HELMHOLTZ

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große Herausforderungen.

Helmholtz Imaging Platform
Concept for a Distributed HIP Core

Helmholtz Centers (in alphabetical order)

Deutsches Elektronen-Synchrotron DESY

Deutsches Krebsforschungszentrum DKFZ

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Motivation and background

In September 2018 the Helmholtz Association started the implementation of five platforms fostering joint activities to strengthen information and data sciences in all research fields of the association. Based on an extensive discussion including all Helmholtz centers, imaging sciences have been identified as a common scientific focus of growing importance in all scientific domains the centers are acting in. On the one side, Helmholtz in all research fields operates unique facilities for image data acquisition such as synchrotron radiation sources at German Electron Synchrotron (DESY) and Helmholtz Center for Materials and Energy (HZB), or satellite imaging at the German Aerospace Center (DLR). The Research Field Health, for example, hosts latest-state modalities for medical imaging such as in the context of the Optical Imaging Center (OIC) at the Max Delbrück Center for Molecular Medicine (MDC) or the Radiological Research and Development Center (REZ) at the German Cancer Research Center (DKFZ).

At the same time, image data provide a substantial part of the data being generated in scientific research. For example, deep sea monitoring at AWI of Geomar produces large amounts of image data which is fed into scientific analysis. Similarly, the Karlsruhe Institute of Technology (KIT), HZB and the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) use imaging modalities to unravel properties of new materials.

Therefore, the association agreed on establishing a Helmholtz Imaging Platform (HIP) comprising research in imaging, provision of imaging consulting, and enabling access to imaging modalities and imaging data. Taken together, HIP will increase the visibility of the Helmholtz Association as a leading partner in imaging sciences on an international level.

HIP will operate through three core components: At first, the HIP Network will bring together expertise in imaging modalities, imaging algorithms and image analysis with domain expertise using imaging as a scientific methodology. Second, the network will be supported and technologically operated by the HIP Core. This central unit also fosters transfer of knowledge from methodologically oriented imaging research into its concrete application within experimentally working domains. As a third component, HIP Projects will provide funding for collaborative imaging research joining research fields and research centers.

Based on a call by the president in December 2018, DESY, DKFZ, and MDC have expressed their interest to host the HIP Core and provided an application in February 2019. A high-level expert group headed by the Helmholtz President has evaluated the proposals in the sequel. The discussion raised by the evaluation panel made clear that enabling quick transfer of knowledge from method-oriented research into application in experimental domains poses a major challenge. In order to make best use of the potential provided by the centers, it has been suggested to join forces and thereby leverage the impact of the platform onto all areas of research within the Helmholtz Association.

Based on the general HIP concept approved by the General Assembly of the Helmholtz Association [1] the present document describes the distributed HIP core proposed by the three centers, their common strategy, their portfolio of expertise and services and its benefits for the HIP Network and all centers of the Helmholtz Association.

Presentation of the HIP core consortium

The HIP Core consortium comprises Deutsches Elektronen-Synchrotron (DESY), the Max Delbrück Center for Molecular Medicine (MDC), and the German Cancer Research Center (DKFZ).

DESY is one of the world's leading accelerator centers. DESY's research infrastructures include unique imaging facilities, featuring for example the brightest and shortest X-ray pulses and accelerated particles at record energies. Based on these new experimental capabilities, DESY develops and improves many new highly sophisticated imaging techniques and modalities, giving access to the structure and function of complex matter on all length and time scales. This diverse research environment makes DESY a magnet for more than 3000 guest researchers from over 40 countries every year. Their research covers all research fields of the Helmholtz Association.

The Max Delbrück Center for Molecular Medicine (MDC) is an internationally renowned biomedical research center in Berlin. MDC is devoted to collaborative and interdisciplinary research, covering an entire range of imaging methods across several scales in space and time and levels of analysis – from basic sciences to a broad range of applications across research domains. The MDC's imaging technology platforms provide a versatile spectrum of instrumentation and methodologies and are part of numerous collaborative research projects and technology developments in and outside of the Helmholtz Association. The MDC has a strong track record in imaging sciences and offers outstanding imaging and data analysis know-how.

The German Cancer Research Center (DKFZ) is among the world's leading cancer research centers and the largest biomedical research institution in Germany. The center offers the critical mass of leading scientists, excellent research infrastructures to provide a world-class environment in imaging sciences embedded in its vast network of local, national and international partners. DKFZ is recognized for its unique and broad spectrum, continuous development of imaging techniques from cells to humans, application of artificial intelligence in computational analysis and post-processing of images and application of state-of-the-art imaging techniques. The imaging research infrastructure at DKFZ imaging includes cutting-edge platforms and innovative imaging technologies, as well as several core facilities supporting data management, computation demands and software tool development.

Complementary expertise of the partners

The classical imaging pipeline covers the full range of data acquisition, data preparation, data management up to data analysis (Figure 1). Every part of this pipeline comes with its specific scientific challenges and research software tools. The HIP core team partners focus on different parts of the pipeline corresponding to their main expertise. The consortium aims to cover the full imaging pipeline with the necessary scientific depth. Following the original HIP concept this approach will enable the Helmholtz Association to build and increase synergies, international visibility and maturation in the complete spectrum of imaging techniques. This joint approach across communities and research fields provides a unique opportunity to combine expertise and strength of single centers for the benefit of the entire Association. For all parts of the imaging pipeline, the HIP core team shall be able to systematically find and leverage synergies across modalities and research questions, thus carving out common challenges and generalizing solutions across the Helmholtz Association.

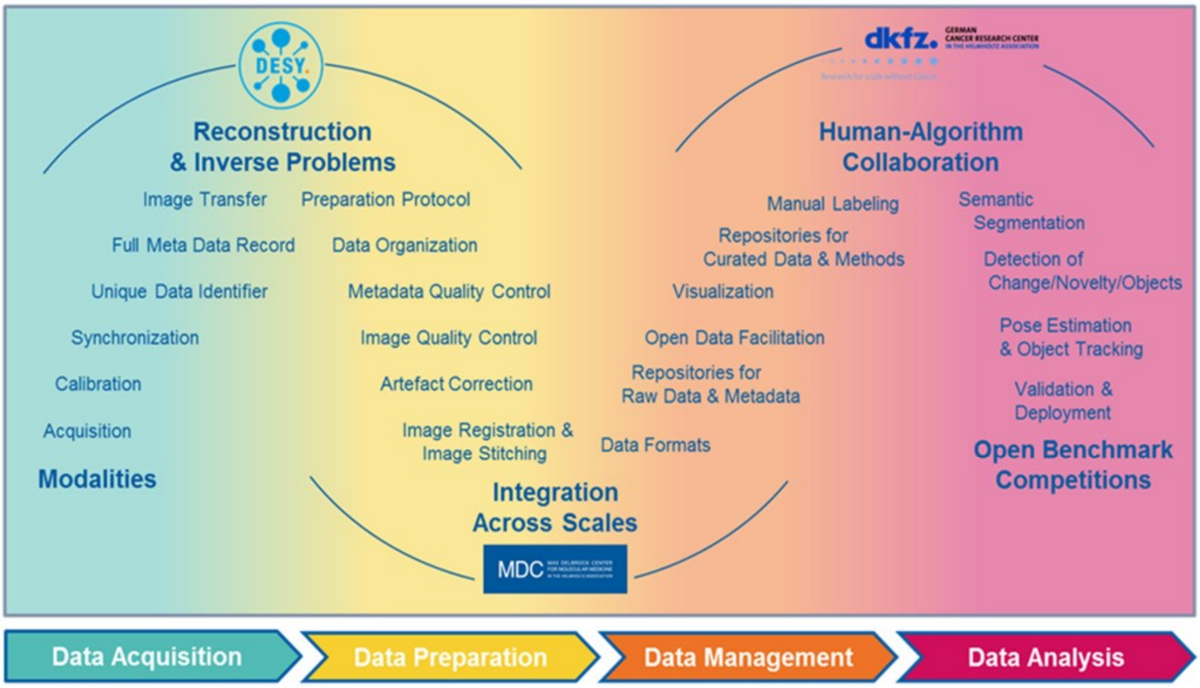


Figure 1. The complete image pipeline from data acquisition to data analysis covered by the three HIP core partners. DESY will focus on modality development and image generation. The MDC will concentrate on data preparation, data integration across multiple scales as well as data management. The DKFZ will be in charge of data analysis with a focus on semi-automatic and automatic image annotation including validation and production-scale use of image analysis software.

The three HIP core partners cover the full imaging pipeline, each with a distinct focus of expertise. At the same time, there are significant scientific and methodological commonalities between the partners to tightly interlink their foci of expertise and develop synergies among them. In this way, the HIP Core shall be able to give support to imaging questions in all areas of the Helmholtz Association. Therefore, none of the steps in the pipeline should be looked at in isolation. Rather, the complete pipeline forms a logical unit with various interdependencies between its building blocks. Consequently, the focus areas of the partners continuously merge into each other facilitating a tight interaction and common governance to maximize the benefit to the Helmholtz Association.
The DESY will focus on the first part of the imaging pipeline, thus dealing with modality development and image generation, with a specific scientific focus on reconstruction and inverse problems. This focus area is well-aligned with the track record of the center. Within DESY and around the DESY Campus in Hamburg, there is a wide range of imaging expertise, both on the fundamental methodological side [2-4], with a wide range of modalities [5-7] and inverse problems [8-10] and materials [11] as well as particle and astro-particle physics. Many of the rich imaging activities at DESY are focused around large-scale infrastructures, such as DESY's synchrotron radiation source PETRA III [12] and the VUV, soft-X-ray free-

electron laser FLASH [13] and the European X-Ray FreeElectron Laser (EU.XFEL). These outstanding user facilities, are readily accessed by scientists from around the world.
The MDC will cover the integration across scales band of the imaging pipeline, focusing on data preparation and certain aspects of data management, with a specific scientific focus on information integration across multiple scales and modalities. The MDC maintains a strong track record in imaging sciences and offers outstanding imaging know-how and state-of-the art imaging technology platforms. The scientific expertise of the participating faculty and technology platforms covers a broad spectrum of modern imaging [14,15], data sciences [16] and computational sciences [17,18]. The MDC has established solutions for image data stitching, fusion and visualization across scales with a focus on bioimage analysis [19]. Scientists of the MDC have been very closely involved in the development of the ImgLib2 generic image processing framework [20] that underlies the Fiji open source software platform (http://fiji.sc, [21]). This work has been cited more than 14.000 times so far and provides an outstanding role model for agile development and dissemination of generic imaging software within the HIP. The MDC shares complementary expertise and outstanding research in ultra-high high field magnetic resonance and in advanced optical imaging including the Berlin Ultrahigh Field Facility and the setup of a novel Optical Imaging Center (OIC). The MDC is a hub for the German National Cohort (NAKO, [15]).
The DKFZ will be in charge of the data analysis, with a specific focus in semi-automatic and automatic image annotation as well as the validation and production-scale use of image analysis software. More than 20 DKFZ divisions are dedicated to developing, processing and applying state-of-the-art imaging methodology. At the DKFZ imaging and data science is tightly interlinked and remotely located across partnering networks at NCT and DKTK. The DKFZ has built a strong track record in the application of artificial intelligence in computational analysis and the post-processing of images including crowd-based image annotation the international imaging challenge design, organization and participation [22-24] and AI-based imaging response assessment [25]. The broad spectrum of imaging divisions builds upon close collaboration and synergies between imaging techniques and application domains, across physical, chemical, molecular and biological imaging and from nano to human scale which culminated in the “Research Center for Imaging and Radiooncology” (REZ). The REZ fosters a close links between imaging research and unique computational and technological approaches available at the DKFZ and its partners.

Benefits for Helmholtz of a joint and distributed HIP core team

Joining forces of the three partners will yield manifold benefits for the HIP network and the Helmholtz Association. Only the full coverage of the imaging pipeline at a high level of expertise and excellence enables high-level support for all imaging questions within the Helmholtz Association. The distributed setup guarantees the availability of experts for consultation over the broad scientific landscape within the HIP network and across all Helmholtz centers. The joint approach will improve the ability of the HIP core team to support the HIP network through active participation in HIP projects of other centers. The strong and broad research portfolio available within the joint HIP core will be essential to continuously further the state of the art and provide a stable backbone for the rapidly developing field of imaging. Only in this

way, the HIP Core will be able to sustainably provide the support on the highest level. The joint HIP core ensures long term success and international competitiveness of the HIP concept and the imaging activities across research fields by rapidly adapting new developments and novel trends at an early stage.
Each of the three partners in the HIP core has an outstanding track record in imaging modalities, algorithmic developments, and software. Jointly, they will be able to push the international visibility and leadership of the Helmholtz Association and HIP in applied imaging sciences, raising the interest of leading imaging experts to collaborate with the Helmholtz Association and its partners. Following the HIP concept of the Helmholtz Incubator Information and Data Science, the HIP core team will jointly develop integrative imaging solutions that would have otherwise been difficult to realize. These joint efforts will result in a framework of generalized HIP Solutions (HIPS) that will be disseminated to the network and across domains. In full alignment with the HIP concept research projects can receive support from several partners, service will be coordinated through a central Helpdesk and a central administration unit ("one face to the customer").
With the increasing efforts to fund outstanding open-source software projects the Helmholtz Imaging network will be uniquely positioned to apply for specific software grants on the (inter)national level (e.g., EU grants: ERC, LEAPS, FETOPEN, https://nfdi.dfg.de, https://chanzuckerberg.com/rfa/essential-open-source-software-for-science/) to acquire further funding for the Helmholtz Association and boost its visibility on an international level.

Joint scientific concept of the HIP core

Following the general HIP concept [1] fore front research and imaging sciences provide a competitive foundation and outstanding stronghold for first class and state-of-the art services provided by the HIP core units. Therefore, the scientific concept represents the complete imaging pipeline from data acquisition to data analysis, with specific focus areas covered by the three HIP core partners.

Image data acquisition (scientific focus of DESY)

Inverse Problems

At the beginning of the imaging pipeline, data is acquired in a physical process measuring a metric which represents the interaction of a given probe with a sample. The physics of these interactions can be modelled mathematically and explain how samples generate a signal in the imaging system. For a known sample the physical response of the imaging system can then be predicted in this way. To form an image, however, the model has to be inverted, i. e., the problem has to be solved for the sample for a given measurement. These so-called inverse problems are at the heart of almost any image formation process and shall be addressed in a joint and systematic way.
DESY has a long-standing experience in solving inverse problems, such as the phase problem in crystallography and coherent diffraction imaging, the tomographic problem in many different variants, and many variants in deconvolution [2-13, 26]. The science of the many research groups at DESY shall be complemented within the HIP core with a research group in applied mathematics and computer science, specialized in the field of inverse problems from a mathematical point of view. This group shall bundle the expertise in inverse problems in a

generic way, thus being able to support developments of other groups involved in image formation across the Helmholtz Association. By strengthening the expertise in the mathematical field of inverse problems and creating an overarching support structure within the Helmholtz Association, new modalities in specific domains with new physical forward models can be tackled supporting the domain experts with algorithmic expertise.
Creating comprehensive knowledge via multiple modalities is crucial for many fields of research and gains ever increasing relevance in all research fields. Algorithmic developments that use the input from different modalities synergistically can create additional knowledge well beyond the pure sum of the information from the individual modalities, since the modalities introduce mutual boundary conditions (by appropriate modeling) to improve the individual reconstructions. While this algorithmic lever is already used in some fields within the Helmholtz Association, it is fairly new and can be generalized and extended to many other fields. The HIP core experts (e. g. at DESY) can help exploiting this synergy to push imaging beyond its current limits.
In the field of inverse problems, the application of machine learning is emerging. As the physical forward models are typically very well-known and can be quite accurate, the inverse problem solvers based on machine learning can be trained on artificially generated data sets. This is very powerful, as in this way ideal learning data sets can be created without the need for human interaction. As the concept is rather general, it is expected to be broadly applicable to all kinds of imaging applications.
The idea can be further generalized and extended across the full imaging pipeline, establishing a field of synergy between the three partners (cf. below).
The scientific results and software tools that are obtained in the HIP core unit and in collaborations within the HIP network, shall be made available as open source HIP solutions.

Image data integration across scales (scientific focus of MDC)

Recognizing the imaging pipeline and the needs of the imaging users and experts within the Helmholtz Association the MDC will focus on image data preparation, management and processing with a particular focus on the integration of image data, algorithms, and visualization solutions across multiple modalities and scales in space and time. The goal is to develop and provide HIP solutions that can deal with the very heterogeneous image data that are acquired across the research fields of Helmholtz without imposing constraints on the respective image modalities. To lay the foundations for the implementation of HIP Solutions, the MDC will focus on the following scientific questions:

1. Develop concepts and algorithms for handling and generic processing of high-dimensional datasets,
2. Develop algorithms for large, high-dimensional image data stitching, fusion and visualization.

Handling and generic processing of high-dimensional datasets

The first scientific and development focus is motivated by the shortcomings of modern image acquisition techniques that are collecting ever growing large and high-dimensional datasets. While some years ago it was common to entirely load datasets for processing, it is a rare exception these days. Algorithm development itself is generally not concerned with the problems of applying it to large datasets since it describes only the “essence” of how to solve a given (e.g. inverse) problem. Moreover, modern algorithms that are based on deep learning and require dedicated hardware are additionally limited to even smaller processing batch sizes due to GPU memory limitations. The MDC will develop solutions to address these problems that are present across fields, but can be addressed independently of the imaging domain. This includes the generalization of existing and development of new concepts for advanced, generic caching, dimension-invariant data formats, operating system-agnostic execution environments, or interfaces and version management systems that span different programming languages. These concepts will lay the foundation for software that enables a googlemaps-like integration of datasets across scales in time and space, modalities and domains. The HIP research group to be established at the MDC will build on existing concepts (e.g. ImgLib2 or MITK) to develop a the cross-platform HIP Solutions framework that allows generic software implementation independent of its dimensionality, size, and datatype. The MDC research group will also address the imminent issues of reproducible software and the compatibility across major programming languages.

Large, high-dimensional image data stitching, fusion and visualization

The second research and development focus of the MDC concentrates on algorithms and software for large, high-dimensional image data stitching, fusion and visualization. This is of high relevance for the integration and analysis of image data across domains and requires powerful and scalable solutions for image alignment, fusion and visualization. The goal of such software is to be able overlay large datasets from multiple measurements into one coherent representation that can be used for visualization, annotating, and processing. The MDC will develop such algorithms and software that are applicable across domains based on its solutions for bioimaging software. We will therefore extend software such as BigDataViewer, BigStitcher, and Fiji to support higher-dimensional data and more versatile data types. The focus will be on feature-based registration, which allows for straightforward user-interaction with the data. With these scientific contributions the MDC provides a framework for implementations of HIP solutions across the Helmholtz Association (see Service section & HIP Solutions).

Image data analysis (scientific focus of DKFZ)

In accordance with the general HIP concept the DKFZ will address important bottlenecks in Helmholtz imaging research concerning the annotation and analysis of imaging data:

1. The manual and semi-automatic labeling of large amounts of imaging data - a core prerequisite for performing AI-based imaging research. In-depth competencies in this area yield a large potential for overarching synergies within Helmholtz imaging sciences.
2. The automated analysis and information extraction from imaging, including semantic segmentation, detection of change, novelty of objects, and the estimation of pose and object tracking in time-resolved image series.
3. The facilitation and implementation of open benchmark competitions for the validation of findings to ensure scalability, reproducibility and applicability of the imaging methods developed in Helmholtz.

Human-algorithm interaction

Manual and semi-automated labeling of images lacks professionalization although high-quality consistent annotations have been identified as a cornerstone in imaging research. We will address these constraints to free a huge potential residing within the Helmholtz Association to link large-scale imaging with computational image analytics in Helmholtz, and to unlock the full potential of machine learning based solutions in the various Helmholtz domains focusing on imaging research.
Professionalization of the manual and semi-automated labeling of imaging will be achieved by research focused on human-algorithm collaboration and topics like gamification, crowdsourcing or interactive workflow design. Related machine learning topics include active learning, transfer learning and handling of out-of-distribution samples. Furthermore - in tight collaboration with the service unit - the scientific group will act as a solution provider for challenging annotation tasks that are not yet covered by the methodology that is openly available. The group will provide scientific input and selected software components in support of the service unit.

Automatic image annotation

High-quality and fast automatic analysis and information extraction from images is a central pillar of various research scenarios across the Helmholtz Association. Reliable and fully automatic image processing is therefore of great relevance in various imaging domains.
Therefore, a critical success factor of the HIP platform will reside in the development of strategies for generalization of analysis methodology between different application domains.
Therefore, HIP core at the DKFZ focuses on the generalizability of methods covering automatic semantic image segmentation, detection of change, novelty or objects, and the estimation of pose and object tracking in time-resolved image series. This will enable not only a reliable and reproducible annotation but also unlock the potential of large-scale data sets.

Validation and Benchmarking

Suboptimal design choices and data sets frequently lead to wrong conclusions drawn from validation and benchmarking studies of image processing algorithms [28-30] and claimed improvements over the state-of-the-art do not hold true [29]. Due to the common bias related to performing validation of image processing algorithms in isolation (i.e. on ones' private data set), open benchmarking competitions (also called challenges) became a dominant measure of validation in many fields involving image analysis. The release of public data sets and the organization of open competitions is a means to stir international research.
Realizing these developments and the opportunities for the Helmholtz Association the HIP core at the DKFZ will develop new methodology for validation and benchmarking of image processing methods at a new level of quality. In the context of the HIP network, we will address open research questions that are posed by modern imaging and image processing technology, aiming to maximize the impact of Helmholtz through leveraging international benchmark competitions. Examples for research questions being addressed include: How to validate algorithms that produce probabilistic output? How to quantify the similarity between different tasks to exploit cross-domain similarities? Further research topics of the unit will cover realization of decentralized, cooperative, federated, peer-to-peer, or user-centered digital data-management architectures.

To summarize the creation of unique annotated datasets will increase the international visibility of the Helmholtz Association affords novel open benchmark competitions, which will draw in even more computational expertise in the application fields of the Helmholtz Association.

Synergetic effects of a distributed HIP Core

The scientific scope of the distributed HIP Core assures an in-depth coverage of the full imaging pipeline. The proposed distributed HIP Core is in full alignment with the HIP concept, with its synergies facilitating new scientific developments that would not be feasible to be achieved by a single center rather than by enabling joint developments that are overarching the whole imaging pipeline.

Currently, the typical procedure is to follow the imaging pipeline sequentially, performing different processing steps one after the other. In this way, the information encoded in the original measured data is transformed and very often reduced to form an image. Several such images are then merged to create a multimodal image containing different pieces of information of a sample or process. These images are then further analyzed by image data processing schemes to identify and extract features and track them in their evolution. This approach lacks coherence and is limited by each of the steps and information can be lost along the way. It is the aim of the distributed HIP Core scientific team to develop robust and overarching processes and algorithms to take advantage of the full information in the measured data and the spectrum of expertise at the three centers.

For example, by combining the inverse problem with feature recognition, the desired information shall be extracted directly from the raw data. This has for example the advantage that model based data consistency and redundancy in the raw data can be exploited to avoid unintentional loss of information by first creating an image and in a second step interpreting this reduced data set. In addition, the information gained by the image processing step can be used to refine the reconstruction model. This approach is rather generic and could be applied to many imaging questions in all fields of science of the Helmholtz Association. For its development, the whole scientific team of the distributed HIP core is needed.

This approach provides major synergies and substantial benefits for the Helmholtz Association since multimodal images and data sets become more and more important in all research fields with the goal to better understand structure-function relationships or understand the interaction of different entities in a complex system. Registering different images from different modalities is thus crucial in the scientific process. Also, here, the scientific team can leverage synergies, by feeding back the multimodal information into a prior image reconstruction.

An example for such a multimodal and multiscale reconstruction problem is three-dimensional microscopy with elemental contrast. Here, (ptychographic) coherent X-ray scattering tomography and X-ray fluorescence tomography are combined. The two data sets yield reconstructions on different length scales and with different contrast, i. e. electron density and chemical contrast, respectively. The fluorescence signal is affected by self-absorption inside the sample, whose estimation requires the knowledge of the sample structure and chemical composition. A multiscale, multimodal joint reconstruction would systematically solve this inverse problem.

By leveraging the scientific synergies, the scientific teams of the distributed HIP Core will also cover many practical aspects of the imaging pipeline. To ensure smooth integration and usability of the methodology and HIP solutions developed by the consortium and to provide first class support to the HIP network and the HIP projects the partners will identify and work on joint Helmholtz use cases that spans the entire pipeline from image acquisition and reconstruction to automated annotation and benchmarking.

A HIP service portfolio to the Helmholtz Association

HIP helpdesk

As an incentive to actively get involved and contribute in the network, fast and non-bureaucratic help to domain scientists at Helmholtz Centers will be provided through the HIP Helpdesk. For example, researchers with a particular and defined problem in imaging sciences can consult the HIP Core Team. HIP Core Team is involved in many different projects from different research domains, it serves to promote and strengthen the HIP network of experts at the Helmholtz Centers, bridging the gap to other Helmholtz platforms, and to external partners within the national and international context. For this purpose, each Helmholtz Center is invited to assign a contact point, who closely works with the HIP Core Team, helping scientists at the center to engage themselves in the HIP platform and HIP network.
The Helpdesk is the first point of contact for any request. It is operated by the HIP Core and shall coordinate all services of HIP. In particular, all requests concerning the HIP network, HIP projects, and technical and scientific support of HIP shall be managed through the Helpdesk according to the principle “one face to the customer”. All requests will be followed using a ticketing system.
The Helpdesk will be operated by the service unit at DKFZ. While some requests can certainly be directly handled by the Helpdesk staff, most inquiries will require the involvement of experts in the distributed HIP core. Therefore, requests concerning administrative and organizational questions as well as the HIP network and the HIP projects will be forwarded to the Administration Unit. Technical and scientific support requests will be forwarded to the experts in the distributed HIP Core and elaborated at the HIP service unit at DKFZ. This concerns in particular the HIP Solutions (cf. below). In this way, the HIP scientific team can leverage the scientific breadth of the Helmholtz Association well beyond its own field of expertise.

HIP projects

A strong incentive to enable interdisciplinary collaboration across the Helmholtz Association and incubator and accelerator of the HIP network is given by HIP projects that are described in detail in the general HIP concept approved by the General Assembly of the Helmholtz Association [1]. Special emphasis for HIP projects is laid on developing innovative approaches, which tackle imaging problems. Such projects often are characterized by higher risk, and will therefore have demonstration character. Thus, HIP will provide seed funding for new ideas The HIP Core Team can be involved in HIP projects as project partner if the content fits their expertise. Thereby the HIP Core Team contributes to the Imaging Network by direct involvement into the projects. The HIP Core will be operated and involved through the so-called Project Support Team (PST), which is formed according to the needs of each HIP project. This approach was detailed in the general HIP concept and approved by the General Assembly of the Helmholtz Association [1].
The submission of HIP project proposals, external peer review, decision making, involvement and support of the HIP core as well as annual reporting on HIP projects will strictly follow the procedure outlined in the general HIP concept, which was approved by the General Assembly of the Helmholtz Association. An important aspect of evaluation of HIP projects is the

development of suitable performance indicators for interdisciplinary projects in data and information sciences. HIP will establish such KPIs, monitor them on its own activities and refine the indicators over time in accordance with the Steering Board (cf. Governance).

HIP solutions

In order to provide a common platform for the solutions created within HIP we will create the HIP Solutions framework (please see MDC focus). The HIP Solutions framework serves the purpose of uniting and generalizing software created within HIP and the Helmholtz Association. Therefore, the HIPS framework will provide mechanisms that enable software developers to easily implement abstract algorithms that can subsequently be applied to a wide range of modalities ("Make algorithms generalizable"). Data together with their annotations can be stored in common formats that enable easy exchange of code and results in between domains ("Make image data findable following the FAIR approach"). Regarding the definition of annotations, HIP will closely interact with the Helmholtz Metadata Collaboration (HMC). The centrally hosted website and software repository will provide access to image analysis solutions to all researchers within Helmholtz, which will also contain detailed documentation on how use the software, and if applicable how to run it on clusters or in the cloud ("Provide technology for automatic processing"). HIP Solutions that do not solely rely on software will also be described on the website, including how to access it. Part of the HIPS framework provides solutions for accessing to annotated large, high-dimensional datasets locally and online. The central web resource will offer to link those datasets and their associated annotations thus easily making image data findable.

HIP integration, dissemination and outreach

HIP is one out of five Helmholtz data science platforms. From a high-level point of view, HIP also promotes information and data science within the Helmholtz Association. Therefore, HIP will take action to integrate with other data science activities, such as the Helmholtz Incubator pilot projects, Helmholtz data science schools, Helmholtz future projects and the other incubator platforms, in particular HIDA, HIFIS, and HAICU. The HIP Core will start cooperation as soon as the platform begins to develop, aiming at leveraging synergies at a very early stage. The HIP Core shall establish relations and modes of collaboration with relevant existing activities as soon as HIP is operating.
In order to foster exchange, the HIP Core shall engage in various dissemination activities. This is of particular importance for the startup phase of the platform. Among these are

- organization of annual HIP meetings including presentations of HIP projects,
- presentation of HIP at national/international scientific conferences,
- organization of regular seminars for the participating scientists together with HIDA,
- incorporation of national and international expertise through invitation of guest scientists and guest speakers at HIP events,
- reaching out to other imaging consortia both on the national and international level, and establishment of courses related to imaging sciences within the framework of HIDA.

HIP Services and support along the imaging pipeline

Following the HIP concept of the Helmholtz Incubator Information and Data Science, services and support provided to the entire Helmholtz Association is inherent to the HIP Core team and essential for the success of HIP. Recognizing this need and opportunity, the distributed HIP core offers services and support along the imaging pipeline ranging from data acquisition to data analysis. While the scientific Core team dedicates 30% of its resources to services and support along the imaging pipeline, the service units are fully (100%) dedicated to software and algorithmic support.

Reconstruction and inverse problems (HIP Modalities, DESY)

Facilitating access to imaging modalities

The HIP network will comprise a large number of scientists from all the fields of science, making use of a large variety of imaging modalities within the Helmholtz Association. Starting from the network, the HIP Core will create a modality database along with a list of contact partners. Interested domain scientists can then search the database, contact experts for a given modality, and engage in collaborations to apply the modality to their field of science, e. g., within a HIP project. With this knowhow special support to access large user facilities of the Helmholtz Association will be provided by the scientific HIP Core team at DESY, which offers advice for writing access proposals to synchrotron radiation facilities, free-electron laser sources, and other large-scale research infrastructures.

Develop HIP Solutions for new imaging modalities and inverse problems

The scientific research group within the HIP core will specialize in the solution of inverse problems, mainly from the mathematical and algorithmic point of view. As such, it will develop new inverse problem solvers, implement them efficiently on various HPC infrastructures and make them available to the HIP network via the HIP Solutions framework (in collaboration with the MDC) and maintain them as part of the HIP Solutions portfolio.
As part of its research, the HIP Core team at DESY will engage in solving inverse problems in various fields of science. Together with domain scientists, the HIP Core team shall address new imaging modalities, help develop the proper forward models and implement and solve them numerically. This work will mainly be performed within HIP projects. To take these developments to a general level the HIP Core team at DESY can find generalizations and abstractions of the concrete problems solved and replace the more special solutions with more general solvers. These can more easily be optimized and made available on various HPC platforms for the entire Helmholtz Association. In this way, the HIP Solutions portfolio covers a growing set of imaging modalities with a manageable growth in software tools that need to be maintained.
Artificial-intelligence-based inverse problem solvers are becoming an important pillar for imaging sciences since they provide fast approximate solutions for real-time reconstruction of data sets during acquisition. The developments and services the DESY HIP core team will enable and support scientists to make educated decisions during an experiment, avoiding the acquisition of unusable data sets and wasting resources, e. g., beamtime at large-scale facilities. The main advantage of these AI-based solvers is that they can learn the solution to the inverse problem directly from the forward model, with no need for an experimental training data set.

Generate and make available benchmark datasets for different modalities and algorithms

The abovementioned services are mainly directed towards domain scientist and users of imaging modalities. However, within the Helmholtz Association and beyond, there is a large community of experts for imaging methods, working on image reconstruction. To develop, test, and benchmark new algorithms and software, the latter need relevant data sets representative of the applications. The scientific HIP Core team shall make available such data sets for a variety of applications following the FAIR principle. In addition, the Core team shall organize benchmark competitions (in collaboration with the HIP core at the DKFZ) for prominent imaging modalities.

Integration across scales (HIP Solutions, MDC)

The concepts and algorithms described in the scientific concept of the MDC will be the basis for development of the HIP Solutions framework and of central HIP Solutions that are provided as a service to the Helmholtz Association. The HIPS framework encompasses the integration of image data, algorithms, and visualization solutions across multiple modalities and scales in space and time framework will foster development and application of HIP solutions and other software developed within Helmholtz across projects and research fields. To achieve this goal, the MDC will therefore address the following specific aspects within HIP services:

1. Development of the HIPS framework, a common data and algorithmic model for the Helmholtz Association,
2. Provide HIP solutions for image data stitching, fusion and visualization.

Development of the HIPS framework, a common data and algorithmic model for Helmholtz

A central goal of HIP is to develop a structure that fosters and encourages the development of common image processing solutions across groups, centers and research fields. For this purpose, the MDC will develop the HIPS framework that enables abstraction of data access, algorithm implementation, and visualization solutions. Past experience in the bioimaging field has shown that such software solutions (Fiji, ImgLib2, Bioformats, MITK) needs to fulfill three important criteria in order to be successful: functionality while imposing few or no constraints, it needs to be easy-to-use, and it needs to provide substantial benefits in order to convince scientists to adapt. We propose to translate the concepts behind these successful bioimaging software solutions to the much more multidisciplinary Helmholtz environment. The incentive to implement this approach is high since it immediately gives scientists access to advanced caching strategies and distributed access, as well as to all algorithms and visualization solutions that build on top of these previously established interfaces including minimal costs for maintenance and development. Based on the access interfaces we will provide a framework that enables abstract implementations of central algorithms that are important across fields, such as inverse problems developed at DESY thus ensuring maximum usability and reuse of software developed within Helmholtz. To ensure generic, compatible and reproducible software we will leverage a “Containerization” strategy based on our interface structure and systems.

Provide HIP solutions for image data stitching, fusion and visualization

To facilitate and promote synergies across research fields, to connect domain experts and to exploit scattered potential in imaging sciences we will provide the concepts and algorithms for large, high-dimensional image data stitching, fusion and visualization that are developed within the scientific concept of the MDC as HIP solutions. We anticipate that these powerful "google-maps-like" tools for integration of image data across scales will prove valuable tools within HIP and spur the development of exciting HIP projects. We will work closely with DKFZ in order to create HIP solutions that allow a smooth reconstruction and annotation of large, heterogeneous datasets.

Human-algorithm collaboration (Central Service Center and Helpdesk, DKFZ)

As the operator of the HIP Helpdesk, the DKFZ coordinates all service activities in the distributed HIP core. It further provides specific services in the areas of image annotation, automatic image analysis as well as validation and benchmarking, as detailed in the following paragraphs:

Manual and semi-automatic labeling of image data

Realizing the value of the main service unit for the Helmholtz Association we aim at advancing the manual and semi-automated labeling of image data. For this purpose, the service unit will develop and maintain a variety of image data annotation tools and put into place a joint large-scale online image data annotation platform, which will be part of the HIPS. Supported projects will receive training of their annotation workers which will be jointly organized by the service unit and the scientific group. A data annotation and training lab will be established in Heidelberg. HIP projects will offer the opportunity to fund annotation workers that can be trained in this lab. These activities will lead to unique annotated data sets and substantially increase the international visibility of Helmholtz.

Automatic image analysis

The service unit will maintain an open codebase of state-of-the-art analysis methods that are applicable across different domains, particularly in the areas covered by the Joint Scientific Concept of the HIP core, and will provide tools made ready for production-scale use in the HIP environment. By continuously developing the code-base and actively identifying and integrating relevant new methodologies, the output to the HIP network is maximized for the benefit of the Helmholtz Association.
The unit will provide the necessary service for groups that work with this method repository, facilitating code reuse and synergies. These services further include consulting in questions concerning for example problem formulations, the optimal match of problems and methods, required amounts and quality of data, method robustness and generalization, deployment and production-scale use as well as quality control.

Validation and Benchmarking

The service unit will support Helmholtz researchers during the performance assessment of image processing algorithms. This will include classical algorithm validation as well as facilitation of the organization of open benchmark competitions throughout Helmholtz imaging research. The unit will assist during the design of validation studies (data sets, annotation strategy, algorithm properties, validation metrics, uncertainty handling, dataset publication and semantical description) as well as the organization of open benchmark competitions (training and test data set design, high quality gold standard annotations, metrics and ranking schemes, recruitment of participants, set up of benchmarking infrastructure, analysis, visualization and dissemination of results). The service unit will actively contribute a codebase of

state-of-the-art analysis methods to the service unit's Open Standards and Software Toolkits Platform and the planned Open Helmholtz Data Resources.
The provided services will have numerous advantages:

1. Domain scientists will be enabled to post their problem to the international imaging community, thus increasing the probability of solving domain-specific problems.
2. Scientists can benchmark their methods and gain visibility by advancing reproducibility and comparative validation within their communities.
3. Good scientific practice principles as well as high validation standards will be enforced thus contributing to the credibility of Helmholtz research. The underlying standardization will be to the benefit of open sciences within HIP and beyond.

Governance and implementation

Governance

The general aspects of the governance and the general concept of HIP remain applicable (as decided by the General Assembly of the Helmholtz Association in September 2018 [1]).
HIP shall be located at three Helmholtz Centers (HIP core units). The HIP core units have the disciplinary responsibility of the personnel of HIP. The HIP core units operate HIP in accordance with the goals and services agreed to by the HIP core units with the Helmholtz Association.
Various quality control processes are set in place. HIP will report annually to the General Assembly of the Helmholtz Association. The Steering Board as well as the Scientific Advisory Committee guide the development of HIP. There will be an assessment of HIP after three years.
The HIP core units, which together form the HIP Core, are each led by a coordinator. The three coordinators are jointly responsible for the successful implementation and integration of HIP. They are represented by one spokesperson. The spokesperson is supported by the administrative unit of HIP. The spokesperson represents HIP internally and externally and facilitates internal coordination and reporting.
The three coordinators (one of each center) shall be part of the Steering Board (the Head Office joins this board as a guest). The Steering Board shall consist of up to 10 members who have an affiliation with a Helmholtz Center. All members of the Steering Board shall jointly cover the research fields of the Association. The Steering Board is constituted by the General Assembly of the Helmholtz Association. The Steering Board supervises the joint HIP core units and monitors the platform's as well as project's progress. It reports to the General Assembly and is responsible to ensure the strategic development decided by the General Assembly of the Helmholtz Association.
The Scientific Advisory Committee is constituted by the President of the Helmholtz Association. The three coordinators and the Head Office are guests in the Scientific Advisory Committee. It shall consist of at least 5 national and international imaging experts from institutions outside the Helmholtz Association. It provides external advice and shall prevent HIP from being dominated by an internal perspective. It could be involved in the review process of HIP projects.
With regards to service requests and HIP projects, the administrative unit of HIP handles all processes. HIP will present itself with one face to the customer for the service requests. The

three coordinators decide jointly which HIP core unit will be responsible for handling the individual service request (joint work is encouraged).
For HIP project proposals the Steering Board develops a review process that takes into account the requirements by the Initiative and Networking Fund and the aims of HIP. This may involve a Project Review Panel as stated in the general HIP concept. The Head Office of the Helmholtz Association and the Steering Board decide the implementation of this process.
The Head Office of the Helmholtz Association develops an annual reporting framework to the General Assembly of the Helmholtz Association. The Steering Board develops key performance indicators that measure the progress of HIP in all relevant dimensions and that are part of the reporting. They may include the key performance indicators developed in the general concept for HIP.

Implementation of the distributed HIP core teams

Administration Unit

The Administration Unit shall be located at DESY. It covers the following main tasks:

- building and maintaining an internationally visible network of experts and enable synergies (network & synergies),
- driving and fostering imaging sciences in the Helmholtz Association (dissemination, outreach),
- running the platform (operation & organization),
- management of the complete HIP proposals process,
- coordination and compilation of the reports as described in the Governance.

as detailed in the services section and in the general HIP concept [30] . The Administrative Unit comprises 5 FTE:

- Administrative Manager: Managing the Administrative Unit of the HIP Core, representing HIP in- and outside of the Helmholtz Association, responsible for the coordination and compilation of the reports,
- Assistance: Team assistance,
- HIP Proposals officer and controller: Managing the complete HIP Proposals process, monitoring and controlling cash flow within HIP, in particular of the HIP projects. The controller will be in close cooperation with the Head Office of the Helmholtz Association.
- Scientific & Industrial Relation Officer: Maintaining & expanding the academic imaging network in- and outside the Helmholtz Association, promoting all imaging modalities & establishing/deepening contacts in industry. He/She acts as a scout and broker for interesting imaging datasets in the Helmholtz Association and organizes the community events.

- IT Expert & Programmer: In charge of the IT services of HIP, including web site and platforms for services (e. g., networking, community building and dissemination), the network data base, the HIP Proposals portal and repositories for HIP Solutions and reference data sets.

Scientific units (Local units with 70% research, 30% support)

DESY:

- W3 Group leader in the field of applied mathematics, numerical mathematics, or computer science, joint appointment with University (UHH or TUHH),
- 2 Postdocs,
- 2 PhD Students,

MDC:

- W3 Group leader in the field of computational imaging data science joint appointment with,
- University (HU, FU or TU),
- 2 Postdocs,
- 2 PhD Students.

DKFZ:

- Junior Group leader in the field of applied machine learning and human-algorithm interaction. Joint appointment with Heidelberg University,
- 1 Postdoc,
- 2 PhD Students,
- 2 existing units will be leveraged with 1 postdoc and 1 PhD student each.

Service and support units (100% support for the Helmholtz Association)

DESY:

- 1 Senior Software Developer,
- 2 Software Developers.

MDC:

- 1 Senior Software Developer,
- 2 Software Developers.

DKFZ:

- 1 Senior Software Developer: Head of the service unit & HIP Helpdesk,
- 1 IT Expert: Infrastructure and IT within the service unit & HIP Helpdesk,
- 3 Software Developer: SW development and code optimization for the three service areas.

Mechanisms for collaboration

- Recruiting strategy: The three centers will sync and agree upon a joint advertisement for the professorships and research groups and will publish joint advertisements.
- Recruiting strategy: The search committee (Berufungskommission) to be established at each center will be supported by at least one (non-voting) member of each of the other centers.
- The annual PhD committee sessions at each center will be supported by at least one member of each of the other centers.
- Plan for continuation of Young Investigator Groups: the DKFZ young investigator group will receive a tenure evaluation after 5 years. If positive, the center will cover the additional costs (difference between junior and senior group). If negative, a new junior group will be recruited.

Financial planning

Table 1: Grouped annual costs in k€ of the Helmholtz Imaging Platform. Here, the aggregated cost representation is shown according to the formal specification of the Head Office of the Helmholtz Association. It shows the expected costs per year for the fully established platform, broken down into personnel (with overhead) and material costs (basic funded) and project costs (IVF-funded). Estimates of the working groups included in this presentation are found in Table A1 – A7 of ANNEX 1.

Platform part field of engagement *cost type*	costs p.a. in k€
HIP Administration	
Management, Controlling, Assistance, etc.	
non-personnel costs	30
personnel costs	228
Outreach, Relation Officer	
personnel costs	176
Sum	**434**
HIP Joint Core Team, Project Support Team	
Technical Staff, Software Development	
non-personnel costs	60
personnel costs	938
Scientific Staff, 3 units (70% Science, 30% Service)	
personnel costs	1,615
Sum	**2,612**
Projects & Scientific Exchange	
Scientific Exchange, Guest Scientists	
non-personnel costs	135
HIP Projects	
Project funds	1,500
Sum	**1,635**
Events	
HIP events	
non-personnel costs	120
Sum	**120**
total p.a.	**4,801**
non-personnel costs (basic funding)	345
personnel costs (basic funding)	2,956
project funds (IVF funding)	1,500

Annex

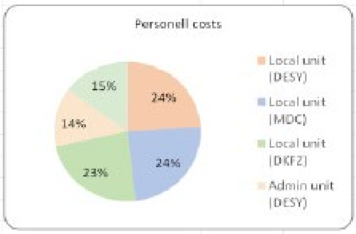
Annex 1

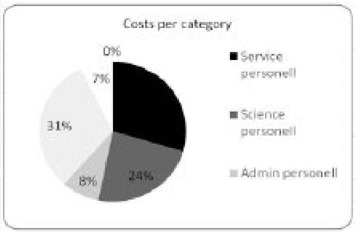
Table A1-A7: Costs in k€ of the Helmholtz Imaging Platform. Here, the detailed cost representation is shown summarizing the expected costs per year for the fully established platform, broken down into dynamic and static costs and estimates of the distributed HIP core teams at DESY, DKFZ and MDC.

- New items as compared to the original concept are marked with a (*) in the first column.
- Color code:

DESY
MDC
DKFZ

Table A1. Executive summary





Personell costs (per partner)	
Local unit (DESY)	€711.625
Local unit (MDC)	€711.625
Local unit (DKFZ)	€688.875
Admin unit (DESY)	€402.938
Service unit (DKFZ)	€440.250

Total costs (per category)
Service personell
Science personell
Admin personell
Dynamic project funds
Scientific exchange & misc.

HIP total costs	Original HIP	Joint HIP
	€4,376.56	**€4,800.001**

Table A2. Personnel costs for administration

#	Description	Original HIP	Joint HIP	Details
1	Manager	83.40	83.400	Managing HIP administratively, member HIP Coordination Team
2	Assistance	48.00	48.000	Team assistance
3	Assistance	24.00	24.000	Team assistance, 1/2 FTE
4	Controller	27.15	27.150	Controls and monitors the projects, 1/2 FTE
5	Scientific Relation Officer	69.90	69.900	Maintaining & expanding the academic network within and outside Helmholtz
6	Industrial Relation Officer	69.90	69.900	Establishing/deepening contacts in industry
	Total	322.35	**322.350**	
	Incl. overheads	402.94	**402.938**	

Table A3. Personnel costs for service

#	Description	Original HIP	Joint HIP	Details
7	Senior SW Developer	69.90	83.400	Head service unit & help desk
8	Senior SW Developer	69.90	69.900	Highly qualified SW developer for professional SW and code optimization
9	SW Developer	54.30	69.900	Highly qualified SW developer for professional SW and code optimization
10	SW Developer	54.30	64.500	Professional SW and code optimization
11	IT Expert	54.30	64.500	Professional SW and code optimization, responsible for IT in the service unit
*	Senior SW Developer	69.90	69.900	Highly qualified SW developer for professional SW and code optimization
*	SW Developer	69.90	64.500	Professional SW and code optimization
*	SW Developer	69.90	64.500	Professional SW and code optimization
*	Senior SW Developer	54.30	69.900	Highly qualified SW developer for professional SW and code optimization
*	SW Developer	54.30	64.500	Professional SW and code optimization
*	SW Developer	54.30	64.500	Professional SW and code optimization
	Total	302.70	**750.000**	
	Incl. overheads	378.38	**937.500**	

Table A4. Expenses for the HIP Scientific Core Team (70% Science, 30% Service)

#	Description	Original HIP	Joint HIP	Details
12	Principal Investigator 1	101.60	101.600	W3 Reconstruction & Inverse Problems (group 1)
13	PostDoc	69.90	69.900	PostDoc level scientist, research group 1
14	PostDoc	69.90	69.900	PostDoc level scientist, research group 1
15	PhD Student	64.50	64.500	PhD candidate in research group 1
16	PhD Student	64.50	64.500	PhD candidate in research group 1
17	PhD Student	64.50	0.000	Moved to service unit
18	Principal Investigator 2	101.60	101.600	W3 Integration Across Scales (group 2)
19	PostDoc	69.90	69.900	PostDoc level scientist, research group 2
20	PostDoc	69.90	69.900	PostDoc level scientist, research group 2
21	PhD Student	64.50	64.500	PhD candidate in research group 2
22	PhD Student	64.50	64.500	PhD candidate in research group 2
23	PhD Student	64.50	0.000	Moved to service unit
*	Principal Investigator 3		83.400	Junior Group Human-Algorithm Interaction (group 3)
*	PostDoc		69.900	PostDoc level scientist, research group 3 "Semi-automatic Image Annotation"
*	PhD Student		64.500	PhD candidate in research group 3 "Semi-automatic Image Annotation"
*	PhD Student		64.500	PhD candidate in research group 3 "Semi-automatic Image Annotation"
*	PostDoc		69.900	PostDoc in affiliated group 4 "Automatic Image Annotation"
*	PhD Student		69.900	PhD candidate in affiliated group 4 "Automatic Image Annotation"
*	PostDoc		64.500	PostDoc in affiliated group 5 "Validation and Benchmarking"
*	PhD Student		64.500	PhD candidate in affiliated group 5 "Validation and Benchmarking"
	Total	869.80	**1291.900**	
	Incl. overheads	1087.25	**1614.875**	

Table A5. Expenses for scientific exchange

#	Description	Original HIP	Joint HIP	Details
1	Guest Scientist	240.00	20.000	Scientific visitors DESY
2	Traveling	300.00	24.896	Traveling, hospitality costs DESY
*			20.000	Scientific visitors MDC
*			24.896	Traveling, hospitality costs MDC
*			20.000	Scientific visitors DKFZ
*			24.896	Traveling, hospitality costs DKFZ
	Total	540.00	**134.688**	

Table A6. Miscellaneous costs

#	Description	Original HIP	Joint HIP	Details
1	Misc	48.00	0.000	
2	Marketing	60.00	0.000	
3	SW Licences	180.00	60.000	Special SW licenses / fees for open competition plattforms / hosting services
4	Platform Events	120.00	120.000	Annual conference, workshops, meetings
5	conferences, fairs	30.00	0.000	
6	SAC board (trip&allowance)	30.00	30.000	min. 1 meeting per annum
	Total	468.00	**210.000**	

Table A7. Dynamic project funds

#	Description	Original HIP	Joint HIP	Details
1	Projects	1500.00	1500.000	HIP projects
	Total	1500.00	**1500.000**	

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