

Nordic WLCG Tier-1(NT1) facility evaluation

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Executive summary

The Nordic Tier-1 (NT1) NeIC project is one of the computing centers for the Worldwide LHC Computing Grid (WLCG) serving the computing needs of the ATLAS and ALICE experiments at the CERN Large Hadron Collider (LHC).

This document presents a description of the NT1 project, its relevance to NeIC, the future plans and coming challenges with the High Luminosity upgrade of the LHC (HL-LHC) and implications on NT1. This project involves engagement with a multitude of stakeholders, from core computing teams of the ATLAS and ALICE collaborations up to relevant actors in Denmark, Finland, Norway and Sweden, mainly Principal Investigators of national High-Energy Physics (HEP) R&D projects, computing service providers offering resources to NT1, namely NBI, CSC, HIP, UiB, UiO, and SNIC (with HPC2N and NSC) HPC sites, and network providers (NORDUnet, SUNET, Uninett and DeiC). As an added value, experts in every country gain invaluable experience in operating a challenging international e-infrastructure that originally led to the creation of NeIC itself in 2012. NeIC has an operational responsibility for NT1 and its infrastructure is expected to run until at least 2038. As of today, NT1 provides 30PB of storage (200M files) and has averaged 7800 running CPU cores over the last year.

The High Luminosity LHC (HL-LHC) is an upgrade of the LHC to achieve higher luminosity, which is planned during this decade and will increase the data volumes by an order of magnitude. This sharp increase in storage and CPU requirements presents a new challenge for the NT1 computing infrastructure and the development of open source software needed for operating NT1. This report provides some estimates on the resources (storage, compute and network) needed for the computing upgrade for the LHC Run-3 (2022-2025) and the future data handling of the HL-LHC (2027-2030).

Although heavily distributed, NT1 appears as a single site thanks to NorduGrid's Advanced Resource Connector (ARC), dCache and SGAS softwares. These open source software solutions are internationally used and serve as an abstraction layer between the distributed Tier-1 facility and the researchers, to provide them transparent access to the data and computing services and hiding the complexity of the infrastructure behind. The continuation of innovation and well recognised effort in these projects will be essential for the continued success of NT1 and its international visibility. We cannot assume that scientific computing technology evolution will solve the HL-LHC challenges and problems, nor will hardware improvements come to our rescue, so software upgrades need urgent attention. New topics, workflows and functionalities focusing for example on advanced network usage have been identified together with the WLCG. We will also discuss the opportunity for NT1 with its collected expertise and experience to evolve into a multidisciplinary distributed facility that will be beneficial for other data-intensive sciences.

This report comes from a request by NeIC, and it is intended to be input to the next NeIC Board meeting in June, 2021.

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Overview of the Nordic Tier-1 (NT1)

Framework

The Nordic Tier-1 (NT1) is one of the Tier-1 data intensive computing centres for the Worldwide LHC Computing Grid (WLCG)¹. The technical implementation of the Nordic Tier-1 was initially (since 2006) performed by the Nordic Data Grid Facility (NDGF), and since 2012 it is a part of the Nordic e-Infrastructure Collaboration (NeIC)². While NDGF was established with the primary purpose to operate the Tier-1, success of this international endeavour led to the transition to NeIC, which opened opportunities for cooperation in other sciences. NeIC has an operational responsibility for NT1, which provides both compute and storage capacity to the ALICE and ATLAS experiments³ at the CERN's Large Hadron Collider (LHC)⁴ and its infrastructure is committed to operate until at least 2038, in accordance to the WLCG MoU signed by the contributing countries⁵.

The specifics of NT1 is that it is built from hardware provided by user communities themselves. ALICE and ATLAS communities in the Nordic countries ensure funding from national Funding Agencies or universities to cover computing and storage needs of the respective experiments. Principal Investigators of these projects and representatives of national resource providers who are subcontracted to operate the facilities constitute the Nordic LHC Computing Grid (NLCG) Committee which oversees NT1 operations and ensures that user needs are met. NeIC has an operational responsibility for NT1, provides the governance structure, interacts with the Nordic user representatives, coordinates the computing sites in the Nordic region and manages the central operations and middleware deployment.

As a result, NT1 has a distributed setup across 5 countries and 7 computing centres: CSC⁶ and HIP⁷ (Finland), HPC2N⁸ (Sweden), NBI⁹ (Denmark), NSC¹⁰ (Sweden), UiB¹¹ (Norway), UiO¹² (Norway) and SiGNET¹³ (Slovenia). All countries contribute individually to the storage and computing resources via university computing centres and national resource providers, such as SNIC, CSC, DeIC, Uninet/SIGMA2 and NORDUnet. The involvement of the Nordic countries in the LHC experiments is summarized in [Table 1](#).

¹ <https://wlcg.web.cern.ch>

² <https://neic.no>

³ Finland is the only country involved with the CMS experiment, and provides a CMS Tier-2, which is out of scope of this document

⁴ <https://home.cern/fr/science/accelerators/large-hadron-collider>

⁵ <https://wlcg.web.cern.ch/mou>

⁶ <https://www.csc.fi>

⁷ <https://www.hip.fi/>

⁸ <https://www.hpc2n.umu.se>

⁹ <https://www.nbi.ku.dk>

¹⁰ <https://www.nsc.liu.se>

¹¹ <https://www.uib.no>

¹² <https://www.uio.no>

¹³ <http://signet.ijs.si>

Country	HPC center	ALICE	ATLAS
Denmark	NBI	Tier-1	Tier-1
Finland	CSC, HIP	Tier-1	
Norway	UiO		Tier-1
	UiB	Tier-1	
Sweden	SNIC/NSC	Tier-1, Tier-2	Tier-1, Tier-2
	SNIC/HPC2N	Tier-1, Tier-2	Tier-1, Tier-2
	SNIC/LUNARC	Tier-2	Tier-2

Table 1. Involvement of the Nordic countries in the LHC experiments.

A collaboration agreement ([Appendix A: NT1 Collaboration agreement](#)) between ALICE and ATLAS user communities and NeIC determines the NT1 services and resources to be provided to the LHC experiments by each country. NT1 has as a target providing 6% of the total Tier-1 resources for ATLAS, and a share of overall computing in proportion to physics contribution to ALICE, respectively. The CMS Tier-2 resources are currently located in Estonia and Finland, they are for the moment out of scope for NT1.

Total deployed capacity: Storage, computing and network connectivity

NT1 currently provides for storage a total of 16 PB of disk (11 PB for ATLAS and 5 PB for ALICE) and 14 PB of tape (12 PB for ATLAS and 2 PB for ALICE), which is in good agreement with the targets. [Table 2](#) shows the current contribution in PB for the storage per country and NT1 HPC centers both for the ATLAS and ALICE experiments.

Country	HPC center	Disk	Tape
Denmark	NBI	0.75	2.7
Finland	CSC, HIP	0.69	0
Norway	UiO	4.83	3
	UiB		
Sweden	NSC	5.68	8.08
	HPC2N		
Total:		16.31 PB	13.78 PB

Table 2. Storage capacity per country and HPC center (in PB).

NT1 has averaged 7800 running CPU cores over the last year, corresponding to more than 7.7 M jobs done and 600K HS06¹⁴ years (400K for ATLAS and 200 K for ALICE). [Figure 1](#) shows the number of jobs done per month and the contribution from each partner.

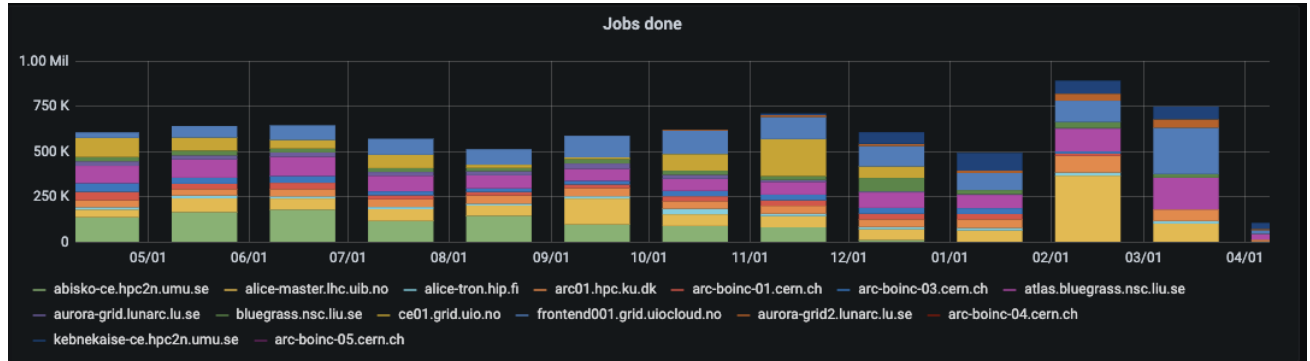


Figure 1. Total number of jobs done per month per site.

The NT1 external connectivity is partly based on a layer 2 private network, the so-called LHC Optical Private Network (LHCOPN¹⁵), which interconnects the Tier-1 with Tier-0 at CERN and the rest of the Tier-1s in WLCG. NT1 connects, via NORDUnet, to the LHCOPN as an overlay network on two geographically redundant 100 Gbps links to CERN, as shown in [Figure 2](#).

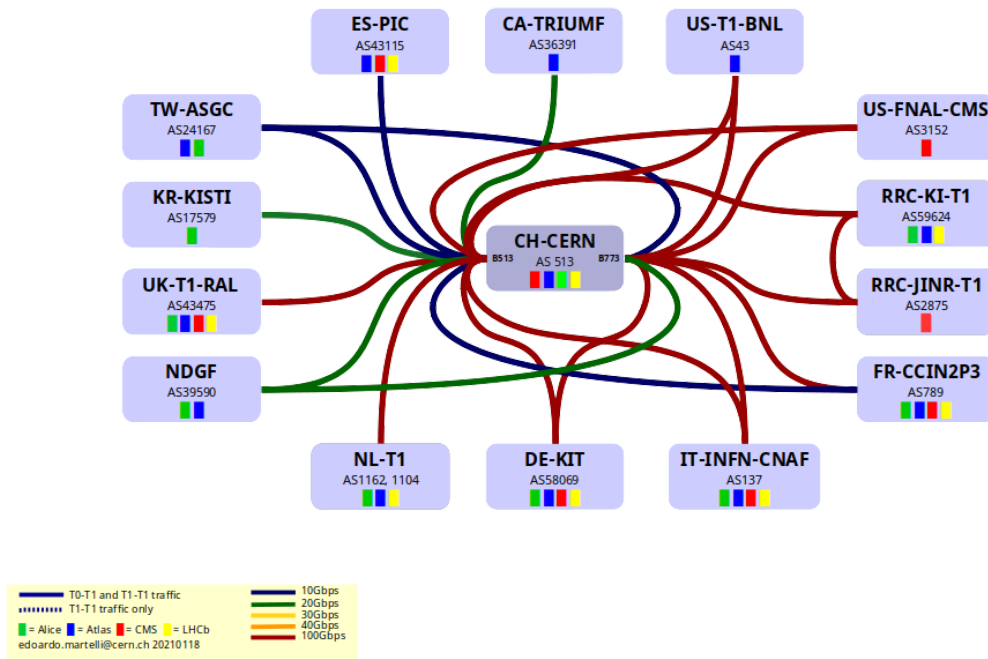


Figure 2. LHCOPN network map, showing primary and backup links.

The capacity to CERN is 20Gbps to each of the two LHCOPN routers at CERN for a total of 40Gbps of capacity with options for quick upgrades when the need arises.

¹⁴ HS06 is a unit that results from a combination of the SPEC2006 suite floating point and integer benchmarks.

¹⁵ <http://lhcopn.web.cern.ch/lhcopn>

In addition to the private LHCOPN network between Tier-0 and Tier-1s, there is a second network called LHCONE that consists of a L3VPN that provides connectivity to most Tier-2 sites around the world, in Europe this is provided by GEANT. The NT1 capacity to LHCONE and the general internet is 80Gbps. These external WLCG network services are provided by NORDUnet in accordance with the agreement between NORDUnet and NordForsk against an annual fee.

The NT1 sites are connected by overlay networks inside the Nordics on shared 100Gbps links by NORDUnet and NRENS, individual HPC sites are connected to these with 20-100Gbps capacity. For the Nordic network topology¹⁶, see [Figure 3](#).

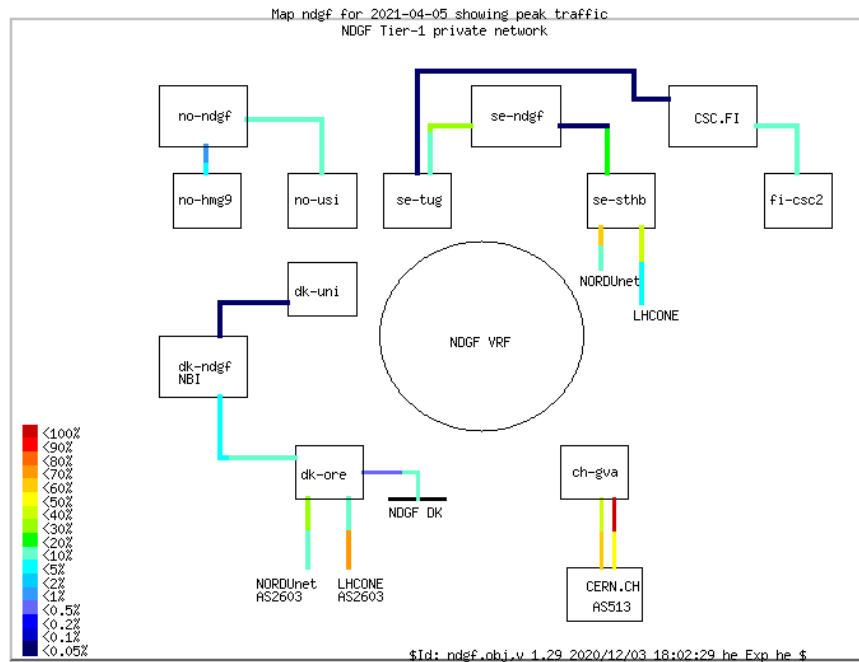


Figure 3. NT1 private network. The color code shows the percentage load of the monitored circuits.

The traffic exchanged to and from CERN over LHCOPN is roughly 4% of the total traffic between CERN and all Tier-1s, or 4.3 Gbps on average with 17 PB total data transferred during the last year, as illustrated in [Figure 4](#).

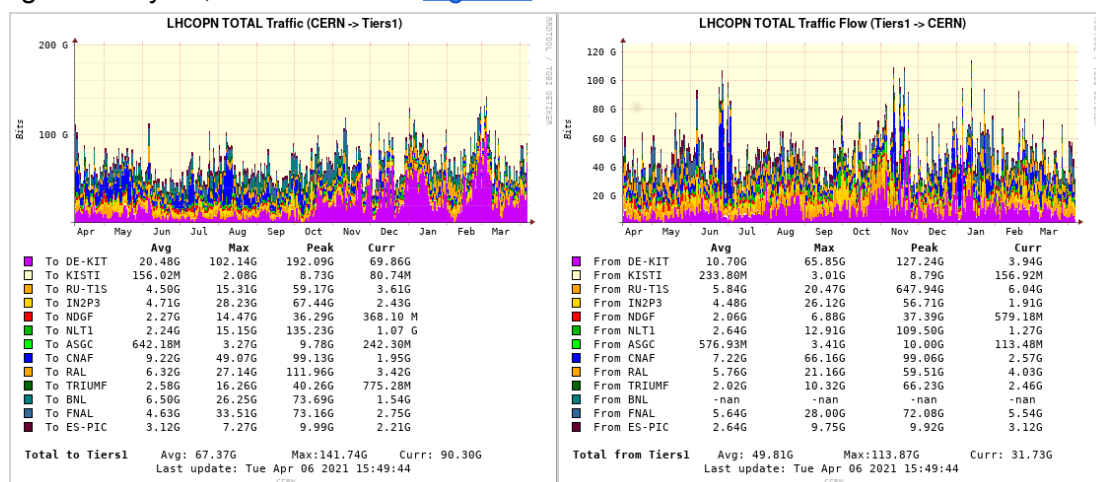


Figure 4. Network traffic between CERN and Tiers-1.

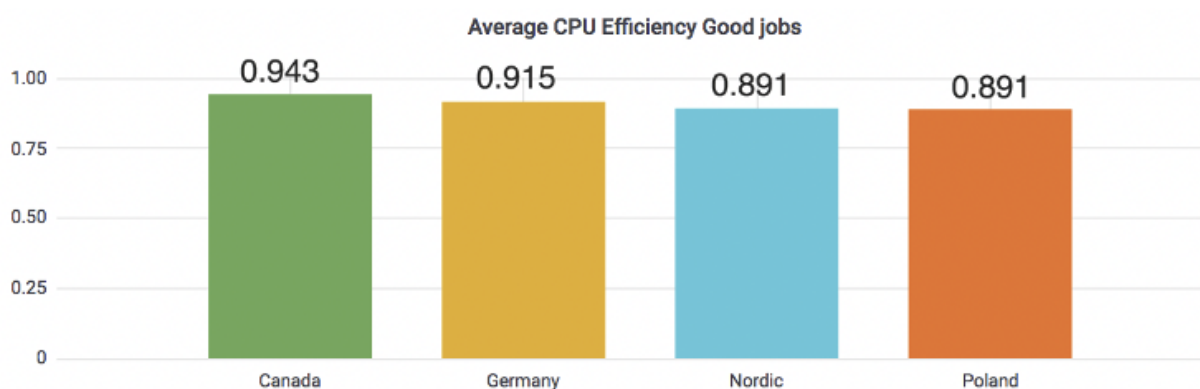
¹⁶ <http://stats.nordu.net/stat-q/load-map/ndn-map..traffic.peak>

The ARC and dCache key software solutions for NT1

Although all its resources are heavily distributed, NT1 appears as a single site to WLCG thanks to the innovative approach that relies on NorduGrid's Advanced Resource Connector (ARC)¹⁷ and dCache¹⁸ software. Both software solutions serve as an abstraction layer between the distributed Tier-1 facility and the researchers, to provide them transparent access to the data and computing services and hiding the complexity of the infrastructure behind.

ARC is an open source software that was originally developed to allow Nordic compute and storage facilities to contribute to the large compute needs of the LHC experiments. The Nordic sites are predominantly HPC facilities with heterogeneous systems, wide-area network inaccessibility from the worker nodes, and separated compute and storage services. This required special software which at the time (year 2001) was not available. Therefore ARC was developed to cater for these needs. It was soon adopted by several other HPC sites outside Nordics, and today ARC is widespread, with roughly 200 WLCG sites deploying it. Developing and maintaining ARC supports NeIC's vision to be a global role model, it's fair to say that the ARC's success can be to a fairly large extent attributed to NeIC.

NT1 with remote storage performs as well as WLCG sites with a centralised architecture and local storage thanks to the way ARC handles data staging and caching. Once a job arrives on an ARC site, ARC will fetch all the requested input files, and only once they are all in place, will the job be handed to the local batch system for execution. If files already are present in the cache from an earlier download, no data staging is necessary for those files. The ARC data staging together with the ARC cache results in very efficient job processing, and even more so if the input files in the cache are reused frequently. This gives a very important contribution to the overall efficiency of the system as described in the paper "Nordugrid ARC Data Staging and Cache: Efficiency Gains on HPC and Cloud Resources"¹⁹. [Figure 5](#) below compares the NT1 federated and distributed storage sites to four dedicated central sites with local storage. Thanks to ARC and its data staging/caching capability, the performance for NT1 is as good or comparable with a centralised site. ARC is therefore a key success factor for NT1 where the storage is shared among sites.



¹⁷ <http://www.nordugrid.org/arc/>

¹⁸ <https://www.dcache.org/>

¹⁹ Nordugrid ARC Data staging and Cache: Efficiency gains on HPC and cloud resources
Maiken Pedersen et al., EPJ Web Conf., 245 (2020) 03011 DOI:
<https://doi.org/10.1051/epjconf/202024503011>

Figure 5. Average Job CPU efficiency in four different ARC sites with central storage (Canada, Germany, Poland) and with the Nordic Tier-1 with federated and distributed storage sites.

Complementary to ARC, the dCache software solution federates the distributed storage resources and controls the data stored on them as a high availability and scalable storage solution. This multi-petabytes NT1 model is unique in being distributed across five countries, and offering 24x7 services. The dCache project provides an open source storage software solution and is a joint venture involving the Deutsches Elektronen-Synchrotron (DESY), the Fermi National Accelerator Laboratory (FNAL) and the Nordic e-Infrastructure collaboration, NeIC / NT1.

Service management, operational and support model

NT1 has developed a unique and recognized expertise in running a physically distributed but logically single Tier-1 facility. The current IT service management model is the result of more than a decade of experience and iterations with a fully distributed operations team, including responsibilities for the covered services and interactions. Most of these have a primary and secondary skilled expert assigned as responsible. The deployment workflow relies on continuous integration and delivery paradigms complemented by FitSM²⁰ practices. The service management model is effective to allow smooth distributed operational tasks and to deliver high availability core services while offering opportunities to extend and complement the NT1 operational model with new paradigms, tools and automation. NT1 relies on established tools in the open source DevOps community, most notably Git²¹ for version control management, Ansible²² for configuration management & control, service monitoring tools (e.g., ELK stack²³), and RocketChat²⁴ for communication.

The high availability deployment schema allows robustness and horizontal scalability by accommodating multiple instances of each service with fail-over, backup and possibly transparent interventions. Prior to any changes in production, a required validation is done in several environments, called preproduction or experimental, depending on the classification of the changes, e.g., minor, major or patch. The different environments share the same configuration management templates as in production, with distinct respective variables like database, software version, etc. The preproduction environment is the exact clone of the production deployment model with a constant load generated by the ATLAS and ALICE experiments, validating a rich set of functionalities, changes or new features. This workflow allows us to detect, fix and report issues as soon as possible and reduces the probability of issues in the production environment.

The 24/7 support is organized through the Operator on Duty (OoD) role during working hours and the Operator on Call (OoC) role otherwise. The OoD is the person responsible for

²⁰

<https://apmg-international.com/fr/product/fitsm-lightweight-streamlined-it-service-management-certification>

²¹ <https://git-scm.com/>

²² <https://www.ansible.com/>

²³ <https://www.elastic.co/>

²⁴ <https://rocket.chat>

running day to day operations of NT1 and approves everything that is happening. The OoD, with possible backup, is a full-time engagement when there are alarms, incidents or problems. This person is in charge of incident escalation for the mitigation and resolution actions. All operational procedures and known errors are documented, classified and maintained. In addition, an operator on duty log is updated to keep track of all the interventions and important events facilitating the reporting, hand-over and rotation to a new OoD person. These reports are discussed and followed up, e.g., via post-mortem analysis/actions during the NT1 weekly meetings.

High Luminosity upgrade of the LHC (HL-LHC)

The computing requirements for LHC experiments are unprecedented in physics research and in scientific computing in general. With the LHC upgrade (HL-LHC), the data volumes will increase by more than a factor 10 when compared to the current status, giving new challenges to the whole analysis chain, from readout electronics to offline computing. The schedule of the LHC plans is illustrated in [Figure 6](#).



Figure 6. The schedule of the LHC. The LHC and the detector upgrades are completed during the long shutdowns (LS2 and LS3).

The full exploitation of the HL-LHC, which has the status of a Landmark on the ESFRI Roadmap²⁵, is only possible if the capabilities of the e-infrastructure and the experiments are improved significantly. The estimated CPU, disk and tape resources needed at NT1 for the years 2020 to 2034 for both ATLAS and ALICE experiments are shown in [Figure 7](#). These estimates are based on the inputs provided by the experiments.

²⁵ European Strategy Forum on Research Infrastructures, "Strategy Report on Research Infrastructures - Roadmap 2018," 2018. [Online]. Available: https://ec.europa.eu/info/sites/info/files/research_and_innovation/esfri-roadmap-2018.pdf

For ATLAS, a flat budget model with +10% resource capacity increase per year is assumed for the period 2022-2025. For the period 2027-2030, the updated Computing Conceptual Design Report²⁶ in view of the HL-LHC requirement provides some resource estimates with different scenarios which have been used to define the future storage and computing needs of NT1. This gives a factor 4 for the needed resources in 2025 and a factor 15 for 2030. The ALICE experiment foresees a flat budget model with +20% resources capacity increase per year. This results in a factor 2 for the needed resources in 2025 and a factor 5 for 2030. The network capacity requires a closer look as well, as 100 Gbps dedicated links per each site will be needed and the current links are between 20 Gbps and 100 Gbps shared. WLCG has estimated the LHC network throughput requirements for NT1 between 140 Gbps and 280 Gbps. Some major upgrades are already investigated or planned by the sites or NORDUnet. As faster and cheaper links are coming, the flat budget model will have to be revised to accommodate the estimated throughput requirements for NT1.

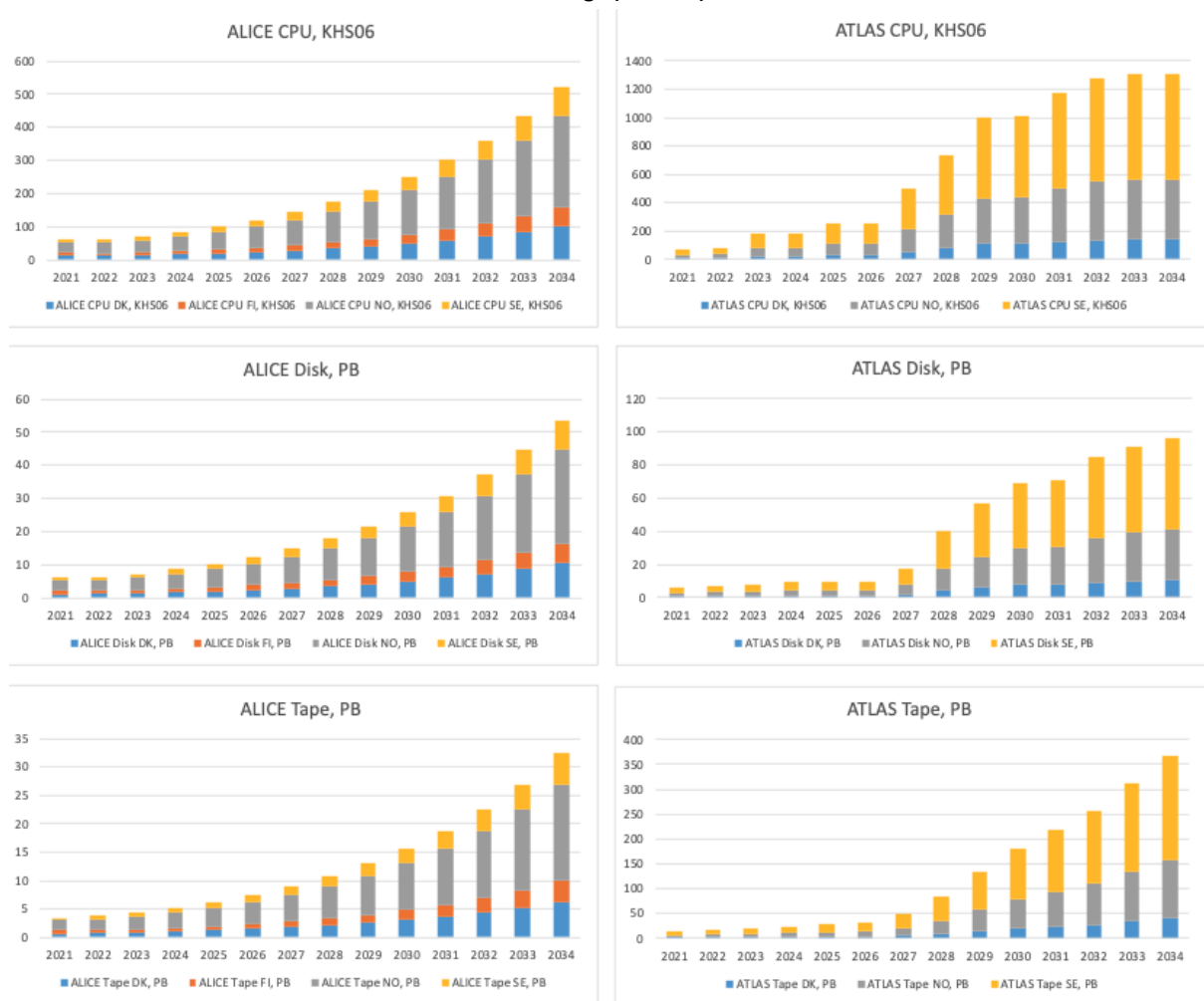


Figure 7.

Figure 7. Estimated CPU, disk and tape resources needed at NT1 for the years 2020 to 2034 for both ATLAS and ALICE experiments

²⁶ <https://cds.cern.ch/record/2729668>

Impact and consequences on NT1, central services, resource and software

With the start of the High-Luminosity LHC, the year 2026 will see a significant increase in the data rates due to the increase in the number of HL-LHC collisions, higher event triggering rates, and more data products in offline computing. This presents both a funding and technological challenge on the maintenance and development of software needed for operating NT1.

We need to guarantee that ARC can sustainably operate at the needed HL-LHC scale and that the necessary level of development effort and expertise is available to address these challenges. For instance, today a single ARC site normally deals with 10k-20k concurrent jobs, with peaks up to 250k as demonstrated in recent tests. Scaling to HL-LHC might require handling 100k-200k concurrent data-intensive jobs for a single site in a sustained manner, equivalent globally to 500k-1M concurrent jobs for NT1. New topics, workflows and functionalities focusing for example on smart content delivery and caching have been identified within the Data Organisation, Management and Access (DOMA) WLCG project^{27,28}. Other WLCG developments include transition to token-based authorisation, REST interfaces, full workload containerisation, as well as changes in monitoring and accounting services. All these developments require respective changes in ARC, integration and development efforts without breaking the existing functionalities and horizontal scalability of ARC. ARC ensures the reliable and efficient communication among the participating components such as network, caching services, and computing resources like HPC centers. In addition, the impact to wide-area networking and traffic when making changes to local or global infrastructure is especially important and can be hard to assess. It will be essential for the continued success of NT1 to control, monitor and understand the (shared) traffic on the underlying network. It is also important to note that NT1 will work closely with the various networking providers, research efforts and the LHC experiments to effectively prepare for the HL-LHC era and the resulting growth of the network usage.

Another focus will be the scalability of the NT1 storage system which is provided through the dCache software. NT1 in 2021 provides 30PB of storage and hosts 200M files. An order of magnitude increase presents a new challenge for the high availability deployment of the NT1 storage and will require large investments for scaling (out and up) the infrastructure. For example, the relational database storage management system (RDBMS) providing the dCache information persistence is expected to scale to LHC Run-4 rates with billion entries and more few terabytes of storage, but this is yet to be demonstrated. An increasing and large usage of tape is inexorably expected with the consequent challenges of dealing with high latency storage. The dCache software must evolve to support new workflows and required (WLCG) functionalities like new cost models with various QoS and programmable WAN links, e.g., packet marking. Keeping a strong commitment in dCache development will ensure that our storage takes better advantage of the distributed resources with the necessary optimization and guarantee of quality.

Remarks on the centralized and federated NT1 organisational model (today)

Given the expectation that each Nordic country should contribute computing and storage resources to the LHC experiments proportionally to the number of researchers that are

²⁷ <https://twiki.cern.ch/twiki/bin/view/LCG/DomaActivities>

²⁸ <https://iris-hep.org/doma.html>

members of those experiments, one can imagine many different ways of providing these resources:

Distributed sites with no synchronization. In one extreme, each country would run their own Tier-2 sites on dedicated resources. This would lead to a large amount of duplicated effort though, especially for management and running storage systems. A WLCG survey²⁹ put disk-only Tier-2 storage systems at 1-2 FTE in order to run them reliably. While attempted initially, this model proves to be suboptimal: Norwegian and a part of Swedish Tier-2 services have been already merged into Tier-1, and a similar trend towards smaller number of larger sites is observed worldwide.

A single common site. On the other extreme, the Nordic countries would join together and build a single common site providing all the resources that is the fair share of Nordic participation in the LHC experiments. In the design phase of the NDGF/NT1 (in 2001-2005) a synchronized joint facility was proposed for efficiency in terms of money spent, and for ensuring that a critical mass of resources could be reached through a Tier-1 site providing more value to the experiments than an equal amount of resources in several Tier-2 sites. At the time, consolidation into a single geographical facility was not possible due to the difficulties of allocating funds to a facility abroad, and a more recent evaluation³⁰ by Dr. Flix confirmed that such a consolidation would not save much money.

Remarks on multinational HPC facilities, e.g., EuroHPC LUMI and Vega facilities

Future use of multinational HPC facilities needs to be carefully followed to see if, how, and when such use would be both cost-efficient (compared to other options) and feasible. The ALICE and ATLAS workload management systems for data-intensive jobs have different technical demands on a HPC system than the common usage mode.

The NT1 user communities and experts have already started investigating possibilities of using the EuroHPC LUMI facility in Finland. Through an effort coordinated by NLCG, we have provided technical specifications required by LHC workloads and submitted them to LUMI experts. It however remains to be seen whether this will be possible, as most workloads can not be executed in an optimal manner on GPUs, and LUMI is not expected to have a sufficiently large CPU partition.

At the same time, in Slovenia, a full scale test of filling the Vega EuroHPC^{31,32} system with selected ATLAS workloads has been successfully executed during commissioning, momentarily providing 50 times as much CPU power as the entire Nordic Tier-1. Although Vega is not currently suited for all LHC workflows either, this success indicates that in future it may be possible to use a single system to accommodate all the Tier-1 workload. This however would require major changes in workloads and system architectures as well, implying significant extra investments.

Onboarding New Communities within NT1

Thanks to the NeIC framework, the opportunity exists for NT1 to evolve into a multidisciplinary distributed facility like the WLCG TRIUMF³³ data center and the Compute

²⁹ <https://twiki.cern.ch/twiki/bin/view/LCG/WLCGSiteSurvey>

³⁰ https://wiki.neic.no/w/ext/img_auth.php/6/66/NT-1-Evaluation-report.pdf

³¹ <https://eurohpc-ju.europa.eu/news/vega-new-eurohpc-world-class-supercomputer-slovenia>

³² <https://www.izum.si/en/hpc-en/>

³³ <https://www.triumf.ca>

Canada³⁴ initiative, that highlights the depth of skills and capabilities within the Nordic region. The tremendous asset of the collected expertise and experience within the NT1 will allow these expansions towards other data-intensive sciences. Support for non-LHC communities will be driven by their requirements as described in [Appendix C: Project plan, mini Onboarding New Communities within the NT1](#).

Contributions to research excellence in the Nordic region

The WLCG resources, both computing and storage, offered through NeIC NT1, are accessible for all scientists working for the Large Hadron Collider experiments. This means that members of ALICE and ATLAS experiments in all countries worldwide use the Nordic Tier-1 facility. The number of authors (users) has been approximately 7,000 with little fluctuation from year to year and the average number of ALICE and ATLAS authors from the Nordics publications³⁵ is given in [Table 3](#). In the reporting of LHC experiments, diploma students, engineers, system administrators and some of the PhD students are not counted as authors. If those groups are included, the total number of users is approximately 9,000.

Country	ALICE	ATLAS
Denmark	11	13
Finland	10	-
Norway	31	27
Sweden	9	52

Table 3. Average number of ALICE and ATLAS authors in the nordic countries over the years 2018-2020.

The associated list of publications for both experiments is available in [Appendix B: WLCG Publications](#).

The effectiveness at meeting the goals of the project as described in the project or activity plan

The WLCG collaboration

The WLCG collaboration is governed by a Memorandum of Understanding (MoU)³⁵ signed between CERN and countries hosting Tier-1 and Tier-2 centers, represented by their Funding Agencies. The WLCG MoU defines the service levels to be provided by such centers. The resources to be pledged by each country are defined internally by LHC

³⁴ <https://www.computeCanada.ca/>

³⁵ WLCG MoU: <https://wlcg.web.cern.ch/mou>

experiments, in agreement with country representatives. The overall resources provided by WLCG to the experiments are monitored by the LHC Computing Resources Review Board (C-RRB), which meets twice per year, in spring and autumn³⁶. The C-RRB is a subset of the LHC Resource Review Board, that consists of representatives of CERN Member States, and oversees and officially approves the requested resources by the LHC experiments. NT1 agreed with ATLAS and ALICE on targets to provide 6% of the total Tier-1 resources to ATLAS, and a fraction proportional to physics contributions (Maintenance & Operations share) per country to ALICE. The NT1 resources are deployed in HPC centers to accommodate these Tier-1 needs, since the resources are (typically) deployed once and then operated for several years. The hardware is expected to be deployed with a sufficient spare capacity to accommodate for the future LHC needs. These Tier-1 needs are communicated by the NLCG to the national resource providers and the HPC sites, and the systems are adjusted to deliver the resources accordingly to the country shares. Differences in national funding cycles, and sometimes even rejected funding applications, translate to a delivery of resources that does not necessarily match the pledged targets, as can be seen in [Figure 8](#) for the Tape. Sometimes the deviations from the targets translate into deficits or surpluses in the NT1 pledges to WLCG, which might be related to lack of funds to meet the targets or to attempts to maximize the use of the available installed resources for the NT1 at the HPC centers, respectively.

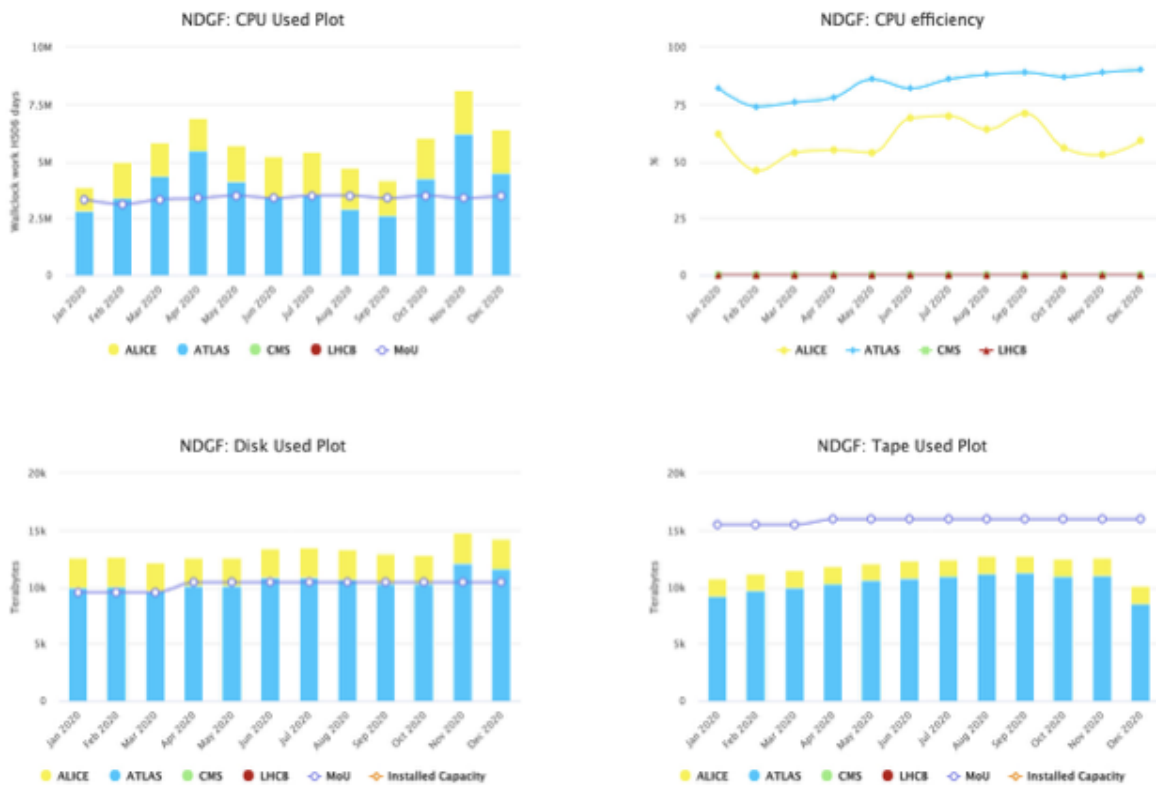


Figure 8. WLCG Accounting report for the experiment pledges for NDGF / NT1.

The main objective of the Nordic Tier-1 is to continuously deliver sufficient production resources towards WLCG until the agreed end, which, according to the WLCG MoU, is LHC

³⁶ List to C-RRB agendas: <http://indico.cern.ch/categoryDisplay.py?categId=852>

lifetime plus 15 years. The minimum success level of the NT1 is defined as WLCG MoU fulfillment by the participating Nordic countries.

By combining the independent national contributions through synchronized operation, the total Nordic contribution reaches a critical mass with higher impact, resilience, risk mitigation, saves costs, pools competences and enables more beneficial scientific return by better serving large-scale storage and computing needs³⁷.

WLCG monitoring tools, accounting and availability/reliability reports

All of the critical services' quality and stability are closely tracked by monitoring two metrics defined by the WLCG monitoring framework: the so-called availability and reliability (A&R) metrics³⁸. These are computed from outputs of dozens of sensors, for each of the experiments, which hourly probe the entire site services and guaranteeing that the reliability of WLCG service keeps improving. The MoU sets a yearly average target of 97% for the reliability metric at the Tier-1 centers.

Generic and specific ATLAS/ALICE experiment tests are used to compare the reliability at the sites towards the targets. The last year availability and reliability Tier-1 rankings are shown in [Figure 9](#) for both ALICE and ATLAS. The measured reliability of the NT1 consistently meets the MoU targets, showing that the NT1 is a stable site towards WLCG and in the top 3 from 2020 of the best Tier-1 sites according to the A&R metrics.

ATLAS Availability & Reliability

Site	Availability ↕	
RAL-LCG2		99.99%
NIKHEF-ELPROD		99.87%
TRIUMF-LCG2		99.63%
NDGF-T1		99.59%
BNL-ATLAS		99.31%
IN2P3-CC		99.30%
RRC-KI-T1		99.21%
Taiwan-LCG2		99.07%
plc		98.94%
FZK-LCG2		98.51%
INFN-T1		96.48%
SARA-MATRIX		96.16%
NIKHEF		95.75%

³⁷ https://wiki.neic.no/w/ext/img_auth.php/6/66/NT-1-Evaluation-report.pdf

³⁸ <https://monit-wlcg-sitemon.web.cern.ch>

Site	Reliability ↓	
RAL-LCG2		99.99%
NIKHEF-ELPROD		99.87%
TRIUMF-LCG2		99.75%
NDGF-T1		99.71%
Taiwan-LCG2		99.69%
BNL-ATLAS		99.62%
IN2P3-CC		99.58%
SARA-MATRIX		99.37%
RRC-KI-T1		99.29%
FZK-LCG2		99.02%
plc		98.97%
INFN-T1		97.18%
NIKHEF		97.00%

ALICE Availability & Reliability

Site	Availability ↓	
NDGF-T1		99.19%
CCIN2P3		99.07%
RAL		98.92%
KISTI_GSDC		98.78%
RRC_KI_T1		98.54%
FZK		98.03%
SARA		96.39%
CNAF		94.42%
NIKHEF		94.26%

Site	Reliability ↓	
SARA		99.44%
CCIN2P3		99.40%
NDGF-T1		99.27%
KISTI_GSDC		99.01%
RAL		98.92%
RRC_KI_T1		98.54%
FZK		98.40%
NIKHEF		95.92%
CNAF		94.90%

Figure 9. Availability and reliability metrics for the ATLAS and ALICE Tiers-1 measured by WLCG for the year 2020.

Budget

NeIC through the NT1 activity has an operational responsibility for the Nordic distributed WLCG Nordic Tier-1 facility. NeIC provides the governance structure, interacts with the Nordic user representatives, coordinates six computing sites in the Nordic region and manages the central operations and middleware deployment for the Nordic Tier-1. The majority of the staff for NeIC projects are employed by a partner organisation in a participating country. Staff members engage in the NeIC projects with 20–80% commitments through a service agreement with their home organisation. The NT1 personnel are funded either by NeIC, national R&D programs or in-kind contributions from the HPC centers or HEP communities, where the Tier-1 resources are deployed. The total NeIC budget in 2021 for NT1 is ~11 MNOK/year. The breakdown per category is shown in [Table 4](#).

	NeIC funding	Partner funding
NT1 Personnel cost	NOK 7 326 678	FTE 5.8
NT1 Travel and Meeting Costs	NOK 333 362	
WLCG NORDUnet cost	NOK 3 247 000	
Total:	NOK 10 907 040	

Table 4. NeIC Budget in 2021 for the NT1 activity.

Personnel

Currently the NT1 activity involves 11 people from 7 partner organisations as summarized in the following [Table 5](#):

Partners	NeIC FTE	In-kind FTE
HPC2N (SE)	0.5	1.2
UiB (NO)	-	1
UiO (NO)	1.75	1
CSC, HIP (FI)	0.75	0.4
NSC (SE)	1	1.2
LU (SE)	0.5	-
NBI (DK)	1	1
Total:	5.5	5.8

Table 5. NT1 Personnel per partner.

The core of NT1 personnel costs is related to Tier-1 operations, covering system administration tasks, the liaison to CERN, the Tier-1 security officer, central management tasks and additional local help for tendering and administrative processes. The NeIC share is backed up with equally skilled manpower at the local sites with responsibilities like batch or cloud computing, storage, local networking or local communication. Not all sites need to offer these services.

Some personnel efforts are spent in development activities for services that are extensively used by the NT1, such as SGAS, ARC or dCache.

SGAS (Swedish Grid Accounting System) is an accounting system for maintaining a grid-wide view of the resources consumed by members of a virtual organization on compute and storage. As the name suggests, it was originally developed in Sweden, but was soon taken into use by other national initiatives elsewhere as well (e.g., Finland, Norway). NeIC funds most of the development activity for SGAS since October 2013.

The NorduGrid Collaboration coordinates the development of ARC as an open source project. The collaboration is based on a Collaboration Agreement³⁹ with 11 institutes involved. Some of these institutes are part of NT1, e.g., UiO, NBI. A party of the NorduGrid Collaboration commits itself to contribute to at least one of the activities listed in the agreement like development, maintenance and support of the ARC middleware or promotion of ARC. NT1 has a leading role in the ARC project because it is critical to its operations and NT1 contributes actively to development, testing, validation and steering of the project.

The dCache project provides an open-source storage software solution and is a joint venture between the Deutsches Elektronen-Synchrotron (DESY), the Fermi National Accelerator Laboratory, FNAL and the Nordic e-Infrastructure collaboration, NeIC / NT1. Today dCache is widely used by nine Tier-1s and many Tier-2 centres around the world. As of today, the dCache developer team consists of six persons at DESY, two at Fermilab and one at NeIC. In the past 20 years more than 50 individuals have contributed to the code base. NT1 contributes to the development of dCache mainly to support the high availability setup with federated distributed storage resources for reduced overhead and better quality of service. These contributions are quite visible and thanks to them some sites like TRIUMF and KIT Tier-1s have shown to provide better resource utilisation and efficiency.

Other expenses are travel and meeting costs for internal coordination, WLCG management and coordination and workshops.

Central services and Network

Part of the Tier-1 running costs is spent for the central NT1 services hosted at NORDUnet, as well as the main WAN network connectivity of NT1. These costs are ~3.2 MNOK/year.

Resources at sites

The basis for the NT1 facility for the WLCG is that the Nordic member countries contribute resources in the form of hardware, hardware operations and maintenance and dedicated national network costs. The hardware resources like tape storage, disk storage and computing cycles are acquired and hosted by the existing computing centres through other national sources. The Tier-1 hardware purchases are funded by research grants coordinated by HEP (ALICE and ATLAS) user communities. These computing needs are normally included as part of global LHC research project applications that are submitted to calls from national R&D programs. These projects include funding requests for LHC Physics, detector upgrades and computing resources for Tier-1, including some personnel needs. Projects are typically granted for periods of three to four years. Additional computing funds may be obtained by dedicated infrastructure grants, in some of the countries. Investments are typically done once during the execution time of the projects.

This section provides an estimation of the total costs for running the NT1, with costs breakdown per categories and countries in [Table 6](#), for a better understanding of the NT1 funding structure. Most of this information has been obtained from the stakeholders by survey, cf. [Appendix D: NT1 Survey](#) and the last evaluation report⁴⁰. Some of the

³⁹ <http://www.nordugrid.org/documents/NorduGrid-Agreement-2011.pdf>

⁴⁰ https://wiki.neic.no/w/ext/img_auth.php/6/66/NT-1-Evaluation-report.pdf

(unavailable) data has been estimated. This estimate gives a total budget of ~31 MNOK/year including the NeIC budget (~11 MNOK/year).

Countries	Physical location (Disk, Tape, Compute with share for ATLAS & ALICE)	Fundings	Budget (Hardware purchase, personnel, electricity)
Denmark	HPC facilities at the Niels Bohr Institute (NBI) for disk, tape and compute	Public grants covering ~35% of the total Tier-1 costs at the site	1 MDKK/year
Finland	CSC and HIP for disk, tape and compute ALICE runs on the cPouta ⁴¹ cloud service	public grants HIP budget for operational costs. Academy of Finland public grants for investments. CSC resources by academic grants to HIP.	~800k€/year ~200k€/year
Norway	University of Bergen (UiB) Compute: NREC ⁴² Disk: NREC Tape: UiB	Public grants from Research Council of Norway, in particular from the Nuclear Physics (HENP) and Particle Physics (HEPP) programs, fund the ALICE and ATLAS Tier-1 activities	ATLAS: ~2.5 MNOK/year Alice: ~2 MNOK/year Split 50-50 for hardware purchases and personnel
	University of Oslo (UiO) Compute: NREC + Opportunistic Disk: UiO Tape: UiO		
Sweden	HPC2N CPU: Kebnekaise Disk: HPC2N Tape: HPC2N	Public funds obtained by the Swedish LHC Consortium (LHCK) and distributed to the centres through SNIC	6.7 MSEK split 50-50 between HPC2N and NSC, Cover the Tier-1 hardware purchases, part of the Tier-1 personnel, and some of the running costs, including the WAN network connectivity
	NSC CPU: bluegrass Disk: NSC Tape: NSC		

⁴¹ <https://research.csc.fi/-/cpouta>

⁴² <https://docs.nrec.no/>

			costs for the centers.
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Table 6. Summary of the current NT1 resources, fundings and budgets per Nordic country.

National contributions to CERN, i.e., membership fees for NT1 countries

CERN membership fees are based on the GDP.

For NT1 countries, excluding Slovenia, the rounded 2021 contributions are:

DK: 21 MCHF, FI: 16 MCHF, NO: 27 MCHF, SE: 30 MCHF⁴³.

The respective 2020 numbers were: DK: 20 MCHF, FI: 15 MCHF, NO: 26 MCHF, SE: 30 MCHF.

The CERN membership fees emphasize the importance that the countries place on this area of research and these fees are much greater than the operations cost of NT1. It's worth noticing that, as discussed later in this document in Relevance and inclusion in national roadmaps, the fees are among the largest items in the respective funding agencies budgets, e.g., in Sweden it certainly was, the ESS (European Spallation Source) in Sweden is growing above it lately.

Provisional NT1 Budget increase in view of the HL-LHC area and future needs

For our future support of the High Luminosity LHC, It is vital to retain and preserve the current competence and expertise for maintenance, operations and support at the same level as today. Moreover, we cannot assume that scientific computing technology evolution will solve the HL-LHC challenges and problems, so demonstrating the scalability of NT1 with the necessary software upgrades in ARC, dCache and SGAS is critical and needs urgent attention.

For the WLCG major upgrade computing program, the ARC software must be extended with the set of authentication, computing and data orchestration services enabling Exabyte scale data delivery to computing resources. dCache to look towards the challenges of the High Luminosity LHC will require a better integration with network zones to optimise data placement and operations in the NT1 data lake model. SGAS must be extended with open source monitoring and analytics features to profile NT1 performance and bottlenecks. A constant and active participation in the relevant WLCG working groups and activities like data Challenges to evaluate changes and alternatives at scale must be possible.

The proposed expansion of NT1 would naturally benefit other scientific communities, most notably in climate and health sciences, and will help to expand the NT1 service catalog, e.g., meta scheduler gateway service.

⁴³ <https://cdsweb.cern.ch/record/2747920/files/English.pdf>

National commitments and partnerships or associated efforts

The work done at NeIC (NeIC NT1) provides the governance structure, interacts with the Nordic user representatives, coordinates six computing sites in the Nordic region and manages the central operations and middleware deployment for the Nordic Tier-1.

The NLCG committee as reference group

The Nordic LHC Computing Grid (NLCG) Steering Committee is a NeIC body that ensures availability of resources in accordance to the LHC experiments requirements and oversees CERN-related activities, such as Nordic Tier-1 implementation and interactions with ATLAS, and ALICE experiments at CERN. The Committee is governed by the [Appendix E: Terms of Reference for NeIC Nordic WLCG \(NLCG\) Committee](#) approved by the NeIC Board.

The NLCG committee consists of members appointed by the national bodies coordinating LHC contributions, including representatives of relevant research communities and infrastructures adding up to a total of two members per country. NLCG Committee meetings are held quarterly, 4 times a year.

Relevance and inclusion in national roadmaps

NeIC NT1 is seen as a highly relevant activity for national High Energy Physics communities, significantly contributing to the LHC physics exploitation. In general one can say that the plan is to keep the funding on at least the same level as today, including the NeIC part, since the national funding agencies have a long time commitment towards CERN. Denmark, Norway and Sweden are among the 12 founding members of CERN (since 1956), and together with Finland, that joined CERN in 1991, are fully committed to support the LHC research program. LHC is one of the cornerstones of national research strategies in these countries, and its high-luminosity upgrade, the HL-LHC, is a Landmark on the ESFRI Roadmap. Through membership contributions, CERN and its experiments, including LHC, is a national research infrastructure in Nordic Countries located abroad, similarly to e.g. the Nordic Optical Telescope located in Spain.

FI, NO and SE specifics are as follows, no input has been received from DK.

FI

Finland supports the continuation of heavy ion collisions at the LHC beyond 2029. In general, the funding for the computing and detector developments is mainly expected to come from Finnish Research Infrastructures (FIRI) calls issued by the Academy of Finland, as has been the case previously.

Finnish contribution to NT1 is realised by Helsinki Institute of Physics (HIP). In the long-term strategy of the HIP it is stated that the main focus of HIP in the coming decade will be to fully

exploit the participation in the LHC experiments. To this end the WLCG resources and detector R&D are essential.

Currently the main research focus is on three of the LHC experiments: ALICE, CMS and TOTEM, in which Finnish scientists are making significant contributions to ultra-relativistic heavy ion physics, new physics searches, standard model measurements and forward physics. Currently, the full physics exploitation of these, including their preparations for the high luminosity LHC (HL-LHC), constitute the highest priority of the Finnish high-energy physics community.

Computing and data access are an integral part of this physics exploitation. HIP participates in the Worldwide LHC Computing Grid (WLCG) through the Nordic Tier-1 and the HIP Tier-2 (T2_FI_HIP) centers⁴⁴. Securing and developing further the WLCG resources will be essential if we are to take full advantage of the LHC data. The Finnish Grid and Cloud Infrastructure (FCCI) collaboration is crucial for developing and maintaining the necessary national grid infrastructure. Collaboration with CSC is important in being able to satisfy the needs of the data intensive LHC computing.

NO

The Norwegian contributions to the distributed Tier-1 centre is financed through the funding mechanisms for the CERN/High Energy Physics activities, with major parts of the funding coming through the NFR Infrastructure programme. Currently resources for ALICE are located at the University of Bergen, whereas resources for ATLAS are located at USIT/UiO.

ALICE/ATLAS computing requirements are mainly focussed on high volume/high throughput computing, pointing to operating clusters of well equipped COTS computers to be the most cost effective solution. Prior to the previous investment, detailed discussions with the national HPC groups were conducted, concluding that colocation with the national HPC centres in Tromsø and Trondheim would be a more expensive solution at that stage.

With the ever increasing demands for LHC computing, but the technical and political developments should be followed closely, to select the most efficient way (both with respect to hardware and operations) to fulfill our requirements at the lowest possible cost.

The current infrastructure project will last to 2022. The final computing investments for ALICE (in this funding round) is planned for autumn 2021. A funding application for the next period is currently being handled by the Research Council of Norway.

SE

The Swedish contribution to NT1 is financed by the Swedish Research Council (VR) through the LHC Consortium (LHCK) consisting of ALICE and ATLAS groups in Lund, Stockholm and Uppsala Universities and the Royal Institute of Technology. LHCK coordinates investments and operation of e-infrastructure for the participation in WLCG, including funding for NeIC. The responsibility for investment and operation of the resources available in Sweden is handled via SNIC.

⁴⁴ <https://www.hip.fi/wp-content/uploads/2020/11/HIP-Long-Term-Strategy.pdf>

The current round of funding is ending in 2023 for the LHCK and in 2022 for SNIC. The planning for the next funding cycle is in its beginning and with the increasing demands for WLCG resources it is vital that all is working well on all levels. The plan is to keep the funding on at least the same level as today, including the NeIC part, since VR has a long time commitment towards CERN.

Nordic added value

The Nordic Added Value concept has been developed in the framework of NeIC strategy work over the years 2019-2020. The major elements of Nordic added value for NeIC activities are: enabling excellence in research, adding value to the Nordics beyond national capabilities in e-infrastructure, enhancing sustainability and integration by sharing infrastructure or data or harmonising systems for utilising data and other resources in the Nordic region and acting as a global role model for e-infrastructure collaborations.

NeIC provides added value for research through the Nordic WLCG Tier-1 and by facilitating development and use of e-infrastructures. Seamless integration and interoperability of services and sharing of capabilities across national borders enabled scientists to conduct the research in a new way. Through joint Nordic development of services NT1 not only enables agile software development and minimised redundant investments but also ensures that the researchers have access to the data and other resources they need for their research also across the borders.

By combining the independent national contributions through synchronised operation, the total Nordic contribution reaches a critical mass with higher impact, saves costs, pools competences and enables more beneficial scientific return by better serving large-scale storage and computing needs.

All NeIC projects and activities, including the NT1, have broader impacts on society, e.g. by contributing to competence development within the Nordic region and beyond (Slovenia, other Tier-1 sites, etc.). As of today, NT1 directly supports more than 150 researchers in the Nordics (ATLAS and ALICE authors) and roughly double this number indirectly (theoreticians, making physics model predictions verified by ALICE, ATLAS and other LHC experiments).

The NT1 contributes in the long-term to the Nordic Council of Ministers Vision 2030⁴⁵, according to which the Nordic Region will become the most sustainable and integrated region in the world. The three cornerstones of this vision and NT1 contribution to these are:

- A competitive Nordic Region - promoting green growth in the Nordic Region based on knowledge, innovation, mobility, and digital integration
 - The construction of Nordic Tier-1 was decided to provide a contribution to the LHC total to advance the research in the Nordic. Nordics were the one among

⁴⁵ <https://www.norden.org/en/information/action-plan-vision-2030>

the sites which established the system in the earlier phase with excellent credibility. According to researchers using the NT1, because of these earlier achievements, they had quite a bit of recognition in computing in general, that helped obtain the competitive advantage at least within ALICE and ATLAS collaboration

- A green Nordic Region - promoting a green transition of our societies and work towards carbon neutrality and a sustainable, circular, and bio-based economy
 - The NT1 partner institutions which contribute the NT1 resources in terms of computing and storage are systematically seeking ways to be more 'green' and are forerunners in the efforts to reduce the carbon footprint of supercomputers
 - The goal is full climate neutrality. Powering the supercomputers with renewable energy, using free cooling, and re-use of waste heat are examples of measures that are taken. For example, the eco-efficient datacenter, placed in Kajaani, Finland, aims to run with zero or even negative carbon footprint by using 100% renewable energy and by efficient waste heat usage (the waste heat can heat up to 20% of the houses of the surrounding city), while still hosting one of the fastest HPC systems in the world.
- A socially sustainable Nordic Region - promoting an inclusive, equal, and interconnected region with shared values and strengthened cultural exchanges and welfare
 - xtNT1, as a NeIC project, adhere to NeIC values and HR policy, which promotes equality and diversity, including equal opportunity in employment practices without discrimination on the grounds of race, religious beliefs, colour, gender, sexual orientation, disability, place of origin, age, marital status, or family status.

Relevance beyond the region

International effort with Nordic component

NT1 operates a Nordic Tier-1 service supporting the LHC research programme. The main objective of NT1 is to deliver continuously sufficient production resources towards the WLCG – the large international e-infrastructure built to provide computing and storage for CERN until the agreed end, which according to the WLCG Memorandums of Understanding is LHC lifetime plus 15 years. The NT1 by contributing its share to the WLCG resources enables High Energy Physics research for the scientists in the Nordics.

Seamless integration and interoperability of services and sharing capabilities across borders enables scientists to conduct research in a new way and to solve new types of research problems.

Role that NT1 plays in High Energy Physics research

NT1 is currently one of 10 ATLAS and 8 ALICE Tier-1 sites. Given that ATLAS has 50 member countries, and ALICE - 39, it is clear that NT1 plays a very important role in High Energy Physics Research. The particular significance of a Tier-1 site is that it provides custodial tape storage, thus ensuring long-term data preservation. The Nordic Tier-1 stands out because of its highly resilient distributed design: indeed, we avoid single points of failures and can provide non-stop operations. Sharing our technological solutions with other WLCG sites has been a part of our daily activities. Nordic Tier-1 is highly regarded not only for its reliability and innovation, but also for the assistance we offer to other WLCG community members. Support of ARC and dCache development further increases the international role of NT1. Complementary to HTCondor⁴⁶, ARC is now the only European computing interface in WLCG. The highly available and distributed setup of dCache at NT1 is also a reference within WLCG.

NT1 through its contribution to the WLCG is participating in the experiments with the largest data analysis in the world and grid-computing which is one of its kind in a sense world-wide communications. It is acknowledged in all scientific papers produced by the experiments, ALICE example: "The ALICE Collaboration gratefully acknowledges the resources and support provided by all Grid centres and the Worldwide LHC Computing Grid (WLCG) collaboration."

NT1, as well as other WLCG Tier-0, -1 and -2 computing and data sites, is preparing to meet the challenges posed by the High-Luminosity upgrade of the LHC. Thanks to our long-standing commitment to innovation, NT1 has a potential to pave a way for developing novel services to respond to the challenges. The role of NT1 in High Energy Physics computing can become even more pronounced by exploring natural synergies with the activities around LUMI supercomputer - NT1 has contributed significantly to first discussions aiming at seamless usage of LUMI resources by the High Energy Physics community, and through ARC and dCache development contributed to the first successful run of ATLAS workloads on the EuroHPC Vega system.

⁴⁶ <https://research.cs.wisc.edu/htcondor/>

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Appendices

Appendix A: NT1 Collaboration agreement

Collaboration agreement

Between

NeIC represented by NordForsk (NO ID: 971 274 255), Stensberggata 25, NO 0170 Oslo, Norway – hereafter referred to as the “Project owner” and

NICE, the National Instrument Center for CERN Experiments in Denmark,

HiP, the Helsinki Institute of Physics,

the **Norwegian CERN project board**

and

LHCK, the Swedish LHC Consortium.

The project owner and the other above organisations are hereafter referred to collectively as the “partners”, or a “partner” (singular).

1 The agreement - scope and purpose

- 1.1 This collaboration agreement regulates the reciprocal rights and obligations of the various partners taking part in the Nordic WLCG Tier-1 facility, hereafter referred to as the “NT1” or the “activity”.
- 1.2 The following attached documents shall also be part of this collaboration agreement:

Appendix 1:	A description of the NT1 framework.
Appendix 2:	The partners’ interest in and competence relative to the NT1.
Appendix 3:	The partners’ obligations to perform activity and/or provide financial resources to the NT1.
Appendix 4:	Sharing Principles
Appendix 5:	Terms of reference for the steering group
- 1.3 Each of the partners shall make their best efforts to contribute resources to the implementation of the activity pursuant to the duties and obligations specified in this collaboration agreement and Appendix 1 and Appendix 3. With regard to one another, each partner bears responsibility for implementation of the duties and obligations specified in this collaboration agreement and in Appendix 1 and Appendix 3 specified for the partner.
- 1.4 This collaboration agreement enters into force when signed by all parties. The terms of the present collaboration agreement coincide with those of the bilateral MoUs¹ between CERN and the National agencies regulating the National WLCG commitment, i.e., its initial validity is five years after the initiation date, after which its validity shall be extended automatically for a period of five years, and until the LHC programme is declared closed by the CERN Council.
- 1.5 This collaboration agreement in no way challenges, contradicts or annuls the different bilateral WLCG MoUs with CERN regulating the respective National WLCG commitments and has to be seen complementary to those MoUs in defining the collaboration and synchronisation of resource contributions among the partners. In case of conflict the National WLCG commitments will take precedence over this agreement.

¹ This document shall specify the individual partners’ obligations to perform work within the NT1 and/or to provide contributions in the form of funding, infrastructure, expertise and its own efforts.

² For a sample MoU please refer to <http://wlcg.web.cern.ch/collaboration/mou>

2 Governance and Management

- 2.1 The NT1 will have a steering group³, a reference group and an activity manager.
- 2.2 The steering group monitors the activity's progress and responds to problems as needed. The terms of reference for the steering group are given in Appendix 5.
- 2.3 Each of the partners is entitled to appoint one member to the steering group. The partners may unanimously agree to appoint additional members of the steering group. One steering group member may represent several partners. Partners are free to replace steering group members, but are required to keep the activity manager apprised of who is representing the partner. The chair of the steering group is assigned by the project owner.
- 2.4 The activity manager will be appointed by the project owner. The activity manager reports to the steering group. The activity manager is responsible for managing the activity and its resources in accordance with this agreement and the guidelines given by the steering group. When appropriate, the project owner enters into a separate agreement with the employer of the activity manager in a way that does not violate the terms of this agreement.
- 2.5 The activity manager will summon the steering group to meetings with reasonable notice, usually no less than two weeks prior to the meeting date. The convening letter should be accompanied by an agenda and the documentation needed to deal with the items on the agenda. Decisions, recommendations and discussions of the meetings are recorded in proceedings that are made available to the partners.
- 2.6 The steering group has quorum when more than half the members are present or participate in the steering group's deliberations. The steering group's decisions will normally be agreed on unanimously among the members that are present or participate in the steering group's deliberations. In ongoing matters that do not affect any of the partners' individual rights under the collaboration agreement, the steering group may take decisions by majority. Voting rules may be refined and approved unanimously by the steering group. When a unanimous decision or consensus is not possible, the meeting proceedings will reflect the diversity of opinions.
- 2.7 The reference group successively ensures the acceptability of the overall NT1 service offering. The reference group advises the Steering Group concerning the design and functionality of the NT1 to ensure successful operation of the NT1 service and the pledged capacity and performance of the e-Science infrastructure committed by the Nordic countries to WLCG. The reference group therefore identifies issues pertinent to the NT1 success and proposes appropriate actions.

3 Partners' activities and/or financial support

- 3.1 The interests and competencies of the partners constitute the basis for their participation in the NT1. These interests and competencies are described in more detail in Appendix 2.
- 3.2 Each of the partners shall make their best efforts to perform the activities, if any, that the partner in question has undertaken pursuant to Appendix 1, and/or provide the financial support specified in Appendix 3 and in accordance to the bilateral MoUs with CERN regulating the National WLCG commitments.
- 3.3 With the approval of the steering group, a partner may assign parts of the activities for which it is responsible to an appropriate subcontractor. This does not release a partner from its obligations to the other partners.
- 3.4 In the event a partner does not perform the agreed activities in a satisfactory manner, as well as on request by a partner who expects to be unable to perform in such a way in the future, the steering group may decide to transfer responsibility for the work in whole or in part to one or more of the other partners, based on

³ Larger collaborations may find it productive to have a collaboration forum with membership from all the partners and a smaller steering group that consists of selected representatives.

specified terms and conditions, given consent of the partner or partners to whom the responsibility is transferred. Such a transfer does not release a partner from its other obligations pursuant to Appendix 3.⁴

- 3.5 The NT1 budget is established yearly according to Appendix 3 and 4. The project owner will remind the partners about their funding obligations if needed. Money streams are following the budget (Appendix 3) and eventual transferred responsibilities (cf. section 7.4). Payments between the partners are made once per three or per four months as agreed between the partners.

4 Location, responsibility for human resources and agreements with employees and other affiliated partners

- 4.1 The partners agree to establish by contract the location of the activities and the manner in which the employer's responsibility will be handled for staff affiliated with the activity. Under normal circumstances, employer responsibility and employment shall not be changed for employees who participate in the activity.
- 4.2 The partners will sign necessary agreements with owners, employees (including individuals with dual employment), partners, sub-contractors, and others that are required to fulfil the relevant partner's obligations under this agreement, including measures to ensure the necessary transfer of intellectual property rights.

5 Framework, ownership, reporting and publication of results

- 5.1 The activities are governed by the LHC and WLCG planning as provided by CERN, on one hand, and by the individual partners' maintenance and upgrade plans, on the other. The activity manager is assisted by the reference group in creating and maintaining a cohesive service offering, as outlined in Appendix 1.
- 5.2 Partners shall without undue delay submit all activity results, reports, accounting documentation and other documents that the project owner requires to fulfil its obligations to its funding authorities.
- 5.3 Activity outcomes, including reports and software, will be made openly available to the public. Attribution is done according to applicable branding policies. Unless otherwise agreed in writing, any equipment purchased for the purposes of the NT1 will remain the property of the partner making the purchase.
- 5.4 Intellectual property rights on documentation, software, models, data – anything a partner brings to the collaboration – remain with that partner.

6 Limitation of liability

- 6.1 The parties have no liability towards each other for damages or losses of any kind related to this collaboration agreement, unless the damages were caused by wilful conduct or gross negligence. Each partner shall be solely liable for any loss, damage or injury to third parties resulting from its actions under this collaboration agreement or from its use of the activity results.
- 6.2 In respect of any information or materials supplied by one partner to another under the activity, no warranty of any kind is given as to the sufficiency or fitness for purpose, nor as to the absence of any infringement of any proprietary rights of third parties. The recipient party shall in all cases be solely liable for the use to which it puts such information and materials.

⁴ It is presumed that the partners can agree on reasonable compensation for the research contributions from which the consortium participant in question has been relieved.

7 Reservations and termination

- 7.1 The agreement may be terminated by either partner for any material breach by the other partners of the obligations set out in the agreement, by giving a written notice to the other partners of the intention to terminate. The notice shall include a detailed statement describing the nature of the breach. If the breach is remedied within a period of 30 – thirty – days after delivery of the notice, the termination shall not take effect.
- 7.2 The partners' compliance with funding requires that the partners receive the necessary funds from their respective authorities. A partner that cannot comply can terminate this agreement with an 18 –eighteen– months' notice in accordance with the bilateral MoUs with CERN on the National WLCG commitment.
- 7.3 The project owner may terminate the agreement with an 18 –eighteen– months' notice based on a recommendation of termination by the steering group.
- 7.4 For withdrawal, the following procedure will apply:
 - 1. If any partner considers it necessary to withdraw its participation, it will promptly, and with a notice of no less than 18 –eighteen– months to the effective date, notify the other partners and the matter will be subject to immediate consultation among the partners to enable them to fully evaluate the consequences;
 - 2. the withdrawing partner will continue its participation financial and otherwise, until the effective date of withdrawal;
 - 3. The withdrawing partner will take all the necessary actions within its control to ensure that the project can be continued by the remaining partners; This includes especially the transferral of data of which one partner as a unique copy or unique permanent backup copy to avoid the loss of data as also regulated in the bilateral MoUs with CERN on the National WLCG commitment.
 - 4. the withdrawing partner will be liable for two types of costs:
 - a. its share, in accordance with the financial responsibilities as described in Appendix 3 up to the effective date of withdrawal; and,
 - b. all direct costs arising as a result of the withdrawal, including costs of any contract termination or modification caused by the withdrawal; the partners will endeavour to keep all direct costs of withdrawal as low as possible.
 - 5. the total contribution by the withdrawing partner, including withdrawal costs, will in no event exceed the amount the withdrawing partner would have contributed had it remained in the project.

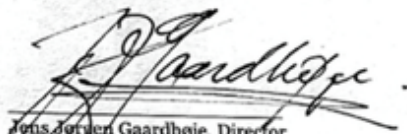
8 Governing law and legal venue

- 8.1 The agreement is governed by and shall be interpreted in accordance with Norwegian law. Any disputes shall be settled by the NeIC Board, and if not possible, the issue can be brought to Oslo district court, unless otherwise agreed between the partners.

This agreement has been prepared in five (5) counterparts, of which each partner keeps one (1).

For and on behalf of NICE

Place/Date:



Jens Jørgen Gaardhøje, Director
NICE

For and on behalf of HIP

Place/Date: Helsinki
8.4.2020



Katri Huitu, Director
HIP

Place/Date: Helsinki/8.4.2020



Antti Väihkönen, Research Coordinator
HIP

For and on behalf of the Norwegian CERN project committee:

Place/Date: Oslo, 2 April 2020



Morten Dælen, Head
Norwegian CERN project board

For and on behalf of LHCK

Place/Date: *Stockholm 2020-05-07*

Bengt Lund-Jensen
Bengt Lund-Jensen, PI
LHCK

For and on behalf of NordForsk/NeIC:
Place/Date: Oslo 18/5-20

A handwritten signature in blue ink, reading "Arne Flåøyen", enclosed in a thin black rectangular box.

Arne Flåøyen, Director
NordForsk

Appendix 1: The Nordic Tier-1 facility framework

Four Nordic countries (Denmark, Finland, Sweden, and Norway) participate in the Worldwide Large Hadron Collider Computing Grid (WLCG), which analyses and stores the immense amounts of data generated by the particle physics experiments at CERN, an infrastructure that is expected to run until at least 2038.

The basis for a Nordic Tier-1 facility for the WLCG is that the Nordic member countries contribute with resources in the form of hardware, hardware operations and maintenance and dedicated national network costs. The establishment of the Tier-1 and relevant operational requirements are formalized through bilateral Memorandums of Understanding (MoUs) between each national funding agency and CERN [Ref 2].

The synchronized operation of this set of national contributions in the form of a Nordic Tier-1 service within WLCG forms the independent national resource contributions into a framework for sustainable and coherent operations.

By combining and cultivating the different National resource contributions, the total Nordic contribution can reach a critical mass which enables a higher impact and a more beneficial scientific return. A common technical coordination of the total contribution through a Nordic Tier-1 saves cost and pools competencies across the four countries.

The technical implementation of the Nordic Tier-1 has been excellently performed by first the Nordic Data Grid Facility (NDGF), and since 2012 as part of the Nordic e-Infrastructure Collaboration (NeIC) under NordForsk. The Nordic Tier-1 service is a NeIC core activity, in accordance with the 10-year Memorandum of Understanding on Nordic e-infrastructure collaboration [Ref 3] signed by the national funding agencies and NordForsk.

The developed unique expertise in running a physically distributed but common Tier-1 facility is expected to be very valuable for future methods of analysing large amounts of data. More centralised alternative options were investigated but those wouldn't be as beneficial for the competence development, the redundancy and reliability as depicted in the evaluation report by Dr Josep Flix [Ref 1, 4-5] conducted in 2016.

1 Objective

1.1 Idea

The Nordic Tier-1 service contributes to the Large Hadron Collider (LHC) physics programme and to high-energy physics research in general by coordinating efforts and procedures to achieve efficient, coherent, predictable and sustainable national contributions to the Nordic Tier-1 and by operating the Nordic Tier-1 facility for the Worldwide LHC Computing Grid (WLCG).

1.2 Objective

The main objective of the Nordic Tier-1 is to deliver continuously sufficient production resources towards WLCG until the agreed end, which according to the WLCG MoUs [Ref 3] is LHC lifetime plus 15 years.

The minimum success level of the NT1 is defined by WLCG MoU fulfilment of the participating Nordic countries.

Mission: Operating a high-quality and sustainable Nordic Tier-1 service within the WLCG.

1.3 Priority of the objective

Priority	0.7	Result	0	Time	0.3	Cost
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1.4 Limitations

The resources (computing and storage hardware components, dedicated national networks as well as operational staff) are provided by national efforts, the NT1 activity just coordinates these into a coherent service, but does not fund or purchase them. For exact details on NeIC's contribution, consult Appendix 3.

Besides the contributions to a common Tier-1, the NT1 collaboration partners may also contribute to national Tier-2s with reduced service levels, however this is outside of the scope of the NT1-service which concentrates on the Tier-1 contributions. For details, consult Appendix 4.

2 Organisation

2.1 Activity organisation

The Tieto Practical Project Steering (PPS) model is applied within NeIC with good practical experience since 2014. Ideas and practical experience from this model are mixed with the long lasting, well-established, tested and adapted procedures since the very start of the Nordic Tier-1 collaboration in 2006.

2.2 Authority and responsibility

The proposed structure is a continuation of the currently applied structure with a very small technical and operational steering group and the historically well established NLCG committee that acts as a reference group within the applied Tieto PPS model.

Steering group

The NT1 Steering Group (SG) monitors the NT1 operational activity and responds to problems as needed (see also 2.2 in the Collaboration Agreement). It's composition is regulated in 2.3 in the Collaboration Agreement. The terms of reference for the SG are given in Appendix 5. All SG minutes are public.

Current composition of the NT1 SG:

Name / Organisational reference	Partner	Role	Active from - until
Michaela Barth, PDC-HPC	NeIC	Chair, representing the owner	2017-06-01 -
Oxana Smirnova, HEP, LU	NeIC	representing Nordic LHC community, representing CERN experiments	2017-06-01 -
Mattias Wadenstein, HPC2N	NeIC	Secretary, activity manager, representing operational management	2017-06-01 -

The NLCG committee as reference group

The Nordic LHC Computing Grid (NLCG) committee consists of members appointed by the national bodies coordinating LHC contributions, including representatives of relevant research communities and infrastructures adding up to a total of two members per country [Ref 8]. The Chair is elected for one year at a time and the duty is rotating between countries. The NLCG committee can appoint observer members whenever it is deemed necessary. NLCG Committee meetings are held 3-4 times a year with minutes being kept internal.

Current composition of the NLCG committee:

Name	Cty	Email	Role
Farid Ould Saada	NO	Farid.Ould-Saada@fys.uio.no	Experiments
Håvard Helstrup	NO	Haavard.Helstrup@ift.uib.no	Experiments
Jørgen Beck Hansen	DK	beck@nbi.ku.dk	Experiments
Josva Kleist	DK	kleist@cs.aau.dk	Infrastructure
Sebastian Von Alfthan	FI	sebastian.von.alfthan@csc.fi	Infrastructure
Mattias Wadenstein	SE	maswan@ndgf.org	Ex officio, Activity leader
Michaela Barth	SE	caela@pdc.kth.se	Ex officio, Activity owner
Mikael Rännar	SE	mikael.rannar@umu.se	Infrastructure
Oxana Smirnova	SE	oxana.smirnova@hep.lu.se	Ex officio, Secretary
Richard Brenner	SE	richard.brenner@physics.uu.se	Experiments
Tomas Lindén	FI	Tomas.Linden@Helsinki.fi	Experiments

3 Working methods

Day to day operation of the central services and the distributed systems includes responding to incidents, user requests and site questions. It also includes database operations, troubleshooting, and tuning as well as monitoring, automation, testing, and validation of services. One fundamental aspect of NT1 work is to act as an interface to our users. This includes taking care to resolve any issues promptly and to everyone's satisfaction but also taking part in conversations on how to serve the needs of the LHC experiments even in the future. The resulting continuous adaptation and improvement of the distributed Tier-1 is of highest importance in order to be able to guarantee a sustainable high-quality infrastructure answering it's users needs for the whole lifetime of the Worldwide LHC Computing Grid. Operational procedures are well established already since the NDGF era. Documentation on operational procedures is kept in the NeIC internal wiki [Ref 6] with meeting minutes going all the way back to 2006.

As for all NeIC activities the NeIC HR policy [Ref 7] applies encouraging competence development and regular development dialogues. The activity manager of the NT1 is part of the community of project managers and project owner representatives with regular (bi-weekly) meetings and two Face-to-Face meetings per year and NT1 is invited to the annual NeIC All Hands meeting and biannual NeIC conferences. The management meetings between the NT1 activity manager and the project owner representative are scheduled weekly. The technical and operational meetings are held on a weekly basis in written form over an agreed-on communication platform.

The NT1 staff and the collaborating site managers meet twice a year physically at dedicated all hands meetings.

Sharing keys on the expected national contributions are established in negotiations with each of the supported CERN experiments as described in Appendix 4. NeIC's contribution consists of making those national contributions a coherent service offering towards the supported experiments.

The contribution requirements and sharing keys are monitored by NLCG and serve as a basis for national Tier-1 funding applications. These keys apply to the following resources: tape storage, disk storage and processing capacity. Operational costs and network costs are derived from these, depending on applicable technologies and service levels. For details on NeIC's contribution, consult Appendix 3.

4 Resources and Equipment

Besides manpower the following resources are needed to guarantee a successful NT1 service provision:

- Central servers
- Backups
- Auxiliary servers
- Networking
- Collaboration resources

The total amount of servers maintained within the NT1 is about 50 hosts and about 80 distributed storage pools.

5 Benefit

NT1, as part of WLCG collaboration, has benefited multiple publications already since (and prior to) founding NeIC. The three-year average of the number of publications NT1 has benefited by providing a share of the infrastructure for two LHC experiments, ATLAS and ALICE, increased 2011–2017 (Figure 1).

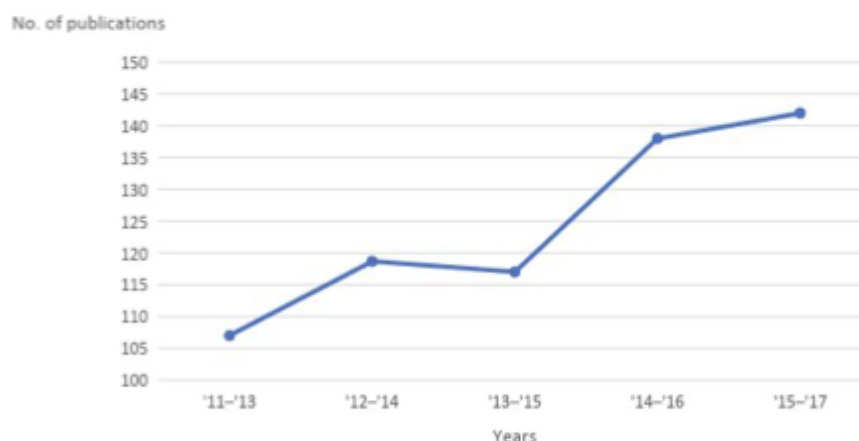


Figure 1: The three-year average of the publications benefited from NT1 and its support for LHC experiments ATLAS and ALICE. The number of publications in 2018 is 157 for ALICE and 557 for ATLAS.

6 Phase out and conclusion

Phase out and conclusion will be planned for at the end of the LHC. The WLCG is expected to run until at least 2038 with exact dates still being unknown. According to the MoU with CERN [Ref 2] we are obliged to conserve data until the end of LHC lifetime plus 15 years.

7 Risks

The NT1 risk analysis is found at [Ref 9].

References

No.	Document name/ designation/Id	Edition, date
1	"Investigating options for future Nordic WLCG Tier-1 operations" https://doi.org/10.5281/zenodo.2029970 (evaluation report by Dr Josep Flix)	10.5281/zenodo.2029970 , 2016
2	Bilateral Memorandums of Understanding between each national funding agency and CERN http://wlcg.web.cern.ch/collaboration/mou	
3	10-year Memorandum of Understanding on Nordic e-infrastructure collaboration https://wiki.neic.no/wiki/ext/img_auth.php/4/49/130506-NeIC-MoU-signed-by-all.pdf	2013
4	https://wiki.neic.no/wiki/Investigating_options_for_future_NT1_operations_project_directive Project directive for the NT1 evaluation	2016
5	https://neic.no/news/2016/07/05/nordic-model/ (NeIC news report on evaluation done by Dr J. Flix)	2016
6	NeIC internal wikipedia https://wiki.neic.no/int/	2012
7	NeIC HR policy https://wiki.neic.no/wiki/NeIC_HR_Policy	2017-05-03
8	Terms of Reference NLCG committee https://wiki.neic.no/wiki/File:NLCG-ToR-2019.pdf	2017
9	NT1 Risk analysis https://docs.google.com/spreadsheets/d/1HbksqLYcNZYknNn4K_e9xkgus9iD8TEjvR5N5A_jDVY/edit#gid=1970198157	2018

Appendix 2: The partners' interest in and competence relative to the activity

Background and rationale for the collaboration:

Fundamental research in subatomic physics is one of the most important strategic scientific directions worldwide. Indeed, detailed knowledge of subatomic processes is key to our understanding of matter and thus is essential in emerging new technologies. Moreover, it is key to our understanding of the Universe, and latest studies on e.g. Quark-Gluon Plasma and Dark Matter using the Large Hadron Collider (LHC) reveal a wealth of new knowledge on how our world evolves. Scientific knowledge obtained with the help of LHC complements other results, such as, astrophysical observations, neutrino experiments, and most recently, gravitational wave observations. Together they constitute a fundamental basis of human knowledge and culture, the strategic importance of which is impossible to underestimate. While much of the relevant infrastructure is located elsewhere, the Nordic countries host the Nordic Tier-1 data center, a significant part of the LHC experiments, that stores and processes a share of the LHC experiment data. This center came into operation together with the LHC and is expected to continue operating until the end of the LHC and High Luminosity LHC (HL-LHC) physics program with obligations reaching 15 years beyond that.

The partners are described in the following:

- NeIC** (the Nordic e-Infrastructure Collaboration) was funded in its current form in 2012 by national research funding organisations in Denmark, Finland, Iceland, Norway and Sweden. The vision of NeIC is to facilitate the development and operation of high quality e-infrastructure solutions in areas of joint Nordic interest.

The collaboration originated from the Nordic Data Grid Facility (NDGF). NDGF began as a pilot project in 2003 and resulted in the innovation and successful deployment of the first distributed Tier-1 computing and storage service (NT1) within the WLCG collaboration. A 10-year Memorandum of Understanding was signed by the national funding agencies in 2013 as part of a larger vision for Nordic e-Infrastructure Collaboration (NeIC). The legal representative of and hosting organisation for NeIC is NordForsk, which is an organisation under the Nordic Council of Ministers. The scope of the Nordic e-Infrastructure Collaboration has grown to encompass a broad range of scientific application areas as areas of collaboration on e-infrastructure. This came about through the implementation of the Nordic eScience Action Plans and from responses to open calls for Letters of Interest by national e-infrastructure providers and Nordic research groups with clear e-infrastructure needs. NT1 remains as a core NeIC activity.

After 13 years of providing world-class service, the Nordic Tier-1 has fine tuned its processes while continuously technologically renewing itself. By working at the forefront of technological development, the Nordic Tier-1 continues to function as a global role model. It provides added value to the Nordic region through the effects and impact of its services and benefits realization.

NT1 remains an intrinsic part of NeIC's renewed strategy for 2020-2025. The new strategy emphasizes beneficial collaborations, motivated people, efficient processes and Nordic influence. Tapping the full potential of beneficial collaborations, the opportunity exists for the Nordic Tier-1 to evolve into a multidisciplinary distributed facility that highlights the depth of skills and capabilities within the region. NeIC plans to make use of the tremendous asset of the collected expertise and experience within the Nordic region and NeIC projects and activities to allow for expansions into other data-intensive sciences.
- HIP**, the Helsinki Institute of Physics is a physics research institute that is operated jointly by the University of Helsinki, Aalto University, the University of Jyväskylä, the Lappeenranta-Lahti University of Technology, and the Tampere University. The research activity at the institute covers an extensive range of subjects in theoretical physics and experimental subatomic physics. The mandate of the institute is to carry out and facilitate research in basic and applied physics as well as in physics research and technology development at international accelerator laboratories. The institute is responsible for the Finnish research collaboration with CERN. Also, the institute coordinates the Finnish contribution

to the FAIR laboratory (Facility for Antiproton and Ion Research) currently under construction in Darmstadt, Germany.

- **NICE** is the National Instrument Center for CERN in Denmark. The purpose of NICE is to support and promote the utilization of CERN and its accelerator, technical and scientific infrastructures by Danish researchers, students and others and make possible their participation in experiments and R&D at CERN.

About 125 Danish researchers and graduate students use CERN, either directly as members of the experiments or work on theory related to CERN physics.

NICE is a 'følgforskingscenter' (research follow-up center) that presently operates on the basis of a grant from the Agency for Science, Technology and Innovation under the Ministry of Higher Education and Science (hjemmeside@ufm.dk).

Since Denmark, as one of the founders of CERN, ratified the CERN convention⁵ in 1953, targeted funding has been provided to ensure optimal usage and exploitation of the Danish CERN membership. Initially the 'følgforskning' was an item on the national budget. From the late 1990'ties to 2013, NICE (and its precursor organizations) operated under DFF (the Danish Council for Independent Research). Since 2014 NICE operates under the Agency for Science, Technology and Innovation with guidance from the NUFI committee ([Nationalt Udvalg for Forskningsinfrastruktur](#)).
- The **Norwegian CERN project board** consists of relevant deans and department heads from the Universities of Oslo and Bergen, representatives from other Norwegian research institutions engaged in research at CERN, and a student representative.

The board coordinates the Norwegian activities associated with research and scientific activities at CERN and is party to agreements with CERN on the size and content of Norwegian contributions to the operation, maintenance and upgrade of the experiments at CERN and related e-infrastructure.

The board is responsible for setting overall goals, principles, priorities and strategies for Norwegian CERN activity in consultation with the academic environments and in line with guidelines from the Research Council of Norway and governmental authorities.

The Norwegian CERN project board is represented in a number of bodies of strategic interest such as the LHC Resource Review Board (RRB) at CERN.
- **LHCK**, the Swedish LHC Consortium, was created in 1997 as a collegial organization, not governed by the Swedish Science Research Council. LHCK is led by a board consisting of the PIs of Swedish High Energy Physics (HEP) groups at Uppsala University, Stockholm University, KTH and Lund University both for ALICE and ATLAS. Since its start LHCK successfully provides national planning and coordination in their field including submitting national plans for operation and investments, e.g. for the development and deployment of a Swedish national Grid Test bed (SweGrid) in 2003 and all previous and current Swedish resources used within the NT1. LHCK is also represented in a number of bodies of strategic interest such as the Strategic Technical Committee of the Swedish National Infrastructure for Computing (SNIC), the ATLAS, ALICE and Computing Resource Review Boards (RRBs) and the LCG Overview Board at CERN.

⁵ <http://council.web.cern.ch/council/en/governance/convention.html>

Appendix 3: Budget and resources

Each partner contributes with resources to the Tier-1 independently, and in accordance with the WLCG MoU⁶. Harmonization is done through the NLCG Committee of NeIC. The partners contribute to a common Tier-1 but may also contribute to national Tier-2s, with reduced service levels. For details, consult Appendix 4. Here only the Tier-1 contributions are of concern. These contributions consist of hardware components and their maintenance and operation, as well as dedicated national network costs. Note that the related costs evolve with time, reflecting the LHC data taking cycles, and are country-dependent, being proportional to numbers of LHC researchers in each country, as described in detail in Appendix 4.

The Flix evaluation⁷ included an external cost evaluation for the Nordic Tier-1 site and concluded that the distributed model worked well at a reasonable cost compared to other WLCG Tier-1 sites.

The NLCG committee is the body to coordinate and advise the national partners in their national funding applications in relation to their WLCG commitment in order to ensure the pledged capacity and performance of the e-Science infrastructure committed by the Nordic countries to WLCG so a successful operation of the joint NT1 is achievable.

NeIC generally contributes towards making the national contributions a coherent service offering towards ATLAS and ALICE and guarantee the technological front-runner role of the Nordic countries even in the future. This includes but is not restricted to:

- providing manpower for Tier-1 coordination and CERN liaison,
- standing for staff for operation of the central services, while the remaining partners jointly stand for operational staff at the included centra. The NeIC part corresponds to 50% of the total operational staff cost.
- contributing to software development needed for Tier-1 operations, such as funding key ARC coordinators, a dCache developer, SGAS maintenance and the like, plus acting as a pilot use case in further relevant Nordic collaboration projects,
- facilitating relevant user support,
- providing a travel and meeting budget for Tier-1 meetings and related networking and outreach, including representation in Tier-1 governing activities, such as the WLCG bodies (workshops, Grid Deployment Board Management Board and Collaboration Board), CERN's Scientific Computing Forum, and other operations-related meetings, including CHEP, HEPiX and experiment-specific computing bodies.
- when necessary, legal and administrative support services are provided through NordForsk as a host institution⁸.

While national network connectivity is the responsibility of each national partner (including the coverage of network costs inside the country), it lies within the responsibility of NeIC to ensure the internordic network and connectivity to CERN and other WLCG Tier-1 centers as required by the WLCG MoU. This is done by covering costs related to international network connectivity in compliance with the WLCG MoU, namely:

- network service costs between the Nordic countries and international network connectivity costs to CERN and the rest of the WLCG,

⁶ <http://wlcg.web.cern.ch/collaboration/mou>

⁷ <https://doi.org/10.5281/zenodo.2029970>

⁸ See again mentioned 10-year MoU ("Document 1" as well as official NeIC governance documents https://wiki.neic.no/w/ext/img_auth.php/d/dc/15-16-01-NeIC_Governance-mandate.pdf ("Document 2", referred in https://wiki.neic.no/w/ext/img_auth.php/1/13/17-22-01-NordForsk-NeIC-interaction.pdf and presented to the NeIC Board in June 2017.

- participation in LHCONE⁹ and LHCOPN¹⁰ projects,
- related software and hardware for the required central services and
- 24/7 Tier-1 service operations coverage¹¹.

The needed overall (national and international) network capacity follows the LHC experiments' requirements, is monitored annually by NLCG, as is the overall compliance with the WLCG MoU. As of January 2020, NeIC has two-year service interval agreements for networking and central services with NORDUnet and smaller additional contracts as needed. Total operations manpower is also revisited annually by the NLCG committee in order to match the annually redefined Nordic contribution to storage and processing capacity. NT1 hiring is done according to competencies, not country location.

The 2019 NT1 central manpower is listed as an example:

2019 Budget (FTE)	NeIC
NT1 Manager and CERN interface	1.3
Remaining operations	3.5
Software R&D (ARC, dCache, SGAS)	1.5
NeIC Total	6.3

The NeIC budget for NT1 furthermore includes dedicated costs for NT1 related travel and meeting costs, as well as costs to cover NeIC's responsibility for the international part of the WLCG related network.

Total NT1 manpower in 2019 comprised of about 12.5 FTEs including operational staff and additional software development at the remote HPC centra. Functions include responsibilities for the covered services and interactions. Most of these have a primary and secondary skilled expert assigned as responsible. Along user requirements the exact technical details for service provision will change over time and follow available technology change. The tasks include:

- LHC data storage central operation (running large-scale (> 20 PetaByte) production and pre-production instances, central management of storage pools, High-Availability storage provision)
- Operator on Duty (rolling duty answering tickets, reacting to alarms, defining and assigning new issues, preparing and holding regular technical meetings,...)
- Accounting and database management
- Monitoring, logging and debugging visualisation, as well as publishing available resources
- Automatization and basic infrastructure services
- WLCG project participation including engagement towards ATLAS, ALICE, EGI and HEPiX
- Site Security Officer role and security in general
- Maintenance and development of software needed for operating the NT1 (at the moment dCache, dCache additions and ARC)
- NeIC community services (wiki, group chat for every day communication)

⁹ <http://lhcone.web.cern.ch>

¹⁰ <http://lhcopn.cern.ch>

¹¹ on-call coverage outside of the prime shift is a specified requirement in the CERN MoU for Tier-1 sites (Annex 3.2). It asks for an adequate level of staffing for the services and defines maximum response times for taking action to actually repair any arising incident. A formal first line support able to only solve a certain type of pre formalized tasks which can be replaced by intelligent automatization is not considered sufficient.

The NeIC share is backed up with equally skilled manpower at the local HPC sites (+ Slovenia) with responsibilities typically as follows:

- Batch or cloud computing with ARC-CE frontend
- Tape library (fair share of operations) and tape frontend pools
- Disk pools (hardware and operating system)
- Local networking
- Communication, meetings, etc.

Not all sites need to offer all services. From experience, underinvesting in operations for those services impacts reliability and increases workload for the rest of the NT1 team.

Appendix 4: Sharing Principles

In order to analyse and store the vast amounts of data on the ExaByte scale generated at the four big experiments at the Large Hadron Collider at CERN, a worldwide computing grid, referred to as WLCG, has been established. WLCG is a wide distributed computing and storage infrastructure, consisting of a hierarchy of nodes, with the top-level Tier-0 node being at CERN, currently 13 Tier-1 nodes covering different geopolitical regions, and a large number of Tier-2 (and Tier-3) nodes at research institutions worldwide. Provision of Tier-0, Tier-1 and Tier-2 services is regulated by the WLCG MoU, signed between CERN and national governments or equivalent bodies. Each of the four experiments (ALICE, ATLAS, CMS and LHCb) has its share of the computing and storage resources pledged by contributing countries. The Nordics are involved in three of the four experiments according to Table 1 below.

Table 1. The grid involvement of the Nordic countries in the LHC experiments.

	ALICE	ATLAS	CMS
Denmark	Tier-1	Tier-1	
Finland	Tier-1		Tier-2*
Norway	Tier-1	Tier-1	
Sweden	Tier-1, Tier-2	Tier-1, Tier-2	

*operated with limited assistance from NeIC as a part of the EGI NGI_NDGF, but out of scope of this document

The Nordic countries contribute jointly with the continuous maintenance and operation of one of the Tier-1s. In addition, Sweden and Finland contribute with Tier-2s. The Nordic Tier-2 nodes are interconnected both functionally and hardware wise to the Nordic Tier-1 by shared infrastructure and software, as well as by the operational procedures within EGI. However, the present sharing principles concern only the Tier-1.

The Nordic Tier-1 supports ALICE and ATLAS experiments at CERN. According to CERN principles, sharing keys depend on the number of scientific authors in each country, per experiment. All contributions are estimated annually. Exact sharing keys are established annually in negotiations with ALICE and ATLAS.

Each year, the experiments estimate their requirements for computing and storage services at Tier-0, Tier-1s and Tier-2s, and these estimates are subject to an international review by funding agency representatives in the WLCG Resources Scrutiny Group. When mutually agreed, they become official requirements sent out to all the contributing countries, which then pledge their shares of the required resources towards the experiments. Substantial negative deviations of any Tier-1 contribution would cause significant problems for the experiments and will impede their research programs. Therefore, it is imperative to sustain the negotiated target pledge levels, with an eventual possibility of minor adjustments on a case-by-case basis.

It should be noted that at the time of writing infrastructure funds from the contributing national agencies are available on a per-project basis, and thus depend on timing and conditions of national funding cycles. As a result, funds for annual pledges are at times delayed, reduced, or occasionally not granted altogether by individual agencies. Tables 2 and 7-9 below illustrate the consequence in 2018: while disk pledges are above the targets, CPU and tape pledges are below. It is our goal to reduce such discrepancies.

Table 2. The Nordic share of the total Tier-1 resources in 2018. Negotiated targets in 2018 were 9% for ALICE and 6% for ATLAS.

Tier-1	ALICE	ATLAS
CPU	9%	5%
Disk	13%	7%
Tape	5%	5%

The share of each country is derived from the official Maintenance and Operations (M&O) shares established yearly by CERN experiments at the beginning of October. For each institute, M&O tables list researchers, PhD students and senior engineers who qualify for inclusion as authors of the respective experiment's publications. Authorship rules are different in ALICE and ATLAS, therefore it has been agreed to calculate ALICE share from the overall M&O authors, and ATLAS - from the proportion of Nordic authors. Since these numbers fluctuate, for the purposes of M&O cost estimates, the average over three preceding years is calculated: the contribution for year n is based on the tables from year $n-2$, $n-3$ and $n-4$, since pledges must be made by the end of September of year $n-1$. The numbers for Nordic contributions to ALICE and ATLAS experiments are shown in Tables 3-6 for 2015, 2016 and 2017, as well as the average share for 2015 - 2017 as used in the 2019 pledges.

Tables 3-6. Example of author share calculation for 2019 pledges, based on the average M&O contribution for ALICE and author numbers for ATLAS in years 2015-2017

M&O and authors (2015)			M&O and authors (2016)			M&O and authors (2017)			Average 2015-2017		
	ALICE	ATLAS		ALICE	ATLAS		ALICE	ATLAS		ALICE	ATLAS
DK	8	15	DK	7	14	DK	7	15	DK	1.18%	14.7
FI	6	0	FI	7	0	FI	8	0	FI	1.13%	0.0
NO	19	30	NO	17	27	NO	19	24	NO	2.95%	27.0
SE	4	55	SE	4	49	SE	5	52	SE	0.70%	52.0
TOTAL	620	100	TOTAL	615	90	TOTAL	628	91	TOTAL	5.96%	93.7

Using these author numbers, each country is expected to contribute according to the following keys:

ATLAS: $0.06 \times \text{ATLAS}(\text{Tier-1-required}) \times \text{AuthorsAverage}(\text{ATLAS-country}) / \text{AuthorsAverage}(\text{ATLAS-Nordic})$

ALICE: $(\text{ALICE}(\text{Tier-1-required}) + \text{ALICE}(\text{Tier-2-required})) \times \text{M\&OAverage}(\text{ALICE-country}) / \text{M\&OAverage}(\text{ALICE-all})$

While ALICE contribution is estimated by ALICE for each country and covers both Tier-1 and Tier-2 needs, ATLAS contribution from Nordic Tier-1 is agreed at 6% of overall ATLAS Tier-1 needs¹², which is then split among countries in proportion to ATLAS authors¹³.

Tables 7-9. The details of the provided contributions for 2018 are shown in the tables below. For comparison the shares agreed with ALICE and ATLAS experiments are included.

CPU (kHS06)	2018 Tier-1	ALICE		ATLAS		Total			
		Share	Provided	Share	Provided	Share	Provided	Deviation	
	DK	4.68	6.69	8.70	6.69	13.38	13.38	0%	
	FI	5.70	5.68	0.00	0.00	5.70	5.68	0%	
	NO	13.89	12.36	16.81	13.44	30.69	25.80	-16%	
	SE	3.36	2.90	31.44	27.10	34.80	30.00	-14%	
	TOTAL	27.63	27.63	56.94	47.23	84.57	74.86	-11%	

Disk (PB)	2018 Tier-1	ALICE		ATLAS		Total			
		Share	Provided	Share	Provided	Share	Provided	Deviation	
	DK	0.46	0.56	0.66	0.56	1.12	1.12	0%	
	FI	0.57	0.65	0.00	0.00	0.57	0.65	15%	
	NO	1.38	2.50	1.28	2.00	2.65	4.50	70%	
	SE	0.33	0.33	2.39	2.39	2.72	2.72	0%	
	TOTAL	2.75	4.05	4.32	4.95	7.07	8.99	27%	

Tape (PB)	2018 Tier-1	ALICE		ATLAS		Total			
		Share	Provided	Share	Provided	Share	Provided	Deviation	
	DK	0.62	1.21	1.79	1.21	2.41	2.41	0%	
	FI	0.76	0.00	0.00	0.00	0.76	0.00	-100%	
	NO	1.85	0.20	3.45	2.28	5.30	2.48	-53%	
	SE	0.45	0.45	6.46	6.46	6.91	6.91	0%	
	TOTAL	3.68	1.85	11.70	9.94	15.38	11.80	-23%	

¹² https://wiki.nordforsk.org/w/int/img_auth.php/3/3c/CP7832159-Principles.pdf

¹³ Prior to 2018 a similar procedure applied to ALICE

Appendix 5: Terms of Reference for the NT1 Activity Steering Group

Definitions

1. The **steering group** (SG) is the decision-making authority to which activity management turns regarding issues for which it does not have the right to make a decision. It consists of decision-makers representing NeIC as the activity owner and representatives of the Nordic LHC community and CERN according to 2.3 in the Collaboration Agreement.
2. The activity **manager** (AM) carries out the operations and its result within the framework of the activity plan. Responsibilities include (among other things) ensuring that the organisation and working methods are suitable, documented and clear; maintaining an active requirements dialogue with the NLCC reference group; providing regular progress reports for the NT1; and leading the operational work toward increased effectiveness, continuously improving routines and processes; and continued stable operation providing high-quality services.
3. The **activity plan** is a consensus between operational management and the activity owner, covering the daily operation. Working from the activity plan ensures that all essential issues are agreed upon and documented. Measurement of success is done via KPIs. The activity plan includes a benefit description and availability, capacity, budget, service, support incident, problem and change management thoughts. Short term development is handled in separate roadmaps. The activity plan is drafted by the activity manager and approved by the steering group.

The NT1 operational activity is governed by a steering group as described above which is chaired by the NeIC representative. The steering group has the following responsibilities:

Contributing to the mission of the NT1 activity, by

- Understanding and communicating the expected benefit.
- Ensuring that the operation reaches the Key Performance Indicators defined in the activity plan and fulfills obligations towards CERN on behalf of the participating Nordic countries.
- Making decisions in steering group meetings.
- Actively supporting the operational programme management.
- Being the formal link between the operational activity and CERN and other involved stakeholders, like the national e-infrastructure providers.
- Making decisions regarding issues where operational management has no authority.
- Approving the activity plan and any additional deliverables as described in the regular roadmaps.
- Monitoring the programme and approving NT1 availability reports.
- Approving issues arising from change management
- Understanding the responsibilities associated with the task and reserve sufficient time to execute them.

Being the formal link entails between the operational activity and CERN and other involved stakeholders:

- Identifying changed prerequisites.
- Taking care of effects in home organisations.
- Priorities and connections to other projects and activities.
- Securing outer dependencies of the activity, outer prerequisites outside the authority of operational management.

Actively supporting operational management entails:

- Marketing the NT1 and acting as its ambassador.
- Being available, and acting as a "sounding board" between steering group meetings.

- Staying constantly informed about the activity's status.
- Provide contacts to other communities.

NeIC coordinates the activity. Activity coordination includes the responsibility to find an adequate activity manager being able to carry out the agreed work.

The operational activity manager will summon the SG to meetings with reasonable notice, usually no less than two weeks prior to the meeting date. The convening letter should be accompanied by an agenda and the documentation needed to deal with the items on the agenda. Decisions, recommendations and discussions of the meetings are recorded in proceedings that are made available to the steering group members and made public after approval. The AM will announce the availability of the minutes by email, either by sharing the URL or providing a PDF copy. Comments on and amendments to the minutes should be raised within two weeks of that email.

The SG may at their own discretion invite observers. With a unanimous decision a major stakeholder (who agrees to deliver something to the activity) may become a full member of the steering group. With unanimous decision they may be given a voting right.

In its first constituting meeting, the steering group has revised its tentative terms of reference – including the voting rules for any decisions to be taken:

Meetings

The SG employs two meeting means to come to decisions: physical and/or virtual meetings (video/phone/chat), and email conversations. In general, these meeting means shall be mutually exclusive.

Meeting Chair

The SG chair usually chairs the meeting, but can delegate the chairing of the whole meeting or individual agenda items to another person being present. If the SG chair is not present, the SG selects a meeting chair among the ones being present.

Quorum & Delegation

The SG has quorum to take decisions if the simple majority of its members participate in a meeting. SG members can exceptionally send a delegate to SG meetings, with the condition that the delegate has authority to make decisions on behalf of that partner.

Decisions

A full quorum is required for the steering group to take decisions. Revising and approving the terms of reference for the steering group requires an unanimous decision by the steering group members being present. For all other decisions, the steering group should strive for consensus, but may reach decisions by voting. In these cases, each partner gets a single vote, and simple majority is required for any decision. In case of a tie, the AM gets an additional vote. When an unanimous decision or consensus is not possible, the meeting proceedings will reflect the diversity of opinions. The SG may postpone decisions.

Decision Procedures

Physical and Virtual Meetings

The proposed decision is stated clearly by the person chairing the agenda item. In physical meetings, votes ("yes", "no", "abstention") are cast orally. In virtual meetings, votes ("yes", "no", "abstention") are cast via audio or a chat function of the meeting service being used.

Email Conversations

The originally proposed decision is written in an email from the SG chair or the AM to all SG members and the AM. Within typically five (5) working days, the SG and the AM can debate the proposed decision. Thereafter, the SG chair or the AM proposes a revised decision in an email to all SG members and the AM, and the SG members have typically five (5) working days for voting ("yes", "no", "abstention"). If a SG member doesn't vote within a given deadline, it is not counted for the quorum.

Appendix B: WLCG Publications

10/05/2021

WLCG Publications - neicint

WLCG Publications

Contents

Status of Publication Summaries

ALICE Publications

ATLAS Publications

Source Code

Status of Publication Summaries

We are currently pulling these numbers from a site which will likely go away soon. The numbers can also be found on the new INSPIRE site, searching for ATLAS (<https://inspirehep.net/literature?sort=mostrecent&size=25&page=1&q=cn%20atlas#with-citation-summary>) and ALICE (<https://inspirehep.net/literature?sort=mostrecent&size=25&page=1&q=cn%20alice#with-citation-summary>). There may be a new solution on the way (<https://github.com/inspirehep/rest-api-doc/issues/3>).

ALICE Publications

Year	Citable Papers				Published Papers			
	Papers	Cit.	Avg.Cit.	h_{HEP}	Papers	Cit.	Avg.Cit.	h_{HEP}
1995	0	0	0.0	0	0	0	0.0	0
1996	2	74	37.0	2	0	0	0.0	0
1997	1	0	0.0	0	1	0	0.0	0
1998	1	131	131.0	1	0	0	0.0	0
1999	11	517	47.0	10	5	169	33.8	5
2000	7	128	18.3	5	3	37	12.3	2
2001	17	77	4.5	5	10	75	7.5	5
2002	4	104	26.0	2	0	0	0.0	0
2003	13	170	13.1	7	4	99	24.8	4
2004	9	176	19.6	5	5	70	14.0	4
2005	17	86	5.1	3	6	25	4.2	2
2006	18	76	4.2	5	8	58	7.2	4
2007	9	38	4.2	4	3	22	7.3	2
2008	21	137	6.5	5	5	13	2.6	2
2009	25	321	12.8	5	13	307	23.6	5
2010	40	3889	97.2	10	12	3800	316.7	9
2011	107	2744	25.6	23	13	1671	128.5	11
2012	153	6902	45.1	31	72	6507	90.4	31
2013	134	10287	76.8	41	46	9834	213.8	40
2014	158	5249	33.2	28	53	4899	92.4	28
2015	167	4873	29.2	41	51	4644	91.1	41
2016	187	4342	23.2	37	51	4010	78.6	37
2017	222	2717	12.2	29	44	2232	50.7	28
2018	165	2263	13.7	28	58	2000	34.5	28
2019	234	1839	7.9	26	78	1560	20.0	26
2020	186	713	3.8	15	53	614	11.6	15
2021	34	50	1.5	4	9	42	4.7	4

10/05/2021

WLCG Publications - neicint

This table was generated from INSPIRE (<http://old.inspirehep.net/?ln=en>) 2021-05-01 05:50:03 by publish-inspire-summary.

ATLAS Publications

Year	Citable Papers				Published Papers			
	Papers	Cit.	Avg.Cit.	h _{HEP}	Papers	Cit.	Avg.Cit.	h _{HEP}
1992	3	0	0.0	0	0	0	0.0	0
1993	3	4	1.3	1	0	0	0.0	0
1994	7	774	110.6	3	0	0	0.0	0
1995	4	0	0.0	0	1	0	0.0	0
1996	13	1082	83.2	6	4	50	12.5	3
1997	17	1913	112.5	8	4	33	8.2	2
1998	13	562	43.2	4	0	0	0.0	0
1999	6	1659	276.5	3	1	20	20.0	1
2000	9	122	13.6	4	3	46	15.3	2
2001	5	75	15.0	2	2	75	37.5	2
2002	6	133	22.2	4	2	117	58.5	2
2003	11	359	32.6	5	7	34	4.9	3
2004	17	363	21.4	8	4	111	27.8	4
2005	16	513	32.1	6	3	144	48.0	3
2006	24	246	10.2	5	3	217	72.3	3
2007	32	361	11.3	8	5	263	52.6	4
2008	101	664	6.6	8	8	513	64.1	6
2009	204	674	3.3	9	7	26	3.7	4
2010	262	9723	37.1	42	37	5277	142.6	27
2011	415	19561	47.1	71	88	11042	125.5	60
2012	483	38172	79.0	91	152	30141	198.3	79
2013	307	23864	77.7	88	147	19754	134.4	81
2014	293	19646	67.1	78	125	18623	149.0	77
2015	350	22062	63.0	85	156	21740	139.4	85
2016	555	18469	33.3	72	162	18008	111.2	72
2017	416	14554	35.0	68	138	14082	102.0	68

https://wiki.neic.no/int/WLCG_Publications

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10/05/2021

WLCG Publications - neicint

2018	516	11580	22.4	64	152	11352	74.7	64
2019	475	5965	12.6	43	134	5735	42.8	43
2020	313	2469	7.9	28	96	2325	24.2	28
2021	78	283	3.6	10	25	250	10.0	10

This table was generated from [INSPIRE \(http://old.inspirehep.net/?ln=en\)](http://old.inspirehep.net/?ln=en) 2021-05-01 05:49:13 by `publish-inspire-summary`.

Source Code

See [File:Publish-inspire-summary.txt](#) for a snapshot of the source code used to generate the above tables.

Retrieved from "https://wiki.neic.no/w/int/index.php?title=WLCG_Publications&oldid=68369"

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Appendix C: Project plan, mini Onboarding New Communities within the NT1

Project plan, mini Onboarding New Communities within the NT1

<The project plan describes the project's commitment and the plan for execution>

The plan is an agreement between the project owner/orderer <name> and the project manager <name>.

It is verified through a steering group decision.

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1 Objective

1.1 Background and project idea

<Briefly describe the background and formulate the project idea, i.e. the link between the expected benefit and the project objective. The expected benefit, i.e. the benefit intended to be achieved within the customer's organisation, should be found in the project directive.>

Fundamental research in subatomic physics is one of the most important strategic scientific directions worldwide. Indeed, detailed knowledge of subatomic processes leads to understanding of matter in its various states and thus is essential for emerging new technologies. Moreover, it is key to our understanding of the Universe, and latest studies on e.g. Quark-Gluon Plasma and Dark Matter using the Large Hadron Collider (LHC) at CERN reveal a wealth of new knowledge on how our world evolves. Scientific knowledge obtained with the help of LHC complements other results, such as astrophysical observations, neutrino experiments, and recent gravitational wave observations. Together they constitute a fundamental basis of human knowledge and, importantly, our culture. Strategic importance of this is truly impossible to underestimate.

Modern fundamental research requires most advanced Big Science tools, such as particle accelerators of the LHC scale, or installations like the Square Kilometer Array Observatory (SKAO). While much of such research infrastructure is located elsewhere, the Nordic countries host the Nordic Tier-1 data center, a significant part of the LHC, that stores and processes a share of the LHC data. This center came into operation together with the LHC, and is designed to continue operating until the end of the LHC and High Luminosity LHC (HL-LHC) physics program in approximately 2038.

The need for the joint Nordic Tier-1 center implied a novel organisation that would coordinate this and other similar e-infrastructures. NeIC (the Nordic e-Infrastructure Collaboration) was funded in its current form in 2012 by national research funding organisations in Denmark, Finland, Iceland, Norway and Sweden. The vision of NeIC is to facilitate the development and operation of high quality e-infrastructure solutions in areas of joint Nordic interest. The legal representative of and hosting organisation for NeIC is NordForsk, which is an organisation under the Nordic Council of Ministers.

The collaboration originated from the Nordic Data Grid Facility (NDGF), which began as a pilot project in 2003 and resulted in the innovation and successful deployment of the first distributed Tier-1 computing and storage service within the Worldwide LHC Computing Grid (WLCG) collaboration. A 10-year Memorandum of Understanding was signed by the national funding agencies in 2013 as part of a larger vision for NeIC. Since then the scope of NeIC has grown to encompass a broad range of scientific application areas in response to Nordic research groups' clear e-infrastructure needs and with the national e-infrastructure providers as partners. Nordic Tier-1 (NT1) remains as a NeIC core activity.

Through many years of providing world-class service, the Nordic Tier-1 has fine tuned its processes while continuously technologically renewing itself. By working at the forefront of technological development, the Nordic Tier-1 continues to function as a global role model. It provides added value to the Nordic region through the effects and impact of its services and benefits realization.

NT1 as a project remains an intrinsic part of NeIC's renewed strategy for 2020-2025. The new strategy emphasizes beneficial collaborations, motivated people, efficient processes and Nordic influence. Tapping the full potential of beneficial collaborations, the opportunity exists for the Nordic Tier-1 to evolve into a multidisciplinary distributed facility that highlights the depth of skills and capabilities within the region.

NeIC plans to make use of the tremendous asset of the collected expertise and experience within the NT1 to allow for expansions into other data-intensive sciences. NeIC has already proven to be an excellent platform for bringing together various communities, and can therefore be instrumental in the extension of the Nordic Tier-1 into such a multidisciplinary distributed facility. Such a facility will amplify the depth of skills and capabilities within the Nordic region. NeIC could make use of the tremendous asset of the collected expertise and experience within the region and NeIC projects and activities to allow for expansions into other cross-border data-intensive sciences.

In the near to medium term future, other scientific communities and infrastructures with Nordic base or Nordic partners will likely need similar services as those developed for the LHC experiments. One such example could be the long-term data archival service for EISCAT_3D, where storage is required with a long service life-time. NeIC could propose to EISCAT_3D that NT1 provides hosting for the data archive and possibly other services. Broadening the user base could create cost-efficiencies for the communities and for NeIC.

While NT1 already offers a range of services, many of these rely on software developed and maintained by or for LHC user communities, such as dCache and Rucio for storage and data handling, ARC and aCT for workflow management, or VOMS for access control. Extending usage of these solutions to new communities will add to interdisciplinarity, and, conversely, adopting new solutions from other communities will enhance NT1 portfolio of services.

Project idea:

The key idea is onboarding new communities to expand the Nordic Tier-1 into a multidisciplinary cross-border distributed facility.

Such onboarding may involve several stages:

1. Attracting new communities by offering spare capacity – a low-hanging fruit.
2. Motivating new communities to contribute through application expertise and/or software – requires stronger involvement from the communities.
3. Engage new communities to a full extent, when they contribute to NT1 with new sites/nodes providing resources and operators, or acquire new hardware for the existing nodes – implies support on national levels.

In the context of this project, we aim to target the first stage only, while working towards progressive engagement of communities and more challenging objectives.

Projected Benefits:

For NT1:

- Keeping the NT1 **relevant, sustainable** and on the **technological forefront** and thereby also **attractive** to its staff.
- Opening a possibility to **expand** to new nodes, services and expertise, improving **resilience**.

For scientific communities:

- Tapping into NT1's pool of highly operational **effective processes** and **competence**.
- Get best practice support and adapted solutions at **less cost** and with **higher reliability** than doing so on their own.
- Ensuring **sustainability** of solutions thanks to a wider user base and community support.
- Profit of **knowledge exchange** and **synergies** with other communities.

1.2 Project objective

<Summarise the result that should be achieved at a certain time, and for which cost.

Describe also the balance in the project objective between the result/time/cost dimensions. The basis for this should be found in the project directive.>

Objective	Description	Priority
Result	At least one new research community makes use of NT1 services	First
Time	Pilot tests no later than 2022	Second
Cost	0 for NT1 (in-kind effort), 1.2+MNOK for users	Third

1.3 Limitations

<Clarify the project objective by describing what is not included in the result, i.e. what other projects, the orderer or line functions are responsible for, alternatively what will not be done at all.>

- Ideally, any new onboarded community should **contribute** with resources (human expertise, software, hardware) to NT1 in a manner similar to the existing user base. This however is a longer-term objective, only partially achievable in the foreseen time frame, especially in terms of hardware resources and/or new NT1 nodes.
- While existing LHC communities have software tools designed to interact with NT1, they are often application-specific and are not easily transferable to new use cases. Development of new tools for new communities may require significant effort on the part of NT1, ARC and dCache developers, as well as new users themselves. It is not clear to which extent this effort can be supported by new user communities, especially given that many communities lack well-defined practices with regards to research workflows and data handling.
- Limited spare capacity (mostly consisting of out-of-warranty servers) at the current NT1 is only sufficient for proof-of-concept tests and best-effort support, which may be not sufficiently attractive for new communities.
- Offering of more capacity or new services required by new communities may be limited by the lack of e-infrastructure funding among most research communities (except for the LHC ones).

1.4 Recipients and approval criteria

<Define for each delivery object who, or what organisation, will be the recipient when the project delivers and transfers the result.>

Below a list of potential communities of interest is given.

Other WLCG communities:

- CMS
- LHCb

NeIC internal communities:

- NICEST2

- Tryggve/Heilsa

Communities that have approached NT1 already:

- XENON
- IceCube
- EISCAT_3D

Other identified communities of interest with spread in the Nordics

- Belle II
- SKA (connection with LOFAR), (very active in Sweden, in Gothenburg)
- CTA (Partners in Norway, Finland, and Sweden including physics KTH)
- DUNE (Fermilab, Finland and Sweden partner, very few though)
- LIGO/Virgo
- HESS
- LDMX
- Simula 59
- ESS

Delivery object	Recipient, delivery	Recipient, transferral
User access granted to computing resource	IceCube	(opportunistic usage since 2019)
User access granted to computing resource	XENON	?
User access granted to storage resource	EISCAT_3D	(technical test during 2019)

<Describe also the approval criteria for the different delivery objects. Use an appendix if needed.>

- **User access granted to computing resource** – approved when users belonging to the community can execute at least one computational workflow at NT1. Requires user authorisation via X509. Typically involves application-specific software deployment. May involve development of a workflow submission utility. May involve SLA.
- **User access granted to storage resource** – approved when users belonging to the community can store and retrieve data sets at/from NT1. May require user authorisation via X509. May involve development of a data and metadata handling utility. May involve SLA.

2 Project schedule and costs

The low-hanging fruit that can be implemented during this mini-project is a demonstrator of a long-term data storage for a new community. It should be noted that actual data retention is subject to the data ownership policies in each community and is beyond NT1 control.

It is anticipated that the new community will need specific functionality or services not yet available with NT1. Development of such will depend on availability of community support, possibly via national grants. This uncertainty is included in the project schedule and costs below.

2.1 Milestones, decision points

<Describe key check points in the form of milestones and decision points. When required, a Gantt chart can be attached as an appendix. Use the PPS templates: "Project schedule" in PowerPoint (see "the Project plan, presentation template") and the "Schedule" in Excel.>

Defined milestones (MS) and decision points (DP):

Date	MS	DP	Description
2020-11-01	1	1	Mini-project investigator appointed, project kick-off.
2020-12-01	2		A contact list of candidate user communities is created, complete with names and contact details of relevant people (preferably PIs) (REPORT).
2021-01-31	3		Definition of the NT1 service catalog and the possible corresponding Service Level Agreements (SLAs). e.g., best effort, with inventory of available spare capacity, services and expertise and/or cost estimates where applicable (e.g., comparison to commercial cloud offerings) is completed (REPORT).
2021-XX-XX	1	1	Call for projects/new communities to apply to resource and service allocations.
2021-03-31	4	2	Examination of the applications and selection of the new projects. An agreement is formalised with a new user community and endorsed by existing resource owners when necessary (e.g. NLCG in case the offered resources were owned by NLCG PIs). Agreement may include draft SLA, AUP and mutual resource commitment (DOCUMENT).
2021-04-30	5		Analysis of new community needs (resource, software, expertise) is completed (REPORT).
2021-05-30	6	3	Access granted to first test users, functionality verified (e.g. file transfers), missing functionality and/or services identified (REPORT).
2021-06-30	7		Cost and effort estimates completed for the desired new functionality development and/or hardware acquisition, such as e.g. a database server or a dedicated workflow server hosted by the community (REPORT).
2021-09-30	8	4	Feedback received regarding further funding; decisions are made depending on the outcome: best-effort support continues in case of no funds, or new service development starts if the situation is favourable.
2021-10-31	9		Documentation of the services chosen to be offered to the new community is prepared (DOCUMENT).

2021-11-30	10		A demonstrator for a long-term scientific data storage tailored for the new community needs is operational (SERVICE).
2022-01-31	11	5	Draft CA is prepared for the new user community, similar to the NT1-NLCG CA (DOCUMENT). Mini-project is completed.

2.2 Project cost estimate

<Specify the number of hours and the expenses required to execute the project, preferably per work area.>

Work package/Calculation item	Hours	Cost
Interaction with user communities, requirement collection, agreements preparation, training and outreach	6 PM	360 kNOK
Technical support: access management, resource allocation, application software support, user support	2 PM	120 kNOK
Development of new services and tools (conditional on requirements and external funding)	12 PM	720 kNOK
Cost of operations for to run storage hardware after decommissioning from production use at one or more participant sites	-	40 kNOK
Total	20 PM	1 200 kNOK

3 Organisation

<Describe the project organisation, roles in the project and the names of those appointed.>

Role	Name
Steering group	NT1 SG
Project manager	To be appointed
Reference group	To be defined
Working group	?

4 Working methods

<If possible, always refer to documented working methods in the organisation. Describe only exceptions or additions to those methods, and also working methods that are specific for this project.>

Working methods will constitute a combination of well-established practices at NT1 and intense cooperation with the selected user community, similar to those pursued during development of services for the LHC community. A key aspect is identification of clear use cases with well-defined goals and time frame, like the LHC Data Challenges of increasing complexity.

4.1 Requirement dialogue and change control

< Describe how the stakeholders' expectations should be clarified, how the requirement dialogue and the work involved in establishing support will be carried out, and also how the project handles changes to the requirements. Who decides what.>

The stakeholders will be asked to appoint a contact person who will communicate to the mini-project leader. Use cases and other requirements collected by this contact person will be documented and the progress towards meeting the requirements will be monitored via an appropriate issue tracking system. Feedback from the stakeholders will be collected both via issue tracking system (on a daily basis), and during scheduled meetings. Technical decisions will be made collegially, involving both NT1 experts and stakeholders. Administrative decisions will be taken by the Steering Group together with the Project Manager.

4.2 Delivery and transferral

<Describe the procedure for delivery and approval, and also for transferral and approval. Appendices can be used for complex deliveries, in order to clarify details regarding packaging, delivery procedure and approval criteria (e.g. requirement and solutions descriptions).>

Delivery procedures will depend on the nature of the delivered product. Reports will be submitted to the Steering Group and approved (or otherwise) by it. Services will be delivered to the stakeholders by the means of providing access to the resources (X509 authorisation, currently) and a complete documentation pertaining to service usage. A formal approval will not be sought, instead, the stakeholders will be guided to report encountered problems and new feature requests via the issue tracking system.

4.3 Monitoring and learning

<Describe how monitoring will be carried out, at what intervals, and the forums that will be used. Describe the activities that the project has planned for continuous learning and lessons learnt, and also how this knowledge will be passed on to others.>

Responsibility for the mini-project monitoring lies with the Steering Group, which will meet on a regular basis (bi-weekly). The issue tracking system will be used to track the progress and status of implementation.

4.4 Information distribution

<Describe how the project information will be spread both internally and externally.

Information about the project progress will be delivered through the following channels:

- Stakeholder community meetings
- Resource owner meetings (e.g. NLCG)
- NeIC meetings (conference, All-hands)
- NeIC Web site

5 Risks

<Present the risks that have been identified during the preparation phase. Present also the measures that will be taken. If the risk profile is extensive, use the PPS template "Risk list".>

No.	Description of risk	Probability	Impact	Priority	Measure and person responsible
1	Low interest in NT1 services among approached communities	Medium	High	High	Prepare attractive description of service offering: PM
2	Lack of the necessary technical expertise in the new communities	High	High	High	Offer training and initial support using NT1 resources: SG
3	Lack of application-specific software tools that can be interfaced to NT1 services	High	High	High	Negotiate support from known software developers, and funding: SG
4	Insufficient performance or capacity of resources offered by NT1	Medium	Medium	Medium	Negotiate extra allocation from national resource providers, and eventual extra funding: PM

Edition history

<Specify the differences between the editions by describing the changes, as well as the purpose and reason behind them. Refer to any decisions if applicable.>

Edition	Date	Comment
0.1	2020-10-07	OS: first complete draft

Appendices

<List the appendices to the document. Documents defined as being appendices are included in the document, unlike references which only constitute a basis for information.>

Appendix D: NT1 Resources and funds survey

NT1 Survey

The Nordic Tier-1 (NT1), also known as NGDF, is internally evaluated for the coming NeIC Board meeting. Your input is needed, preferably by 2021-04-25, about the current computing and storage resources deployed by national infrastructure provider or institutes, and also about your readiness/plans regarding the necessary computing upgrade for the LHC RUN-3 (2022-2025) and the future data handling of High Luminosity LHC (2027-2030).

The estimate on ATLAS and ALICE computing demands in this survey are based on the inputs provided by the experiments.

For ATLAS, we assumed for the period 2022-2025 a sustained budget model with +10% resources capacity increases per year. For the period 2027-2030, the updated Computing Computing Conceptual Design Report [1] in view of the HL-LHC requirement provides some resource estimates with different scenarios which have been used to define the future storage and computing needs of NT1.

The ALICE experiment foresees a sustained budget model with +20% resources capacity increases per year for the same periods.

[1] <https://cds.cern.ch/record/2729668>

Questions:

1 - What are the current fundings (k€/year, public funds, period, in-kind, percentage) covering the cost of the hardware ? personnel ? electricity ? network ?

2 - What are the yearly electricity costs for the HPC center and the LHC needs?

3 - What are the costs of the network (LAN or WAN) per year?

4 - Do you have other possible maintenance costs ? If, yes. Can you describe them (description, yearly cost, etc.)?

5 - When will the fundings be renewed and which period will they cover ?

6 - Do you anticipate any problems regarding the estimates on ATLAS and ALICE computing demands for 2025 and 2030 (Cf. tables) ?

7 - Will you have enough physical space for the number of estimated disks/tapes/cpus required for the LHC computing upgrades ?

ATLAS: Approximately a factor 3/4 for 2025 and a factor 10/15 for 2030 (Cf. tables)

ALICE: Approximately a factor 2 for 2025 and a factor 5 for 2030 (Cf. tables)

Estimates on ATLAS and ALICE computing demands for 2025 and 2030

	Country	CPU [kHS06]	Disk [PB]	Tape [PB]
2021 (Now)	NT1 share	76.3	2.3	11.8
2025	NT1 share	259.1	9.5	29
	Swedish share HPC2N, NSC	148.1	5.4	16.6
	Danish share NBI	148.1	1.1	3.1
	Norwegian share UiO	83.3	4.1	9.3

Table 1: Estimate on ATLAS computing demands for 2025.

	Country	CPU [kHS06]	Disk [PB]	Tape [PB]
2021 (Now)	NT1 share	76.3	2.3	11.8
2030	NT1 share	1014.7	68.9	182
	Swedish share HPC2N, NSC	579.8	39.4	104
	Danish share NBI	108.7	7.4	19.5
	Norwegian share UiO	326.2	22.2	58.5

Table 2: Estimate on ATLAS computing demands for 2030.

	Country	CPU [kHS06]	Disk [PB]	Tape [PB]
2021 (Now)	NT1 share	55.41	5	5
2025	NT1 share	100.8	10.4	6.3
	Swedish share HPC2N, NSC	16.8	1.7	1,05
	Danish share NBI	19.6	2	1.2
	Norwegian share UiB	53.2	5.5	3.3
	Finnish share CSC	11.2	1.2	0.7

Table 2: Estimate on ALICE computing demands for 2025.

	Country	CPU [kHS06]	Disk [PB]	Tape [PB]
2021 (Now)	NT1 share	55.41	5	5
2030	NT1 share	250.9	25.8	15.6
	Swedish share HPC2N, NSC	41.8	4.3	2.6
	Danish share NBI	48.8	5	3
	Norwegian share UiB	132.4	13.6	8.2
	Finnish share CSC	27.9	2.9	1.7

Table 2: Estimate on ALICE computing demands for 2030.

Appendix E: Terms of Reference for NeIC Nordic WLCG (NLCG) Committee

Terms of Reference for NeIC Nordic WLCG (NLCG) Committee

Approved by the NeIC Board 16.12.2015. Adjustments approved by the NeIC Director 02.04.2019.

Background

The Nordic e-Infrastructure Collaboration (NeIC) facilitates development and operation of high-quality e-Infrastructure solutions in areas of joint Nordic interest. NeIC is a distributed organisation consisting of technical experts from academic institutions across the Nordic countries. The management of NeIC projects and activities are usually overseen by steering groups and stakeholders can be engaged through reference groups. The Nordic Tier-1 (NT1) service builds on the success of NDGF and is implemented through the NT1 activity. The NLCG Committee is a reference group to the NT1 activity and its members represent the LHC user community.

NT1 is responsible for operation and further development of ALICE and ATLAS Tier-1 Services and for supporting national Nordic ALICE, ATLAS and CMS Tier-2s within the framework of the Worldwide LHC Computing Grid Collaboration (WLCG).

Terms of Reference

The objective of this Committee is two-fold:

- To advise the NeIC Board on how to ensure successful operation of the Nordic Tier-1 Service, and
- To ensure the pledged capacity and performance of the e-Science infrastructure committed by the Nordic countries to WLCG.

The Committee must therefore identify issues pertinent to the Nordic Tier-1 success and propose actions.

The responsibilities of the Committee are:

1. To report to the NeIC Board on the progress and quality of the service as expected by WLCG.
2. To ensure that resources (computers, storage, network etc.) needed for the success of the Tier-1 Service are made available and to coordinate acquisition and inter-Nordic shares.
3. To identify issues pertinent to the success of the Tier-1 Service and recommend appropriate action.
4. To promote the Nordic WLCG effort and the work by NeIC nationally and internationally.
5. To ensure adequate Nordic representation in bodies relevant for the WLCG project.

The Committee is expected to meet prior to every ordinary NeIC Board meeting. The NLCG Committee Chair attends NeIC Board meetings, if important issues pertinent to the NLCG are on the agenda.

For people in relevant bodies, such as the WLCG Collaboration Board and the WLCG Overview Board, the NLCG Committee will elect Nordic representatives, preferably among the NLCG Committee members. The effort of participating in these boards will come with adequate funding from NeIC.

Membership and Attendance

The NLCG Committee should consist of two members per country covering the areas:

- Representatives from each of the experiments ATLAS, ALICE and CMS,
- Representatives of national infrastructures providing resources to WLCG,
- NeIC CERN Liaison (in attendance, secretary to the Committee),
- NT1 Activity Owner (in attendance),
- NT1 Activity Manager (in attendance).

The Chair is elected for one year at a time and the duty is rotating between countries (DK, FI, NO, SE). The Committee can appoint observer members whenever it is deemed necessary. Appointment of the NLCG members is done by the national bodies coordinating LHC contributions, namely:

- Denmark: the National Instrument Center for CERN Experiments (NICE),
- Finland: Helsinki Institute of Physics (HIP),
- Norway: the CERN project committee appointed by the Research Council of Norway,
- Sweden: Swedish LHC Consortium (LHCK) and Swedish National Infrastructure for Computing (SNIC), one member each.