are the cost and schedule estimates complete, credible, and of sufficient quality to execute current beamline and accelerator projects?
    b. Are the financial systems and staff properly collecting and reporting the project progress, schedule, and costs?

2) **Technical:**
    a. Are up-to-date information on the capabilities and performance parameters of each beamline available and presented in a standardized way so that they can be related to the target specifications?
    b. Evaluate the progress and status of accelerator, undulator development, beamline instrumentation, detector development, data management, data acquisition and data analysis software development, as applicable.

3) **Management and Organization:**
    a. Is the current management structure appropriate for the current phase of the project and operations?
    b. Is the restructuring of the pooled resources correctly done to allow both accelerator and science departments to more fully concentrate on their core tasks?
    c. Are the capabilities and status of the beamlines sufficiently communicated to the user base and are the needs of the user base sufficiently considered by the facility, both for current beamlines and for future developments?
    d. Are project risks appropriately identified and managed?
    e. What is the morale level of the facility scientific and technical staff and their opportunities for career development?

4) **Science:**

a. Evaluate the quality and quantity of the research performed at the MAX IV in terms of number and impact of research publications.
b. Is the current schedule for delivery of the defined scope consistent with a world-leading scientific program?
c. Is the pace of early science output from MAX IV consistent with this schedule?

5) Strategy:

a. Evaluate the progress made towards development of the MAX IV 10-year science strategy.
b. Will the resulting science strategy be likely to enable world-leading research at MAX IV with a strong participation of Swedish researchers?
c. Has a clear prioritization been made for full-scope completion of existing/funded beamlines that make the best use of the unique characteristics of MAX IV?
d. Are the plans for securing and prioritizing future funding consistent with the science strategy and suitable given the funding environment?

6) Recommendations:

Have the recommendations from past reviews been appropriately addressed?

APPENDIX 2: Sources of information

The conclusions drawn in this report were based on three main sources of information, namely; i) a set of documents provided by MAX IV beforehand to the review committee, ii) presentations given by the laboratory management and staff with following discussions together with the review committee, and iii) interviews with several critical persons in the laboratory staff. The list of interviewees, which was compiled based on the request of the reviewers, is given below:

- Olof Karis, Interim Director
- Marjolein Thunnisen, Life Science Director
- Aymeric Robert, Physical Science Director
- Anna Hultin Stigenberg, Technical Director
- Conny Såthe, Beamline scientist
- Mugeni Nuamu, Head of CPO
- Anna-Lena Torstensson, HR
- Anna Lindberg, HR
- Kristian Bergén, HR consultant
- Anne Borg, Chair of SAC
- Olle Björneholm, Chair of URG
- Peter Honeth, Chair of MAX IV Board
- Ann Terry, GM Diffraction and scattering
- Mahesh Ramakrishnan, Post-Doc at Balder