# NATIONAL PARAM SUPERCOMPUTING SYSTEMS

# ANNUAL UTILIZATION REPORT 2023

प्रगत संगणन विकास केंद्र
**CENTRE FOR DEVELOPMENT OF ADVANCED COMPUTING**

# Message from Director General

I am delighted to present this report comprehending the usage of High-Performance Computing (HPC) Systems installed under National Supercomputing Mission (NSM) during 2023. Over the last few years, NSM has been working towards taking Indian supercomputing to new heights by installing new systems at various premier research and academic institutes.

These HPC systems have played a pivotal role across many scientific-engineering domains such as Flood prediction, Seismic-based Oil Exploration, Urban Air Modeling, CFD simulations, Life sciences, Material research and AI/ ML/ DL technologies. Till date, over 9.3 million computational jobs have been executed on these systems nationwide, involving more than 7900 users from nearly 220 academic and scientific-research institutions. This extensive usage of Systems has resulted in a significant number of quality research publications in international journals of very high repute and impact factor.

A few systems were heavily loaded and users experienced a significant wait time, C-DAC team has taken efforts to seamlessly move the user to the alternate HPC resources of NSM. The access process has been automated for the new user's creation thereby reducing the time to fulfill new requests.

The importance of interdisciplinary R&D leveraging HPC technologies for groundbreaking simulations and outcomes deserves much attention and accolades. Strengthening collaborations within the Indian HPC ecosystem has been a focal point for C-DAC, and the NSM has been instrumental in facilitating science and technology through wider utilization of HPC resources.

I would like to express our gratitude to all the researchers who have been contributing to the science via NSM systems. Their passion is the driving force behind our achievements.

I extend special appreciation to HPC Teams of C-DAC for the unwavering dedication and commitment towards the well-coordinated implementation and sustained technical support provided to the NSM HPC users throughout the year. Let us collectively strive to make 2024 a year to be remembered for even more fruitful endeavors.

**E. Magesh**
Director General
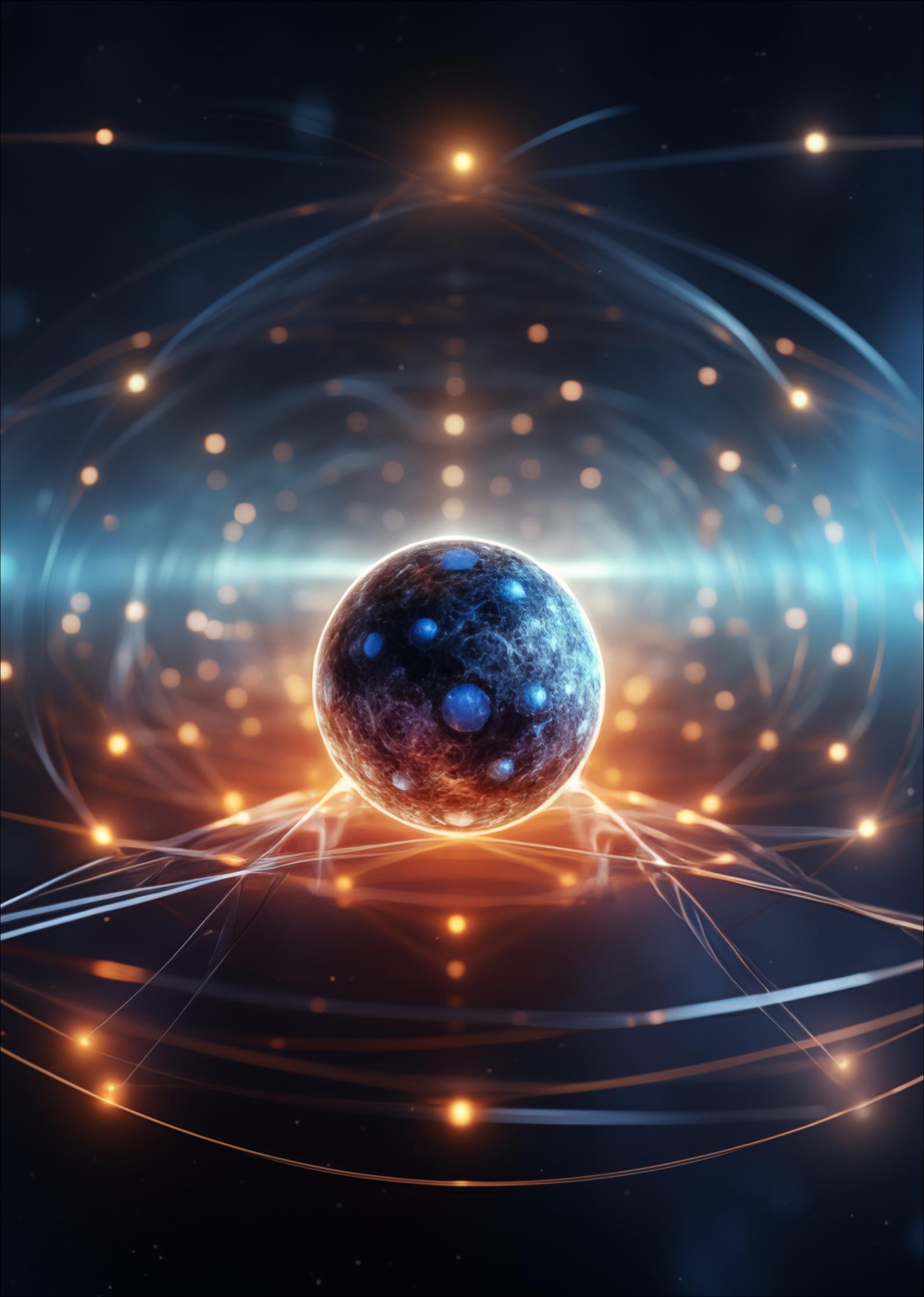C-DAC

# Message from
# Executive Director

The current landscape of High-Performance Computing (HPC) is marked by rapid growth, evolution, and transformative changes. Notably, market expansion is evident, propelled by anticipated developments that continue to fuel its momentum. Influenced by factors such as the aftermath of the pandemic, increasing cross-disciplinary collaboration, and significant advancements in technology, the HPC domain finds itself at the nexus of unprecedented opportunity and exploration.

Computing has pervaded every facet of society, far exceedingly even the boldest predictions. High-Performance Computing (HPC) systems expedite discoveries, refine precision, and stretch the boundaries of human imagination. From pharmaceutical research to forecasting extreme weather and venturing into outer space, these systems play a pivotal role. The next generation of HPC will deploy diverse approaches to surmount a multitude of computational challenges, propelling us into uncharted territories with unparalleled efficiency and capability.

As we advance in our endeavour to deploy HPC systems nationwide, I am delighted to highlight the effective utilization of the systems installed at numerous premier Academic, Scientific and Research institutions across the country through the National Supercomputing Mission (NSM). I extend special commendation to the application teams at C-DAC, who are actively immersed in diverse domains including Climatology, Disaster Management, Computational Biology, Fluid Dynamics, and Computational Chemistry, among others. These domains pose substantial challenges while offering significant societal benefits, underscoring the invaluable contributions of the dedicated teams involved.

## Col. A. K. Nath (Retd.)
### Executive Director
### (Corporate Strategy and C-DAC Pune)

I'm delighted to announce that all forthcoming Supercomputing systems under NSM Phase-3 will be built upon our indigenous Rudra servers, henceforth known as PARAM Rudra Systems. The year 2024 holds immense promise for advancements in High-Performance Computing (HPC), as research initiatives leverage expanded capacities to delve into quantum exploration, implement cutting-edge AI and ML-DL algorithms, and foster interdisciplinary collaborations. These developments will afford the HPC team at C-DAC greater exposure to emerging domain areas, facilitating strides towards our ultimate goal of achieving Exascale Computing.

# CONTENTS

# Executive Summary

The Centre for Development of Advanced Computing (C-DAC), a prominent R&D institution under MeitY, renowned for its pioneering work in High Performance Computing (HPC), remains at the forefront of driving continuous innovation within the HPC domain through advancements across hardware, software and associated technologies.

In accordance with the directives set forth by the National Supercomputing Mission (NSM) to facilitate India's attainment of complete self-sufficiency ("Atmanirbhar Bharat") in the field of HPC, C-DAC has embarked on the designing, development and implementation of numerous supercomputing systems across various locations within India. To ensure synchronization with deployment schedules and design development cycles, the NSM has adopted a three-phase strategy. During Phase 1, supercomputers are built using HPC subsystems assembled within India , while in Phase 2 the supercomputers are built with subsystems manufactured in India. These supercomputers are installed with indigenous HPC software stack. Currently, through the NSM, the country has a cumulative compute capacity of 24 Petaflops which is being used extensively by scientists and researchers.

Presently, in Phase 3, we are in the production phase of the indigenously designed and domestically manufactured Rudra servers which are being used to build the PARAM Supercomputers, marking a significant stride toward achieving our mission's milestones. Additionally, indigenous HPC software stack as well as indigenously designed rack and locally manufactured will be used to deploy the supercomputers.

The "National PARAM Supercomputing Systems - Annual Utilization Report 2023" furnishes a concise overview of the PARAM systems established at various sites, offering statistical insights into their utilization, indigenous hardware and software developments, scientific applications, undertaking awareness initiatives and users' testimonies among other aspects.

The overall utilization of the NSM systems stands at over 80%* with the recent installations gaining utilization by users. In the upcoming year, ten more supercomputers based on Rudra servers will be deployed. These supercomputers include a 3 PF HPC system at IUAC New Delhi, a 650 TF HPC system at SN Bose Kolkata, another 650 TF HPC system at IIT Patna, a 1 PF HPC system at GMRT-TIFR Pune, a 3 PF HPC system at IIT Bombay, a 3 PF HPC system at IIT Madras, a 650 TF HPC system at IIT Jammu, a 20 PF HPC system at C-DAC Bangalore, a 200 TF HPC system at C-DAC Delhi, and a 1 PF HPC system at C-DAC Pune. Additionally, there is a plan for a 250 AI PF System at IIT Delhi.

As of December 2023, a nationwide user base of approximately 8000 individuals, including over 1450 Ph.D. research scholars, has effectively completed a total of 9.3 million computational tasks on the NSM systems. In 2023, NSM systems contributed to a total of 478 publications, out of total 1240 publications over the past three years. The support for these systems is managed through a tailored ticketing tool, with around 10,000 support tickets resolved to date.

* The utilization data is reported for the last two quarters of 2023

# PARAM Systems under NSM

The National Supercomputing Mission (NSM) aims to set up a large network of supercomputers throughout India. Currently, there are 15 supercomputers which collectively boast a computing capacity of approximately 24 PF, while an additional 11 HPC systems will increase this total to reach an impressive 64 PF which will significantly improve the ability of educational and research institutions to conduct research and development. The supercomputers are designed and built to provide the computing power required for modern scientific exploration and operations.

To enhance the research capacities and capabilities in the country by connecting them to form a Supercomputing grid, with National Knowledge Network (NKN) as the backbone The NKN project is aimed at establishing a strong and robust Indian network which will be capable of providing secure and reliable connectivity. The NKN connects academic institutions and R&D labs over a high-speed network. It also allows researchers from these institutions to remotely access these supercomputers.

These supercomputing facilities are being used for developing national level applications in various domains such as NSM Platform for Genomics and Drug Discovery, Flood Forecasting and Disaster Management, Urban Environment and Weather Modelling, Seismic Data Processing System for Oil & Gas, Material science and Chemistry and Telecom Network optimization (MPPLAB).

The NSM also includes a program to train a highly skilled workforce that can handle the complexities of supercomputers and high-performance computing (HPC) applications across scales. This workforce will be able to address the challenges faced in STEM fields. The NSM is helping India to solve complex problems in many scientific disciplines by providing access to these supercomputers.
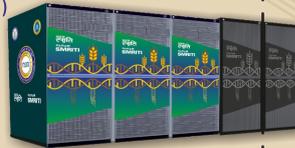
# Reflections on the Journey: NSM Accomplishment



**PARAM Siddhi AI**
210 AI PF C-DAC Pune
(2020)

**PARAM Seva**
838TF IIT Hyderabad
(2021)

**PARAM Smriti**
838TF NABI Mohali
(2021)

**PARAM Himalaya**
838TF IIT, Mandi
(2022)

**PARAM Yukti**
1.8PF JNCASR Bengaluru
(2020)

**PARAM Utkarsh**
838TF C-DAC Bengaluru
(2021)

**PARAM Ananta**
838TF IIT, Gandhinagar
(2022)

**PARAM Shakti**
1.66PF  IIT Kharagpur
(2019)

**PARAM Ganga**
1.67PF IIT, Roorkee
(2022)

**PARAM Kamrupa**
838TF NIT, Trichy
(2022)

**PARAM Brahma**
1.7PF IISER Pune
(2020)

**PARAM Pravega**
3.3PF IISc. Bangalore
(2022)

**PARAM Shivay**
838TF IIT BHU
(2019)

**PARAM Sanganak**
1.66PF IIT Kanpur
(2021)

**PARAM Porul**
838TF NIT, Trichy
(2022)

2019

2020

2021

2022

# PARAM Systems at a Glance

- Airawat-PSAI at C-DAC Pune
- PARAM Pravega at IISC Bangalore
- PARAM Shakti at IIT Kharagpur
- PARAM Sanganak at IIT Kanpur
- PARAM Ganga at IIT Roorkee
- PARAM Yukti at JNCASR Bangalore
- PARAM Brahma at IISER Pune
- PARAM Shivay at IIT(BHU) Varanasi
- PARAM Utkarsh at C-DAC Bangalore
- PARAM Seva at IIT Hyderabad
- PARAM Smriti at NABI Mohali
- PARAM Ananta at IIT Gandhinagar
- PARAM Porul at NIT Trichy
- PARAM Himalaya at IIT Mandi
- PARAM Kamrupa at IIT Guwahati

# Airawat-PSAI

## C-DAC, Pune

C-DAC Pune unveils **Airawat-PSAI**, India's fastest HPC/AI system deployed at C-DAC Pune, featuring 82 GPU nodes of NVIDIA DGX-A100, each equipped with 2 AMD EPYC CPUs, 8 A100 GPUs, and 1 TB RAM. With a total peak computing capacity of 13.17 PF (DP) and 410 PF (AI) performance, it secures the 75th spot globally in the 61st edition of the Top 500 Global Supercomputing List at ISC 2023 in Germany. In 2023, it has onboarded 22 startups.
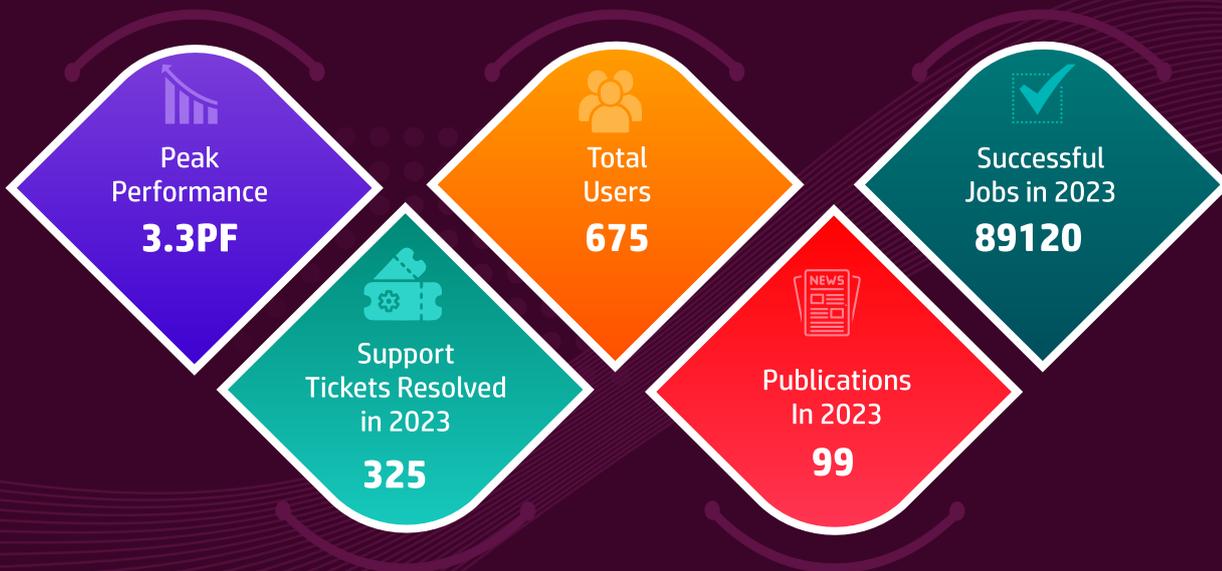
Peak Performance
**410 AI PF**

Support Tickets Resolved in 2023
**2173**

Total Users
**817**

Publications In 2023
**10**

Successful Jobs in 2023
**181604**
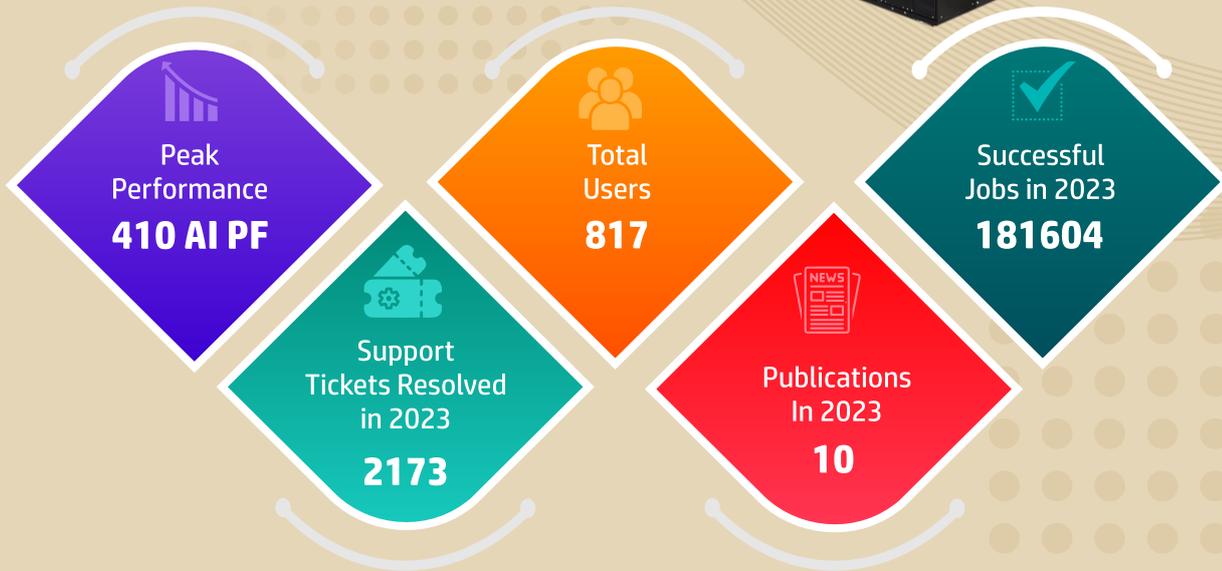
# PARAM Pravega

## IISc, Bangalore

**PARAM Pravega** inaugurated during Phase-2 of the NSM has an impressive peak computing power of 3.3 PF. This advanced facility was meticulously designed to cater to the computational requirements of IISc, Bangalore, and numerous other research and engineering institutes in the vicinity. Notably, PARAM Pravega holds immense value for research across diverse scientific domains.

Peak Performance
**3.3PF**

Support Tickets Resolved in 2023
**325**

Total Users
**675**

Publications In 2023
**99**

Successful Jobs in 2023
**89120**

# PARAM Shakti
## IIT, Kharagpur

**PARAM Shakti,** the cutting-edge supercomputing facility established at IIT Kharagpur as part of the NSM, boasts a peak computing power of 1.66 PF. This system was designed and deployed by C-DAC to meet the computational requirements of IIT Kharagpur as well as nearby scientific and engineering research institutions. Utilizing the latest advancements in hardware and software technologies, the system is equipped to deliver high-performance computing capabilities.

Peak Performance
**1.66 PF**

Total Users
**1326**

Successful Jobs in 2023
**292956**

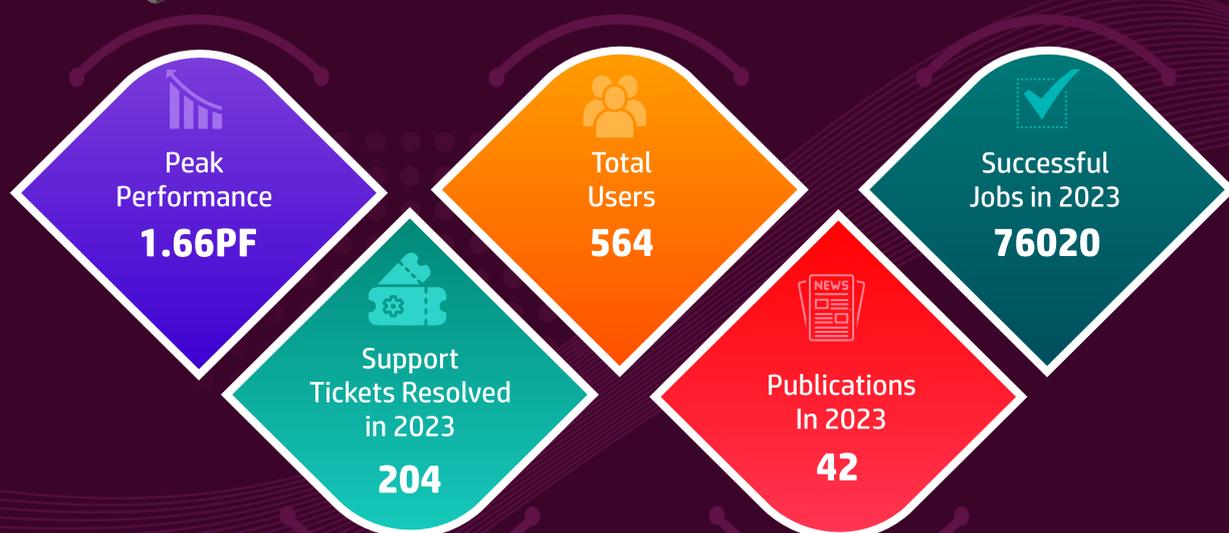Support Tickets Resolved in 2023
**600**

Publications In 2023
**15**
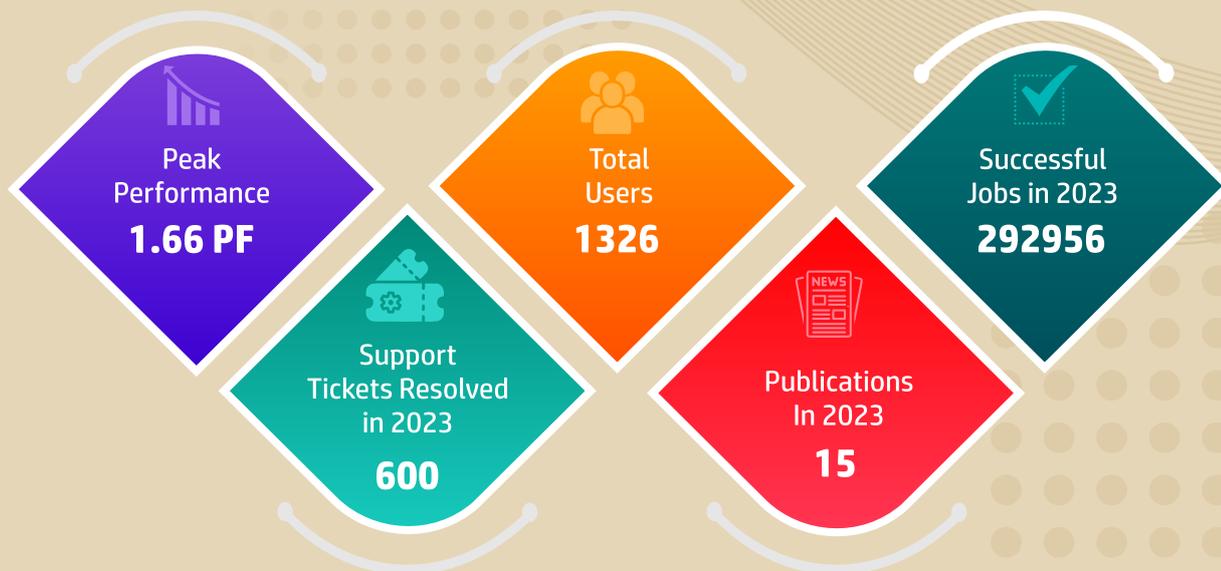
# PARAM Sanganak
## IIT, Kanpur

Envisioned under the National Supercomputing Mission, the supercomputing facility **PARAM Sanganak** shines with a remarkable peak computing power of 1.66 PF. Deployed by C-DAC, this cutting-edge system serves as the computational backbone for IIT Kanpur. PARAM Sanganak embodies the pinnacle of modern hardware and software technologies.

Peak Performance
**1.66PF**

Total Users
**564**

Successful Jobs in 2023
**76020**

Support Tickets Resolved in 2023
**204**

Publications In 2023
**42**

# PARAM Ganga
## IIT, Roorkee

**PARAM Ganga** deployed at IIT Roorkee, an advanced HPC system under the NSM employs a diverse and hybrid setup, combining Intel Xeon Cascade Lake processors with NVIDIA Tesla V100 GPUs, resulting in a collective peak computing capacity of 1.66 PF. The system is composed of 312 nodes, including both CPU and GPU components, interconnected via the Mellanox (HDR) InfiniBand network.

Peak Performance
**1.66PF**

Support Tickets Resolved in 2023
**453**

Total Users
**611**

Publications In 2023
**50**

Successful Jobs in 2023
**57192**
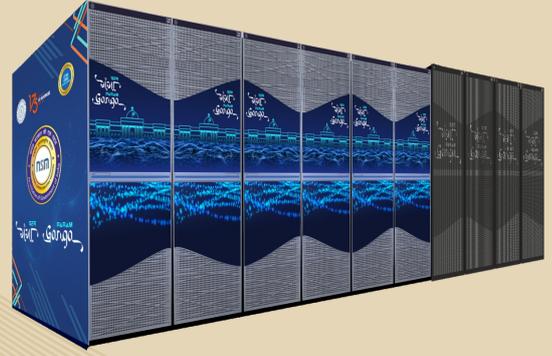
# PARAM Yukti
## JNCASR, Bangalore

**PARAM Yukti,** this state-of-the-art system is designed to address the computational needs of JNCASR, Bangalore. With an impressive peak computing power of 1.8 PF, it is powered by Intel Xeon Cascade Lake processors and NVIDIA Tesla V100 GPUs. A significant portion of the system's components are manufactured and assembled within India, aligning with the Government's Make in India initiative.

Peak Performance
**1.836PF**

Support Tickets Resolved in 2023
**112**

Total Users
**206**

Publications In 2023
**26**

Successful Jobs in 2023
**44381**

# PARAM Brahma
## IISER, Pune

The supercomputing system **PARAM Brahma** deployed at IISER Pune as part of the NSM. The 1.75 PF was designed to meet the computational requirements of IISER Pune and nearby research institutions.

Peak Performance
**1.75PF**

Support Tickets Resolved in 2023
**45**

Total Users
**382**

Publications In 2023
**39**

Successful Jobs in 2023
**619034**
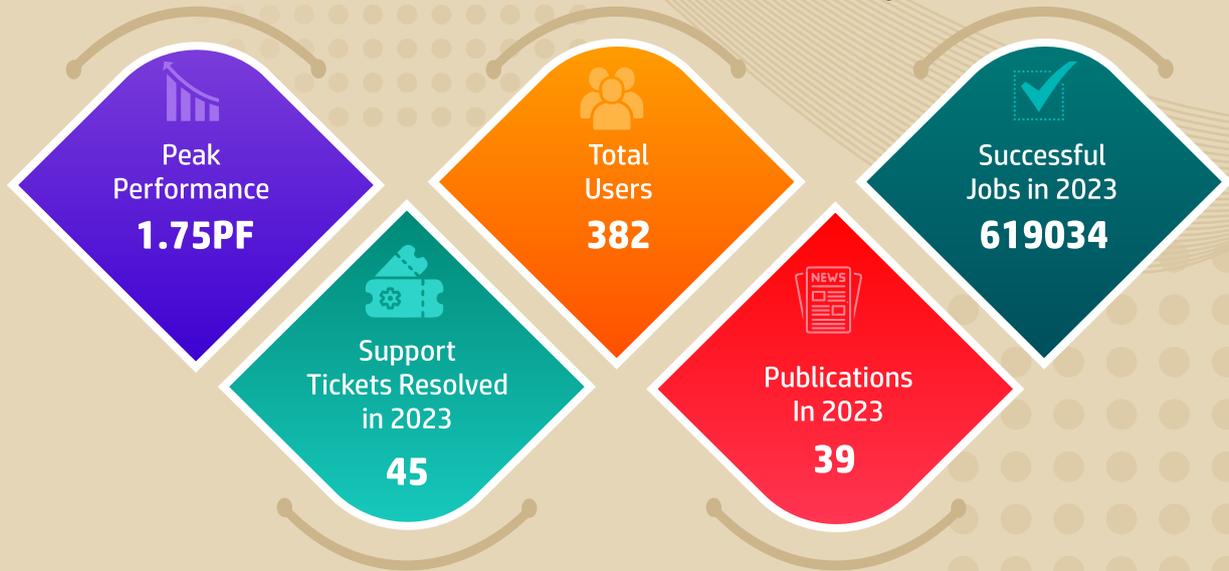
# PARAM Shivay
## IIT (BHU), Varanasi

**PARAM Shivay**, the first supercomputing facility commissioned as part of the NSM by C-DAC at IIT (BHU), Varanasi, was inaugurated by Hon'ble Prime Minister Shri Narendra Modi in Feb 2019. This state-of-the-art supercomputer, boasts a peak compute power of 838 TF through CPUs and GPUs. Its launch marks a significant step towards enhancing research and development efforts across the nation.

Peak Performance
**838TF**

Support Tickets Resolved in 2023
**201**

Total Users
**1044**

Publications In 2023
**131**
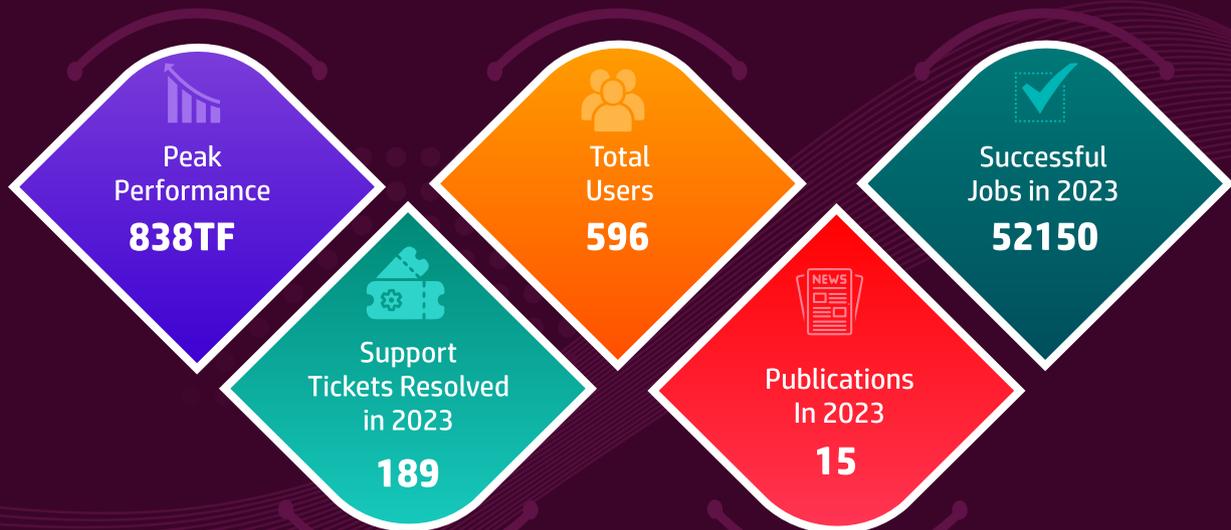
Successful Jobs in 2023
**84717**

# PARAM Utkarsh
## C-DAC, Bengaluru

**PARAM Utkarsh**, at C-DAC Bangalore, having 838 TF, serves as a pivotal resource to support a spectrum of tasks, including HPC simulations, Big Data Analytics, and Cloud services, primarily catering to the needs of the Micro, Small, and Medium Enterprises (MSME) sector. In 2023, it has onboarded 21 startups and MSMEs.

Peak Performance
**1.75PF**

Support Tickets Resolved in 2023
**45**

Total Users
**382**

Publications In 2023
**39**

Successful Jobs in 2023
**619034**

# PARAM Seva
## IIT, Hyderabad

The supercomputer **PARAM Seva** is based on heterogeneous and hybrid configuration, boasting a peak computing power of 838 TF. Commissioned at IIT Hyderabad, PARAM Seva stands as a testament to India's strides in advanced computing technology. The cluster was inaugurated by Shri Dharmendra Pradhan, Hon'ble Education Minister.

Peak Performance
**838TF**

Support Tickets Resolved in 2023
**189**

Total Users
**596**

Publications In 2023
**15**

Successful Jobs in 2023
**52150**

# PARAM Smriti
## NABI, Mohali

**PARAM Smriti** was inaugurated by Dr. Jitendra Singh, Hon'ble Union Minister of Science and Technology and Earth Sciences having a peak computing power of 838 TF. The supercomputer deployed at NABI, Mohali is primarily used for agricultural research.

Peak Performance
**838TF**

Support Tickets Resolved in 2023
**198**

Total Users
**190**

Publications In 2023
**21**

Successful Jobs in 2023
**46534**
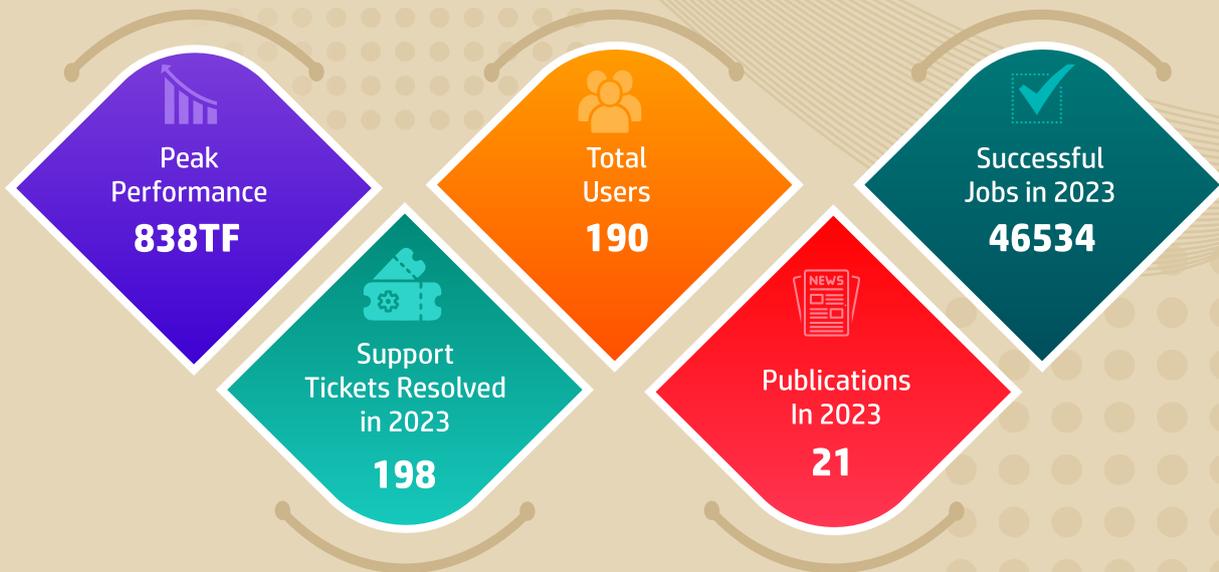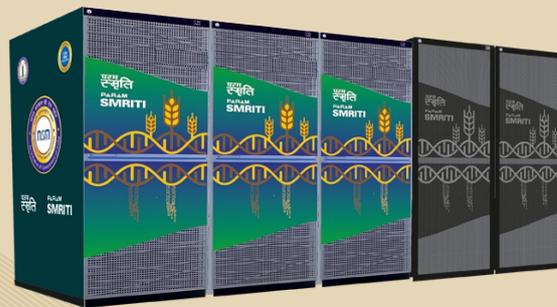
# PARAM ANANTA
## IIT, Gandhinagar

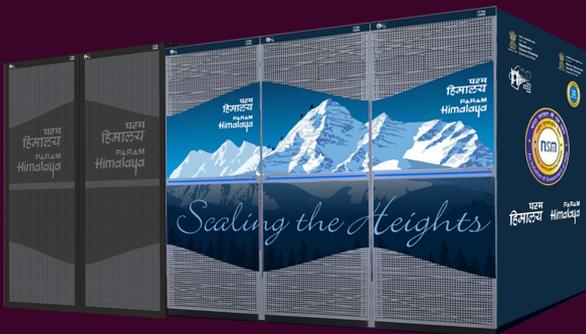**PARAM ANANTA**, housed at IIT Gandhinagar, with a peak computing power of 838 TF was commissioned under the presence of Smt. Sunita Verma, Group Coordinator & Scientist 'G' at MeitY. The system is suitable for a wide range of scientific and engineering applications.

Peak Performance
**838TF**

Support Tickets Resolved in 2023
**191**

Total Users
**252**

Publications In 2023
**11**

Successful Jobs in 2023
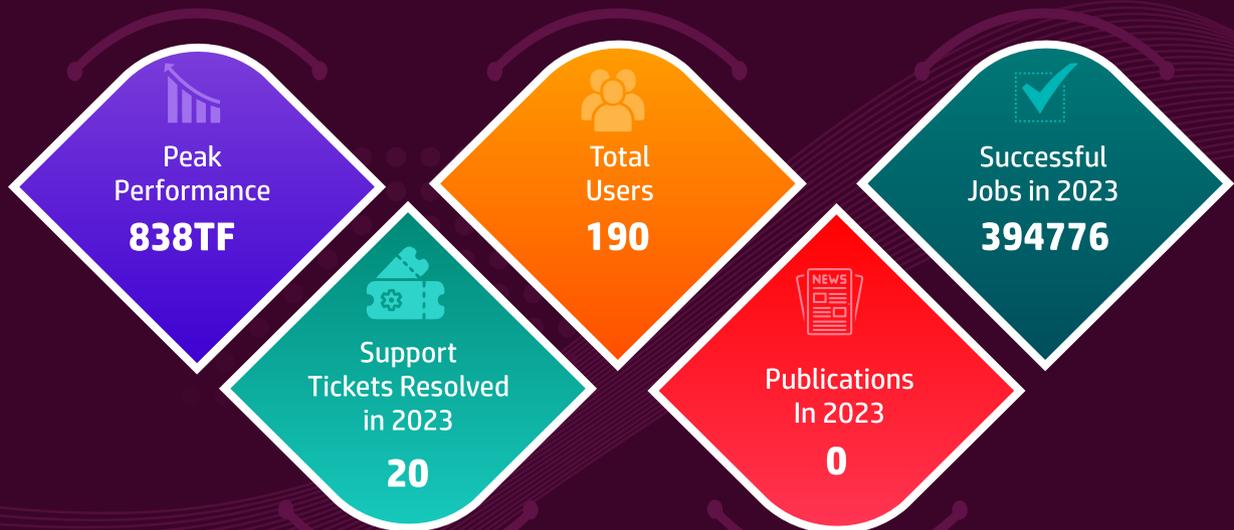**20554**

# PARAM Porul
## NIT, Trichy

**PARAM Porul**, at NIT Trichy an advanced supercomputing facility, was inaugurated during Phase-2 of the NSM by Dr. Bhaskar Bhat, Chairperson Board of Governors, NIT Trichy. This cutting-edge system embraces a heterogeneous and hybrid architecture featuring Intel Xeon Cascade Lake processors and NVIDIA Tesla V100 GPU cards.

Peak Performance
**838TF**

Support Tickets Resolved in 2023
**67**

Total Users
**343**

Publications In 2023
**2**

Successful Jobs in 2023
**24591**

# PARAM Himalaya
## IIT, Mandi

**PARAM Himalaya**, with a peak computing power of 838 TF serves as the computational backbone for IIT Mandi and various esteemed research and engineering institutes in the region. Powered by Intel Xeon Cascade Lake processors, alongside NVIDIA Tesla V100, the system is adorned with the latest advancements in both hardware and software technologies.

Peak Performance
**838TF**

Support Tickets Resolved in 2023
**20**

Total Users
**190**

Publications In 2023
**0**

Successful Jobs in 2023
**394776**

# PARAM Kamrupa

## IIT, Guwahati

**PARAM Kamrupa**, inaugurated by Hon'ble President of India Smt. Droupadi Murmu, is a heterogeneous and hybrid supercomputing setup, deployed at IIT Guwahati.
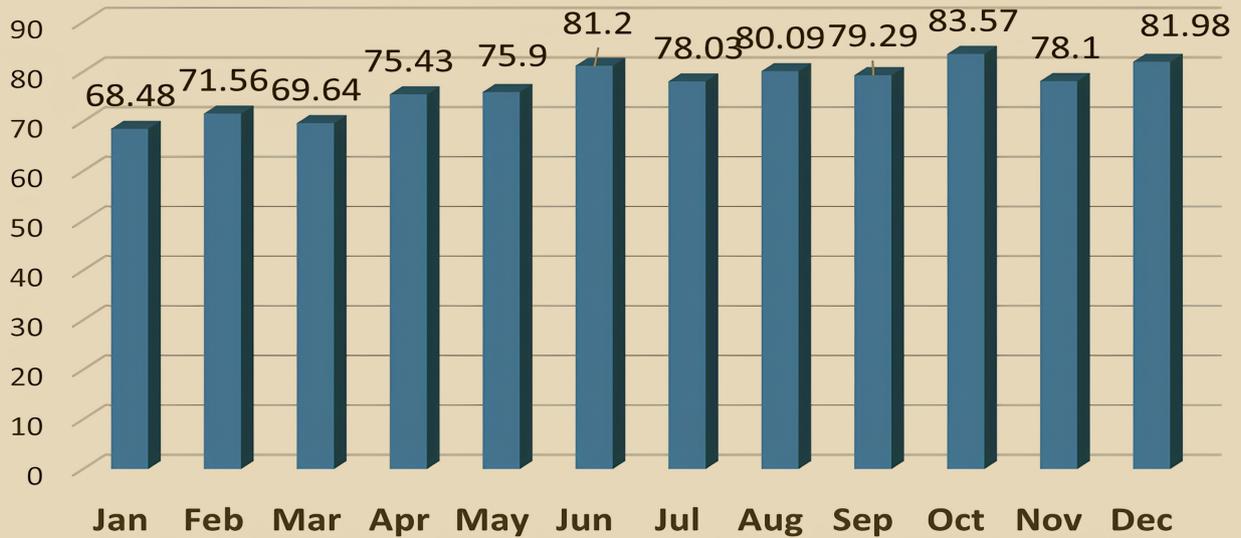


Peak Performance
**838TF**

Total Users
**124**

Successful Jobs in 2023
**16041**

Support Tickets Resolved in 2023
**197**

Publications In 2023
**2**
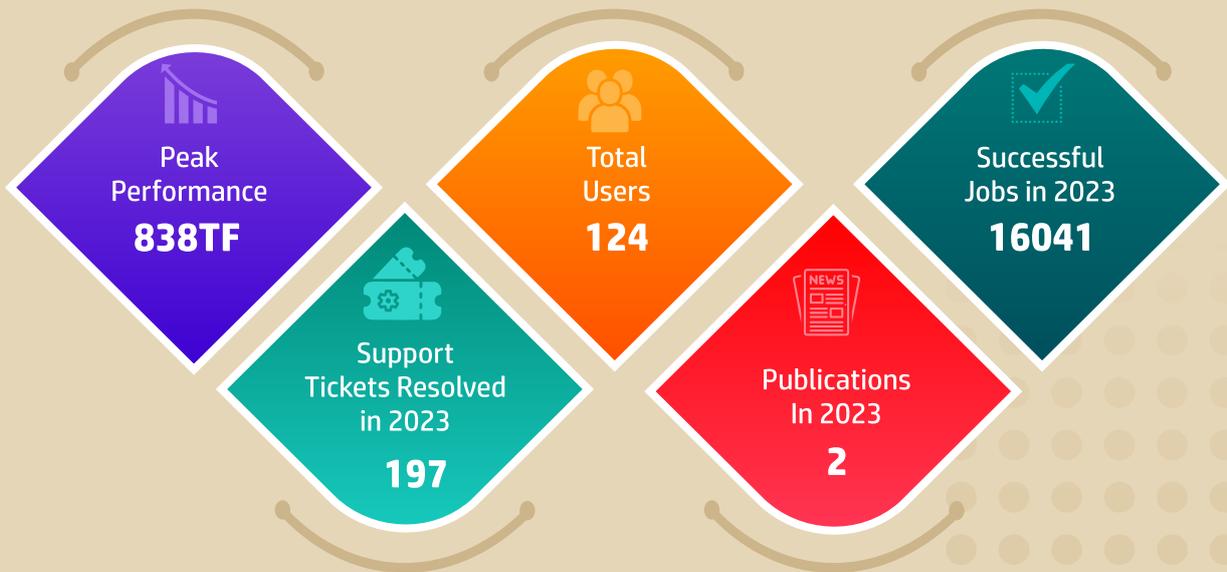
# Comprehensive System utilization Report:

## Month wise System Utilization(CPU)

The cumulative CPU utilization across all NSM sites from January to December 2023 reflects good usage of the system. A steady rise is observed in the overall utilization of the system over time.
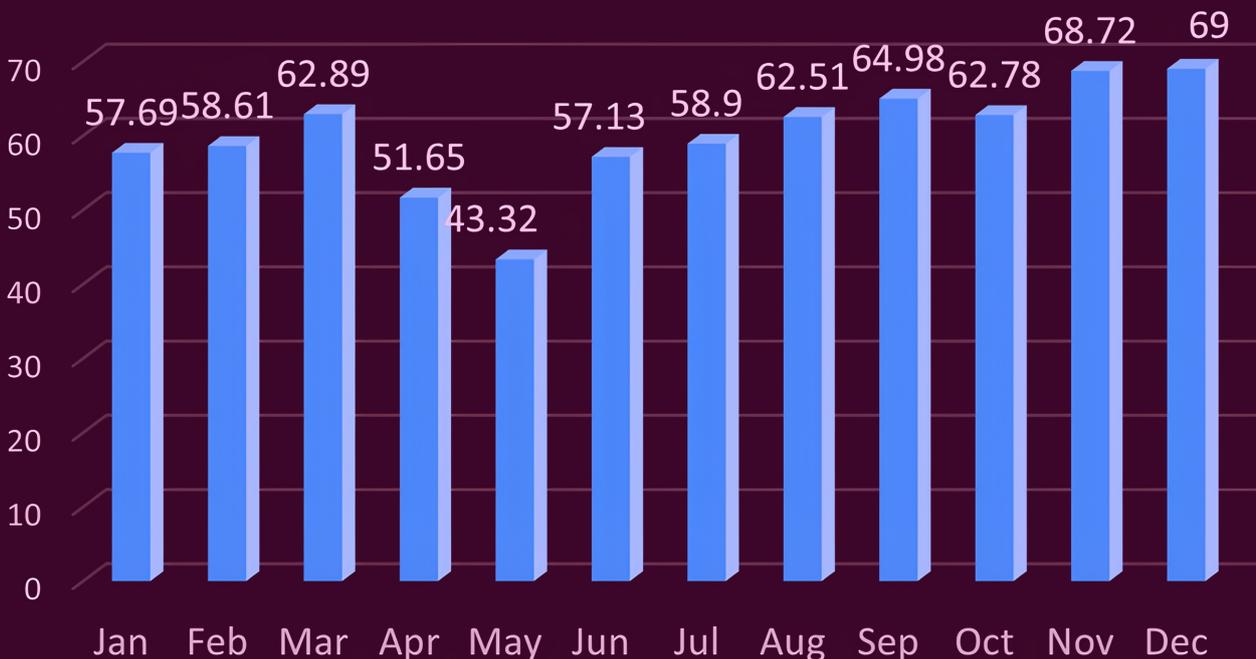
### CPU Utilization (%)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CPU | 68.48 | 71.56 | 69.64 | 75.43 | 75.9 | 81.2 | 78.03 | 80.09 | 79.29 | 83.57 | 78.1 | 81.98 |

## Month wise System Utilization(GPU)

The GPU utilization across all NSM systems over the course of the year has average GPU utilization of 57.69% in January and exhibits a gradual upward trend, reaching a peak of 69% in December.

### GPU Utilization (%)
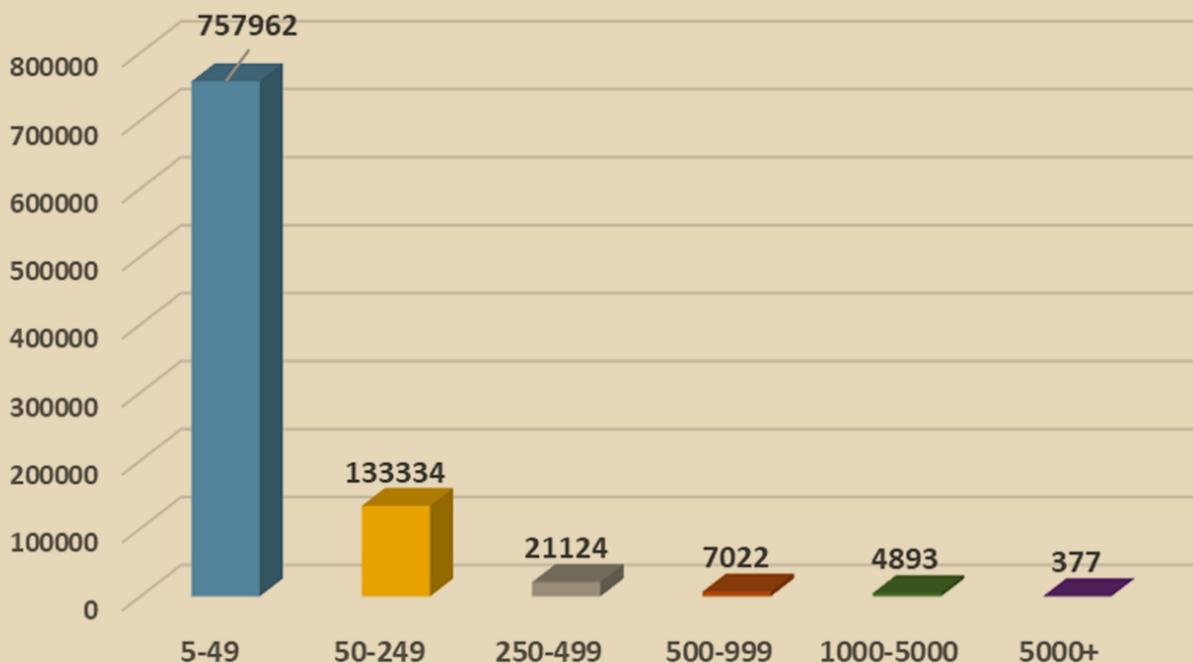
| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GPU | 57.69 | 58.61 | 62.89 | 51.65 | 43.32 | 57.13 | 58.9 | 62.51 | 64.98 | 62.78 | 68.72 | 69 |

# Distribution of Jobs by Job Size

The graph depicts the job count across all NSM sites based on job size, where job size denotes the number of CPU cores utilized by the jobs.

## Size-wise Job Distribution

| Job Size | Count |
|----------|-------|
| 5-49 | 757962 |
| 50-249 | 133334 |
| 250-499 | 21124 |
| 500-999 | 7022 |
| 1000-5000 | 4893 |
| 5000+ | 377 |

# Domain Wise System Utilization

The pie chart shows the system utilization for the year 2023 with respect to different application domains. Other category indicates a diverse range of scientific and engineering fields using the system.

## Domain Wise System utilization

- 23%
- 19%
- 13%
- 11%
- 9%
- 7%
- 6%
- 5%
- 4%
- 3%
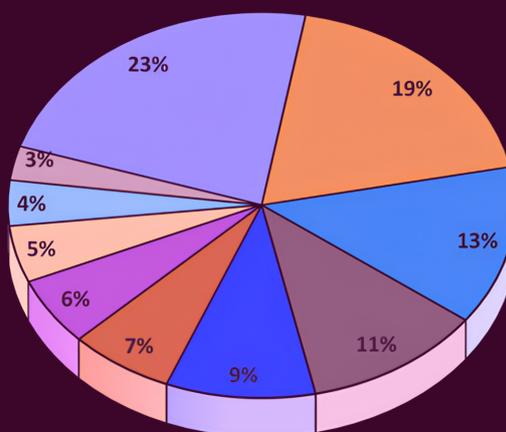
- ■ Computational Fluid Dynamics (CFD)
- ■ Computational Material Science
- ■ Computational Chemistry
- ■ Physics
- ■ Computational Biology
- ■ Earth and Atmospheric Science
- ■ Materials Science
- ■ Molecular Dynamics
- ■ Artificial Intelligence/Machine Learning/Deep Learning
- ■ Others

# User Statistics

The chart below illustrates users of different categories across all NSM sites.

The total number of users is 7128, comprising 1588 students, 1464 PhD scholars, and 4076 others (including faculty, scientists, industry professionals, etc.).

External: 12.51%

Host Institute: 75.11%

NSM: 12.37%

Student: 22.28%
Under & Post Graduates

Scientist,Faculty,etc..: 57.18%

PhD: 20.54%
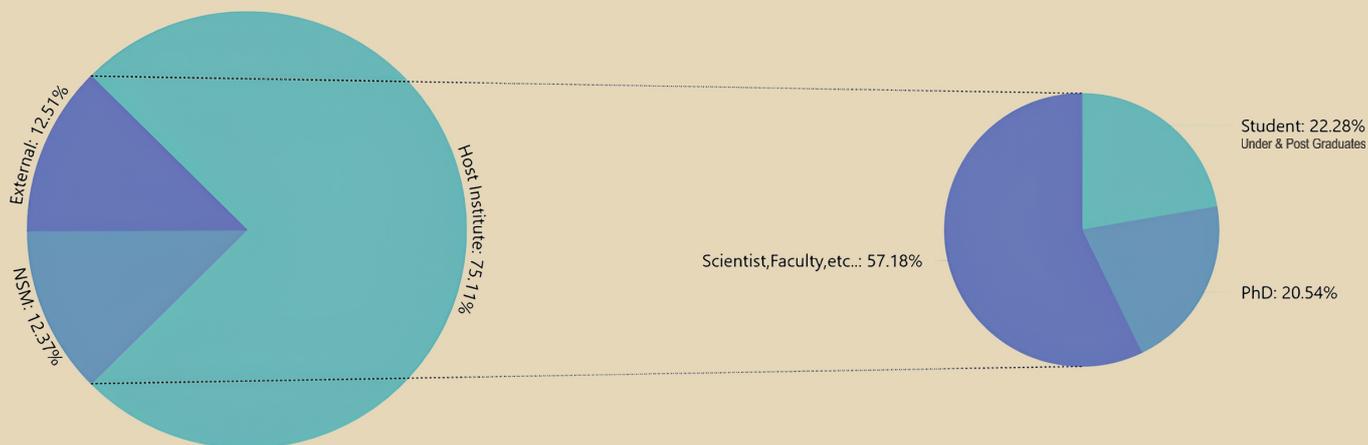
# Publications

In 2023, NSM systems contributed to a total of 478 publications. Included below are the impact factors and indexing counts for these publications.

**Published Articles Indexing Count**

A total of 387 articles are published in journals indexed by SCI/SCIE, which represents the high quality of the research content and its global acceptability.
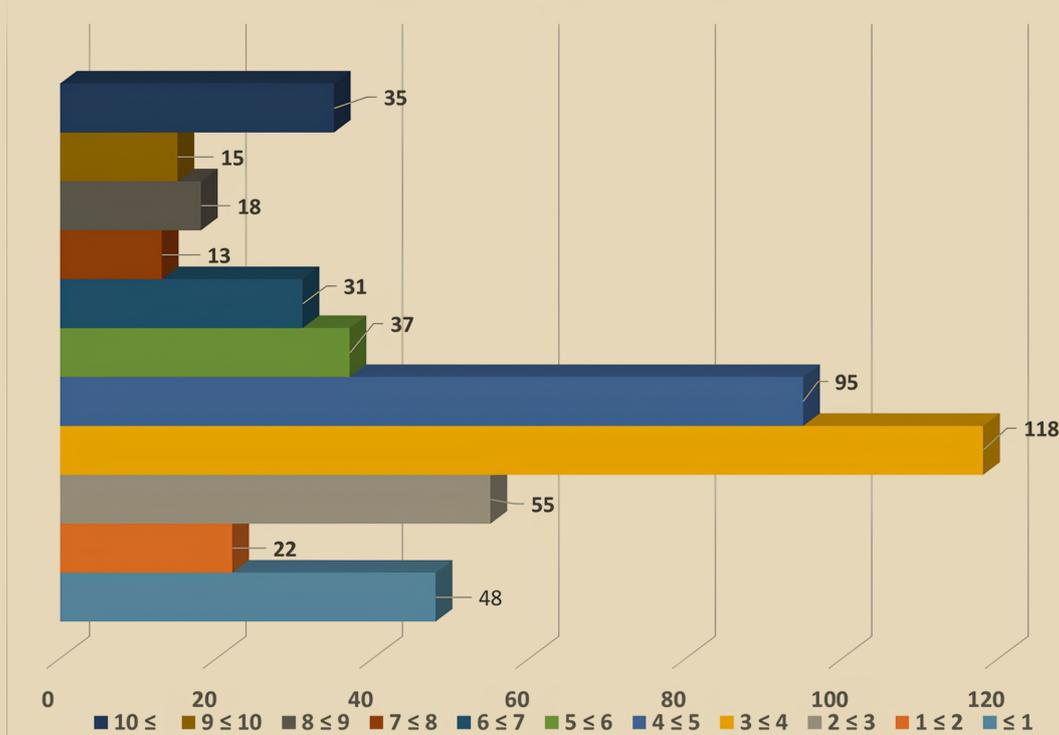
## Published Article Indexing Count

| Count | |
|---|---|
| 387 | SCI/SCIE |
| 97 | SCOPUS |
| 3 | WOS |

Indexing
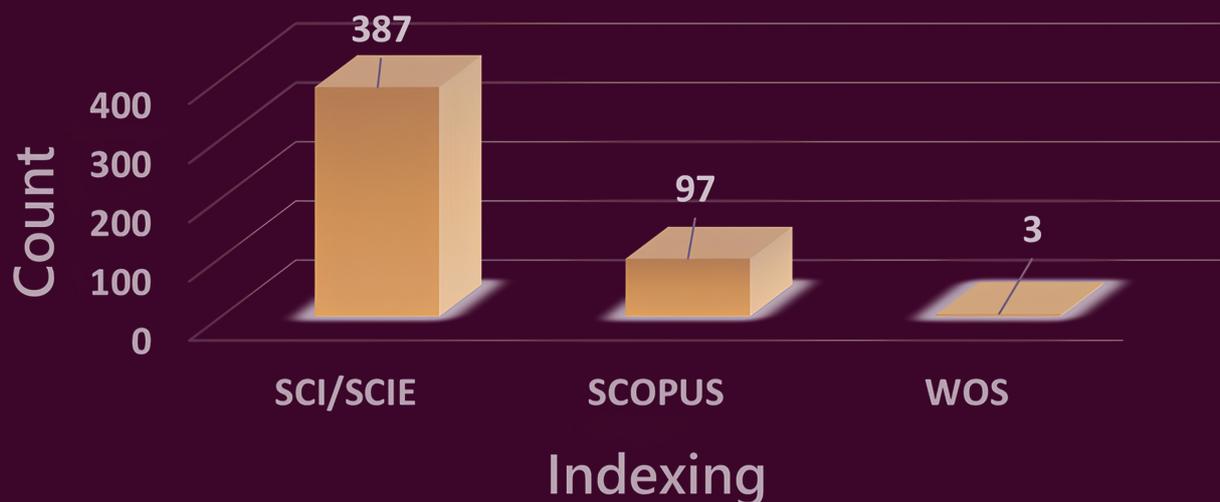
# Published Articles Impact Factor Range

Impact factor measures a journal's citation influence, offering researchers increased visibility and broader readership. The graph indicates 118 and 96 research articles published in journals which have good impact ranges of 3 - 4 and 4 - 5 respectively. Additionally, some journals have exceeded an impact factor of 10.

## Research Papers Impact Factor

| Range | Value |
|-------|-------|
| 10 ≤ | 35 |
| 9 ≤ 10 | 15 |
| 8 ≤ 9 | 18 |
| 7 ≤ 8 | 13 |
| 6 ≤ 7 | 31 |
| 5 ≤ 6 | 37 |
| 4 ≤ 5 | 95 |
| 3 ≤ 4 | 118 |
| 2 ≤ 3 | 55 |
| 1 ≤ 2 | 22 |
| ≤ 1 | 48 |

Legend: ■ 10 ≤ ■ 9 ≤ 10 ■ 8 ≤ 9 ■ 7 ≤ 8 ■ 6 ≤ 7 ■ 5 ≤ 6 ■ 4 ≤ 5 ■ 3 ≤ 4 ■ 2 ≤ 3 ■ 1 ≤ 2 ■ ≤ 1

# Support Call Addressed

This chart illustrates the C-DAC HPC team's efforts in addressing support calls aimed at resolving user issues.

## Ticket Resolved

| Month | Value |
|-------|-------|
| Jan | 230 |
| Feb | 258 |
| March | 254 |
| April | 181 |
| May | 170 |
| June | 227 |
| July | 139 |
| Aug | 183 |
| Sep | 155 |
| Oct | 127 |
| Nov | 194 |
| Dec | 113 |

# Application Services and Development on NSM Systems - Social and Economic Impact

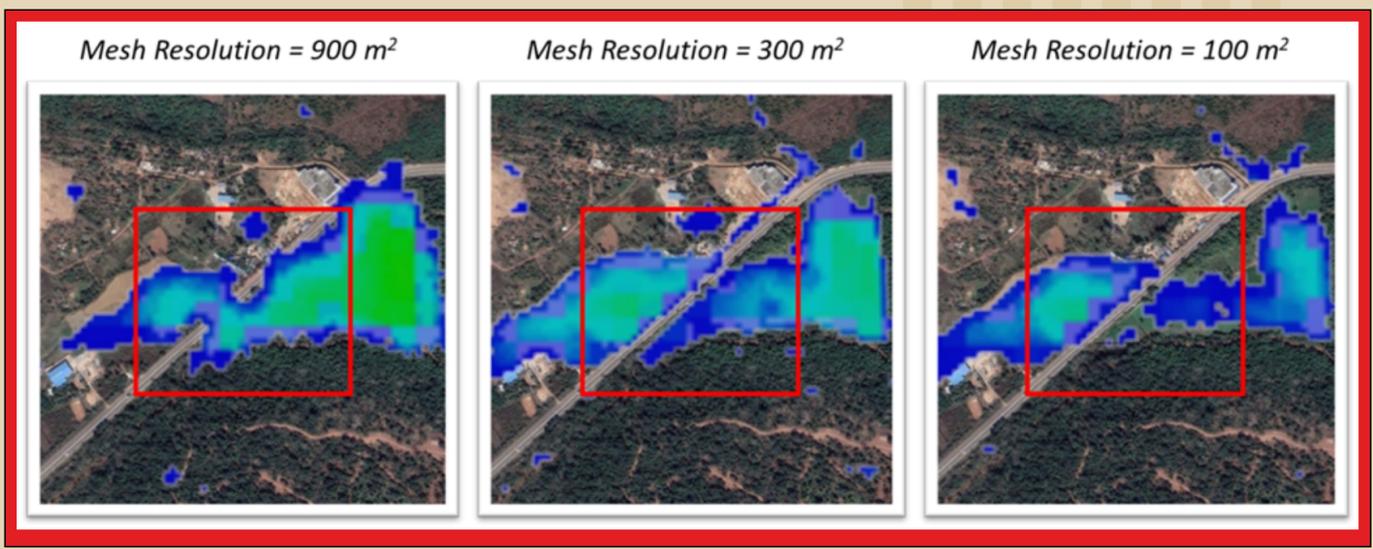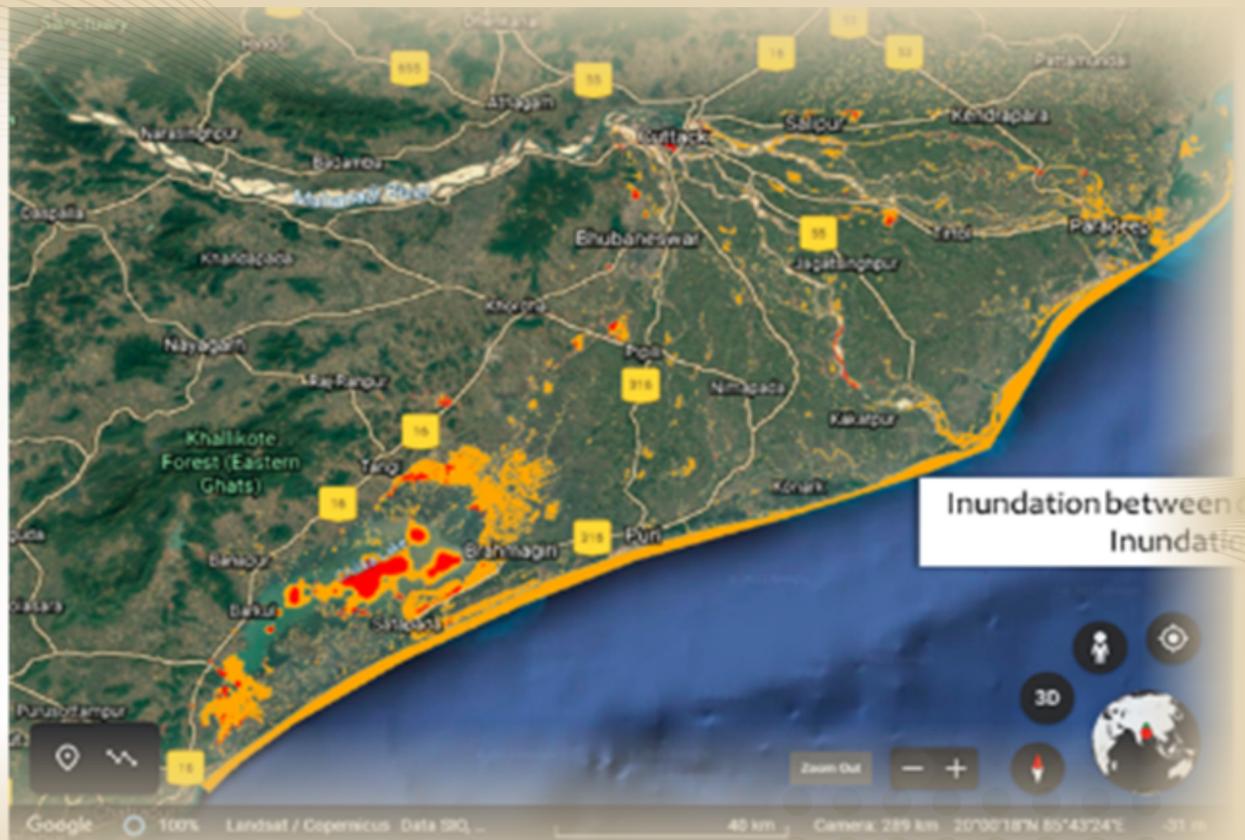**Application Porting, Optimization and Scaling Services on NSM PARAM Systems :**

- To address availability of applications across multiple scientific domains

- Ensure use of best practices and tools on NSM systems by end-users

- Support application developers and users on NSM infrastructure in resolving their technical issues

- Test, scale, benchmark applications along with continuous monitoring of system status to ensure optimal system health and utilization

- Parallelization and optimization of user applications

- Technology trainings, hackathons, bootcamps to proliferate use of HPC

- Play the role of early technology adopter to encourage end-users to adopt emerging tools and technologies such as Accelerator Computing, Hybrid Computing, Programming Paradigms, AI/ML/DL etc.

## Applications, Tools, Programming Models Enabled on NSM PARAM Systems

| HPC Applications | | |
|---|---|---|
| **Bio-informatics** | MUMmer, HMMER, MEME, PHYLIP, mpiBLAST, ClustalW | |
| **Molecular Dynamics** | NAMD, LAMMPS, GROMACS (CPU & GPU) | |
| **Material Modelling, Quantum Chemistry** | Quantum-Espresso, Abinit, CP2K, NWChem | |
| **CFD, Aerospace** | OpenFOAM, FDS, SU2 | |
| **Weather, Ocean, Climate** | WRF, RegCM, MOM, ROMS | |
| **Disaster Management** | ANUGA Hydro, SpeckFEM3D | |

| | | |
|---|---|---|
| **Visualization Programs** | GrADS, ParaView, VisIt, VMD | |
| **Libraries** | Scientific and Mathematical Libraries, NetCDF, PNETCDF, Jasper, HDF5, Tcl, Boost, FFTW | |
| **Programming Models** | MPI, OpenMP, OpenACC, CUDA, SYCL, Julia, Pthreads | |

| AI/ ML/ DL Tools/ Technologies/ Libraries | |
|---|---|
| **DL Framework:** TensorFlow , keras, theano, pytorch, scikit-learn, scipy, cuDNN | |
| **Data Science:** Numpy , RAPIDS | |
| **Dist. DL Framework:** TensorFlow and Pytorch with Horovod | |
| **Container Technology:** enroot | |
| **DL App. Dev. Platform, web based IDE:** JupyterHub | |

**Installed additional applications, libraries, tools on different NSM systems as per requirements from users of respective systems**

### Benchmarks Performed on Latest Architectures

| | |
|---|---|
| **Architecture** | Intel, AMD, IBM, Nvidia, ARM, Graphcore |
| **Key Application Areas** | Atmospheric Sciences, Molecular Dynamics, Computational Fluid Dynamics, Deep Learning |
| **Open Source Applications** | WRF, LAMMPS, NAMD, GROMACS, OpenFOAM |

An early warning system for flood prediction for river basins of India was developed. Currently, it is used as back-up for operational purposes to simulate floods (upto 2 days in advance) in Mahanadi River basin during monsoon. The results are shared with Central Water Commission (CWC) for taking early decisions



Predicted simulation output

Inundation between
Inundation



Mesh Resolution = 900 m²     Mesh Resolution = 300 m²     Mesh Resolution = 100 m²

Developed HPC software suite for Seismic Imaging to aid Oil & Gas exploration. 3D field data from ONGC is being processed. Since January 15th 2023, 50% of data has been processed. Results of SeisRTM found to be compatible with their commercial counterparts.

A science-based decision support framework was developed to address urban environment issues including Meteorology, Hydrology and Air Quality. Predicted urban rainfall for 2023 for Pune, Bangalore and Bhubaneshwar with 0.5 km resolution and all India with 1.5 km resolution. Simulated extreme heat and urban heat island simulations for Pune, Ahmedabad and Bhubaneshwar cities

NSM platform for Genomics and Drug Discovery was developed. Drug Repurposing for SARS-CoV-2 (Covid-19) through docking for Ayurveda Compounds from Giloy, Pimpli was carried out. Developed HPC tools Tango and used simulations expertise for Cardio-toxicity predictions of probable drug molecules given by Pharma Industries - Lupin ltd.
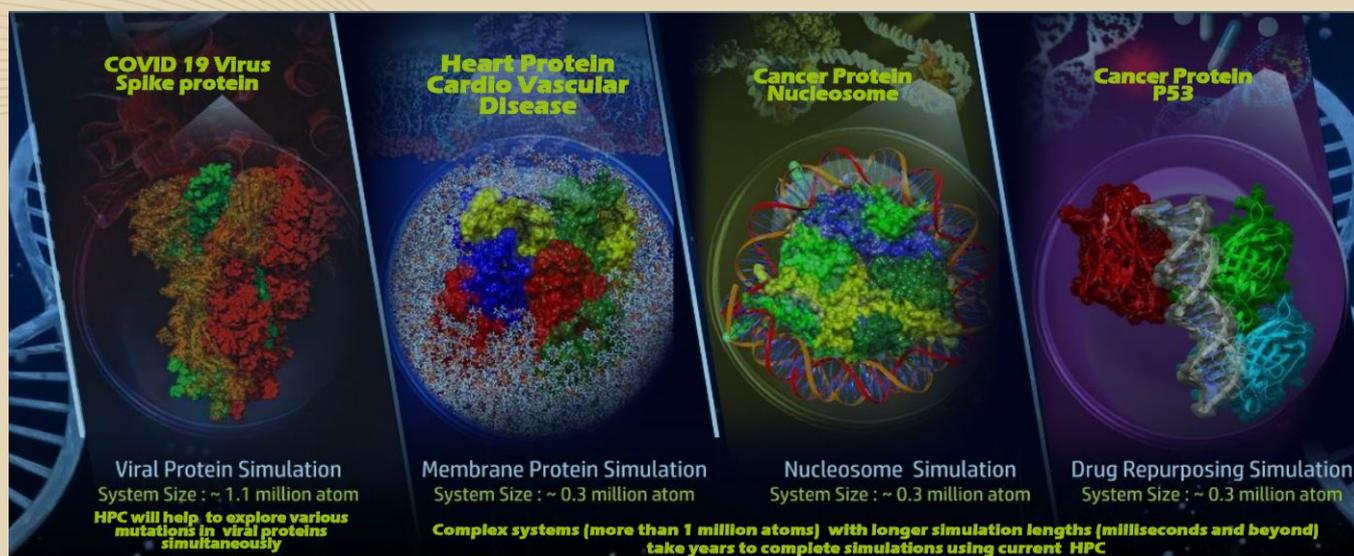


A dedicated team for development of applications in disaster management, weather & climate modeling, air quality, materials research, energy applications, oil & gas exploration, computational chemistry, computational physics, quantum mechanics, drug repurposing, bioinformatics, astronomy ,astrophysics and telecom network optimization was created.

NCRA-TIFR has developed a system enabling simultaneous detection and arc-second localization across the entire 300–1460 MHz radio spectrum for the Square Kilometre Array (SKA) project, currently in progress.

Utilizing PARAM Pravega, high-resolution simulations were conducted for hydrodynamic jets interacting with the interstellar and circumgalactic medium (ISM & CGM) of the Milky Way. Additionally, Pravega facilitated sensitivity analysis for selecting key parameters in the hydrological model SUMMA. The system was also employed for pseudo-spectral direct numerical simulations to solve the 3D Hall-Vinen-Bekharevich-Khalatnikov (HVBK) model of superfluid helium. Moreover, PARAM Pravega enabled the integration of quantum and classical mechanical simulations at the molecular level, advancing our understanding of nanomaterials' structure-property relationships in (electro)catalysis and membrane separation applications, including $CO_2$ reduction, electrochemical water splitting, and seawater desalination. It also supported the design of novel materials for energy storage and harvesting applications using density functional theory (DFT) and machine learning (ML) tools to predict precise material properties.

PARAM Shakti, facilitated an extensive screening of small molecules against various cancer-specific receptors, such as ER-alpha, EGFR, HER2, and DDI2. Additionally, It was also utilized to optimize theoretical research problems in macroeconomics, aiding in the formulation of improved policy responses, encompassing both fiscal and monetary measures, for the future.

Utilizing PARAM Smriti, DNA methylation analysis was conducted in adipose cells to delineate the DNA methylation patterns involved in the differentiation and dedifferentiation processes of adipose cells. Furthermore, PARAM Smriti facilitated docking and molecular dynamics (MD) simulations, identifying Paroxetine as a potential candidate for repurposing as a first-line medication for epileptic seizures.

PARAM Yukti was utilized to enhance hole mobility in semiconducting p-type scandium nitride (ScN) by employing state-of-the-art Boltzmann transport formalism from first principles. This initiative aims to develop high-efficiency devices incorporating semiconducting ScN and nitride heterostructures.

PARAM Ganga was utilized for exploring alternative solid electrolytes to enhance lithium batteries, aiming for improved thermal and chemical stability. Furthermore, a study was conducted on the heightened frequency of cloud bursts and extreme rainfall events in Uttarakhand.

## Use cases of Airawat-PSAI Supercomputer

In a recent case concerning national security, AIRAWAT-PSAI was leveraged by C-DOT to identify issuance of 2.25 lakh benami SIM cards across Gujarat alone. This resulted in 27 FIRs filed in 24 police stations of 13 districts and the arrest of 40 accused in all identities of 15,000 unsuspecting citizens who were being misused by criminals, anti-national elements, and other wrongdoers to commit offenses without fear of prosecution. Gujrat model was extended to states of West Bengal (over 12 34 lakh), Haryana (over 5 24 lakh SIMs), Bihar and Jharkhand together (over 3.27 lakh SIMs), Madhya Pradesh (over 2.28 lakh SIMs) and Uttar Pradesh East (over 2.04 lakh SIMs)

Similarly for Jammu & Kashmir:

- 32094 number of mobile connections obtained on invalid and fake/forged documents.
- 598 number of Point-of-Sale (PoS) blacklisted.
- 86 FIRs registered (173 PoS devices involved in FIRs).

AIRAWAT-PSAI System used in part identification of victims of Balasore, Odisha Train accident.

Mission Bhashini: On the language front, NLTM (Mission Bhashini) has extensively used AIRAWAT-PSAI system for developing India specific language models for ASR, TTS, STS etc. A significant corpus has been across various languages for training of language models. More than 90 models have been trained so far using AIRAWAT-PSAI by 140 users.

## Empowering Startups & MSMEs through AIRAWAT-PSAI
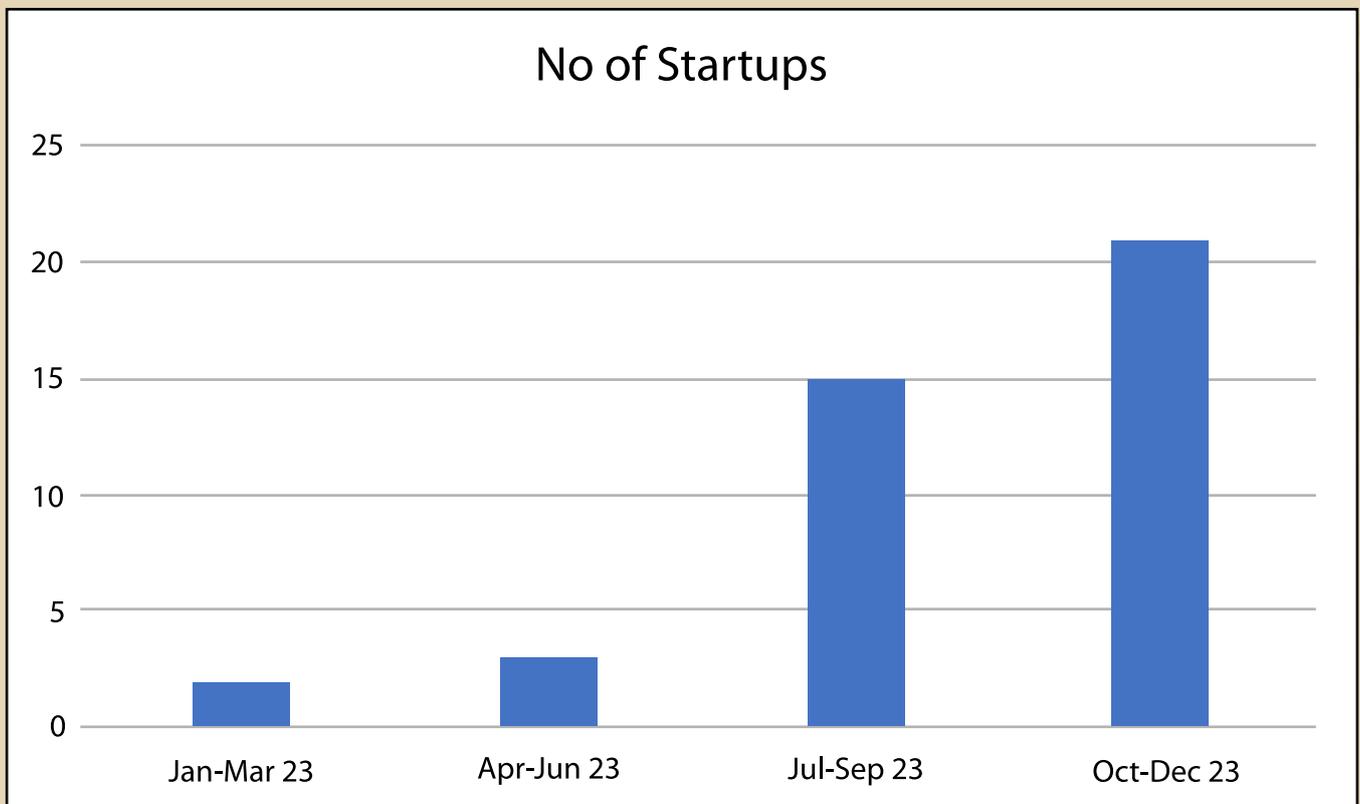
### No of Startups

The depicted graph illustrates the number of startups onboarded on AIRAWAT-PSAI in the year 2023. The consistent increase in the number of startups serves as an indicator of the system's usefulness and relevance within the startup ecosystem.

# C-DAC's Indigenous Products

## Rudra Server

Under the building approach, C-DAC has designed and developed a compute server "Rudra" as one of the most important subassemblies required for Supercomputers. Rudra, C-DAC's indigenous server platform features Intel Xeon 2nd Generation Cascade Lake processor supporting DDR4 memory, with two expansion slots for GPU and Accelerator cards. C-DAC is in the process of deploying HPC Systems across the nation with compute performance totaling 40PF, based on Rudra Servers called PARAM Rudra.
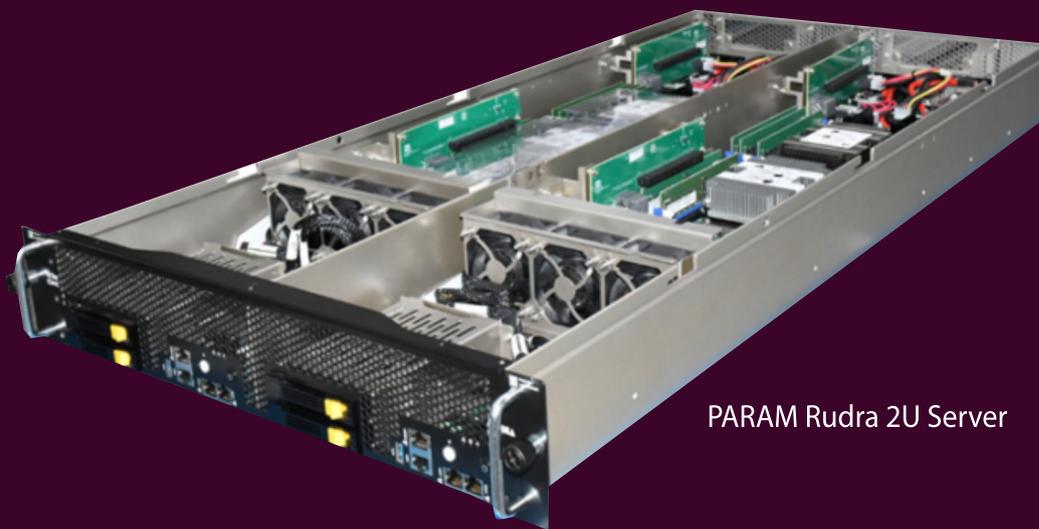
PARAM Rudra 2U Server
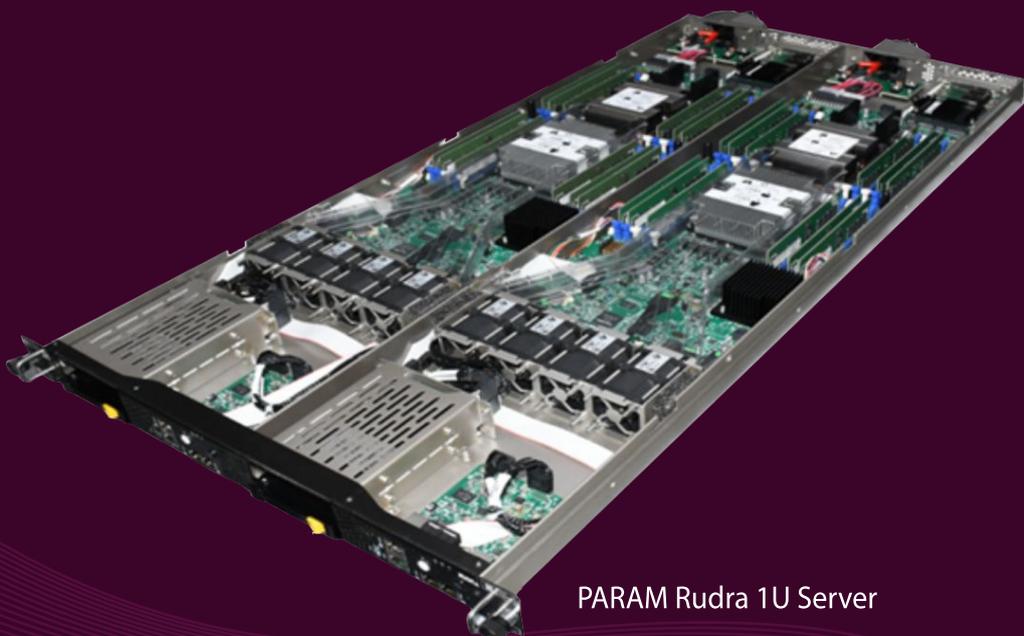
PARAM Rudra 1U Server

# Rudra Key features

- Suitable for diverse applications such as High Performance Computing, cloud and edge computing, and communication
- Dual socket, 2nd Gen Intel Xeon Scalable Processors (up to TDP 165W)
- 20 DDR4 DIMM slots LRDIMM, RDIMM (total upto 1.28TB)
- Support for Intel Optane Persistent Memory (NVDIMM)
- Two PCIe 3.0 x16 slots with GPU/Accelerator support
- Onboard 2 x 10Gbps Ethernet Interfaces
- One additional high-speed network slot (up to 100Gbps, OCP NIC 3.0 compatible)
- One 1GbE BMC management port
    - Support for IPMI2.0
    - Support for KVM
- Support for two U.2 NVMe/SATA
- Compliant with EMI/EMC and safety certifications such as CE, FCC, BIS, and UL.
- Versatile design allowing the possibility of many variants
- Different product SKUs available are
    - 2U server with Built-in power supply (can go as standard 19" server supporting 2 GPUs)
    - 2U storage server with Built-in power supply
    - 1U servers (two servers in one chassis) with centralized Power supply
    - 2U servers (two servers in one chassis) with centralized Power supply
    - ½ width 1U with centralized Power supply
    - ½ width 2U with centralized Power supply
- Designed to support both air-cooling and liquid-cooling server configurations
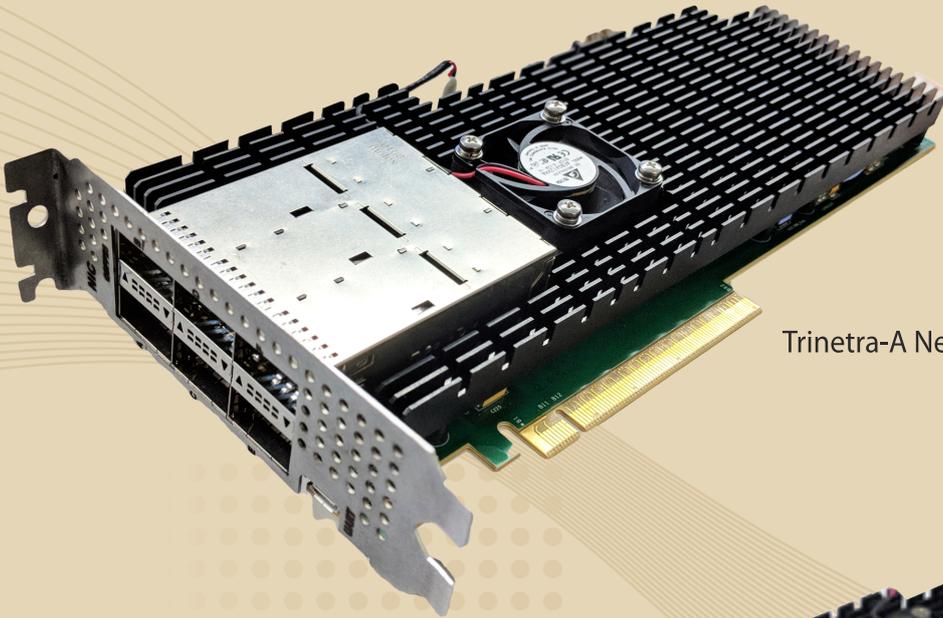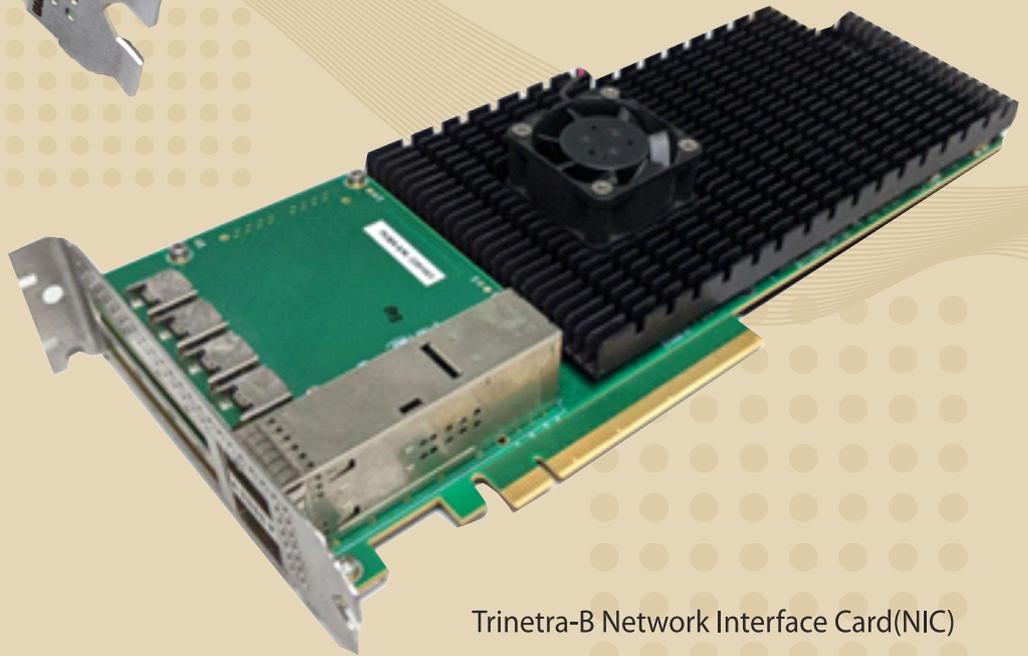
# Trinetra

Development of Indigenous HPC network design 'Trinetra' is an important area of work considering the strategic need for self-reliance in HPC technology development with a focus on state-of-the-art hardware system design. Trinetra network development covers multiple aspects such as complex chip design (NCC: Network Controller chip), Platform design (PCB development), and Lightweight Protocol networking software design. Trinetra network development, done under NSM is a multi-phase project, with the Trinetra-A phase currently reaching the product deployment stage.

Based on the experience gained during Trinetra-A Network development, CDAC is developing a next-generation switchless HPC network called "Trinetra-B" which is based on 200Gbps physical link layer technology. Trinetra-B design uses 10 such links to realize a 'Supercluster' topology which is an improvement over the 3D Torus used by Trinetra-A.

The prototype of Trinetra-B hardware has been completed successfully with validation done using bit error test (BERT) level to validate all the high-speed interfaces concurrently. Aggregate throughput from Trinetra-B physical link layer is 2 Terabits/sec, full duplex. To achieve such high data rates, several critical high-speed PCB design and signal integrity (SI) validation techniques have been used. Work on porting of NCC chip and software is currently under progress.

Trinetra-A Network Interface Card(NIC)


Trinetra-B Network Interface Card(NIC)
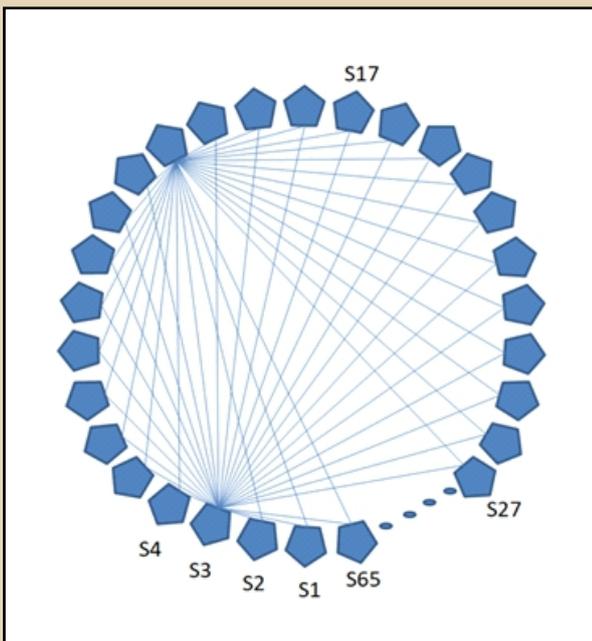

Sx: 32-server Supernode


Rudra + Trinetra-B PoC Cluster

# C-DAC's HPC Cluster Suite (CHCS)

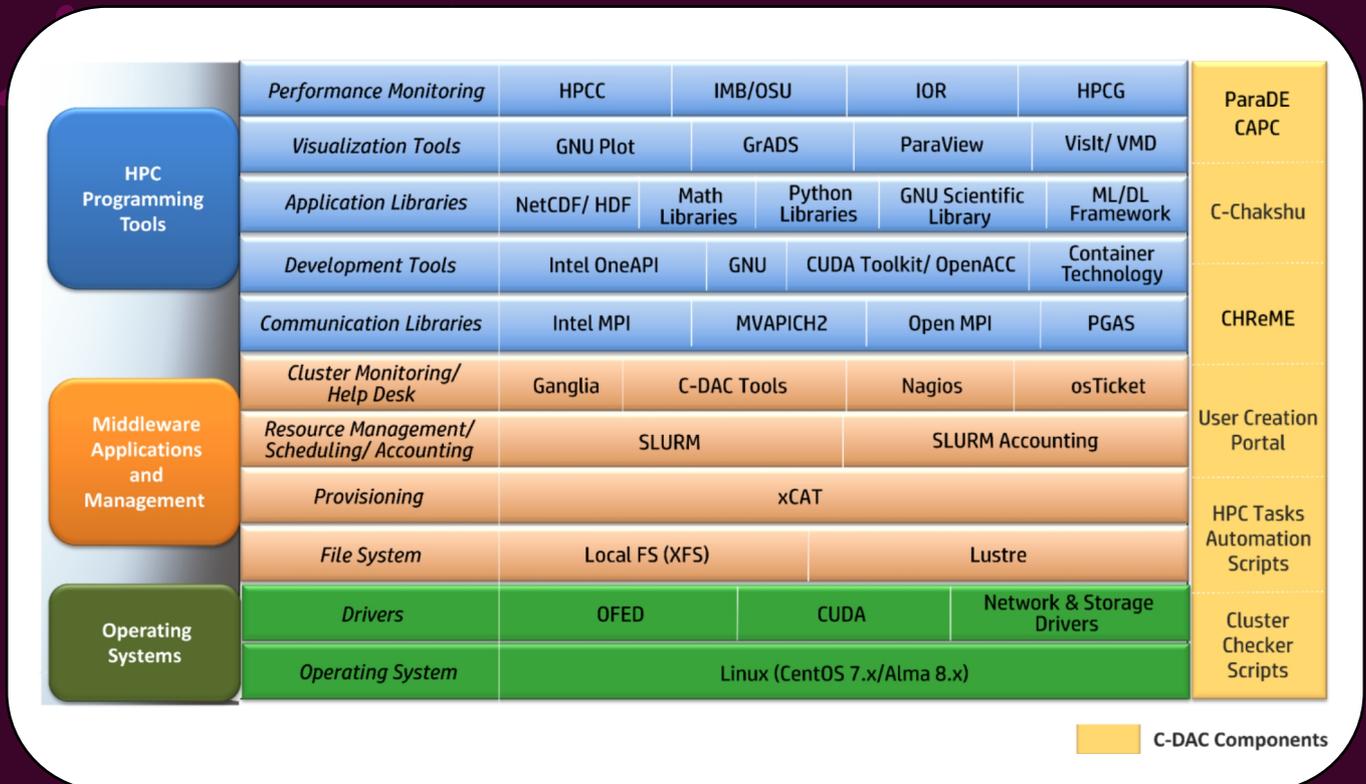CHCS, a system software stack designed for HPC deployment, represents a groundbreaking solution. It is built upon a customized open-source software framework, enriched with value-added indigenous tools, technologies, and scripts. This innovative platform streamlines the process of systematically building, deploying, and managing HPC and AI-based systems. Presently, NSM systems are built using CHCS. Looking towards the future of Exascale systems, CHCS is in the process of developing its customized provisioning tool. This tool will aim to efficiently boot up thousands of compute nodes in significantly less time, marking a significant step in HPC provisioning technology.

| | | | | | | |
|---|---|---|---|---|---|---|
| **HPC Programming Tools** | Performance Monitoring | HPCC | IMB/OSU | IOR | HPCG | ParaDE CAPC |
| | Visualization Tools | GNU Plot | GrADS | ParaView | VisIt/ VMD | |
| | Application Libraries | NetCDF/ HDF | Math Libraries | Python Libraries | GNU Scientific Library | ML/DL Framework | C-Chakshu |
| | Development Tools | Intel OneAPI | GNU | CUDA Toolkit/ OpenACC | Container Technology | |
| | Communication Libraries | Intel MPI | MVAPICH2 | Open MPI | PGAS | CHReME |
| **Middleware Applications and Management** | Cluster Monitoring/ Help Desk | Ganglia | C-DAC Tools | Nagios | osTicket | |
| | Resource Management/ Scheduling/ Accounting | SLURM | | SLURM Accounting | | User Creation Portal |
| | Provisioning | xCAT | | | | |
| | File System | Local FS (XFS) | | Lustre | | HPC Tasks Automation Scripts |
| **Operating Systems** | Drivers | OFED | CUDA | Network & Storage Drivers | | Cluster Checker Scripts |
| | Operating System | Linux (CentOS 7.x/Alma 8.x) | | | | |

**C-DAC Components**

## Indigenous components of CHCS:

C-CHAKSHU: C-Chakshu is a high-performance computing (HPC) multi-cluster monitoring and management platform designed for the National Supercomputing Mission (NSM) sites in India. This innovative platform offers a centralized web-based dashboard, providing a unified view of all NSM HPC clusters across geographically diverse locations nationwide.

CHReME: The C-DAC HPC Resource Management Engine portal is a user-friendly tool designed to streamline job submission, management, and monitoring for High Performance Computing (HPC) systems. It seamlessly integrates with various schedulers like Torque, OpenPBS, Sun Grid Engine, Moab, and Load Leveler, eliminating the need to learn complex command-line interfaces. This innovative portal empowers a wider range of users to leverage HPC resources, boosting overall cluster utilization.

Parallel Development Environment (ParaDE): This innovative Integrated Development Environment (IDE) empowers users to develop hybrid parallel applications with ease. It removes the complexity often associated with High Performance Computing (HPC), making it accessible to a wider audience. Furthermore, the IDE promotes data mobility, ensuring seamless data access regardless of location.

C-DAC's Automatic Parallelizing Compiler (CAPC): CAPC is a powerful tool that simplifies parallel programming. It automatically transforms sequential programs into equivalent parallel versions, unlocking the processing power of parallel architectures.

C-DAC HPC Application Profiler (C-HAP): CDAC HPC Application Profiler is a software tool that provides comprehensive performance analysis for High-Performance Computing (HPC) applications. It offers a wide range of features to help identify hotspots and bottlenecks, analyze application-level and node-level performance, visualize data consumption, suggest compilation options, and more. In addition, the tool has a user-friendly interface, eliminating the need for complex command-line submissions, and provides valuable insights into the performance of HPC applications.

HPC Service Desk :  HPC Service Desk is a ticketing system that streamlines HPC user support by routing inquiries, allowing for customization of data collection, and preventing duplicate responses from agents. It empowers agents with fast responses, SLA management, and collaboration tools. Users benefit from a quick response portal. This Desk provides valuable reporting and scales with the NSM vision, making it a powerful asset for managing user support.

# Future Roadmap

In the coming year, we are embarking on an ambitious plan to deploy 10 additional supercomputers based on indigenously designed Rudra Servers, aligning with the "Atmanirbhar Bharat" Make in India initiative. Notably, they will be manufactured entirely in India, showcasing our commitment to self-reliance and augmenting the nation's supercomputing capabilities. Furthermore, an AI-powered supercomputer will be commissioned.

Moreover, these systems will incorporate advancements such as the Development of Rudra server board 1.0, Trinetra/Mellanox HPC interconnects, HPC system software stack 2.0, and a wide array of benchmark applications encompassing both cloud and HPC/DL/ML domains. The indigenous endeavors have yielded remarkable achievements, including the creation of Trinetra high-speed interconnects and Direct Liquid Cooling units.
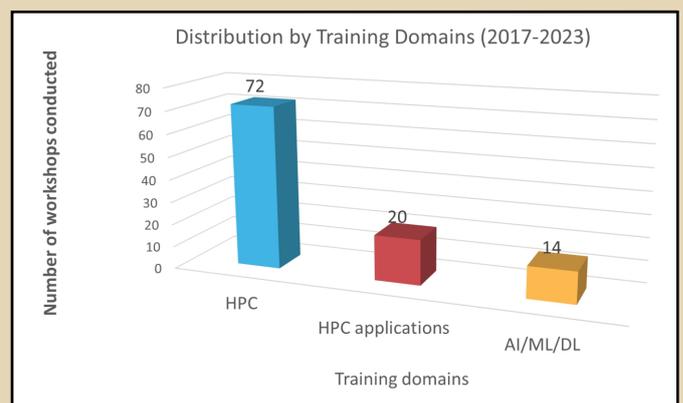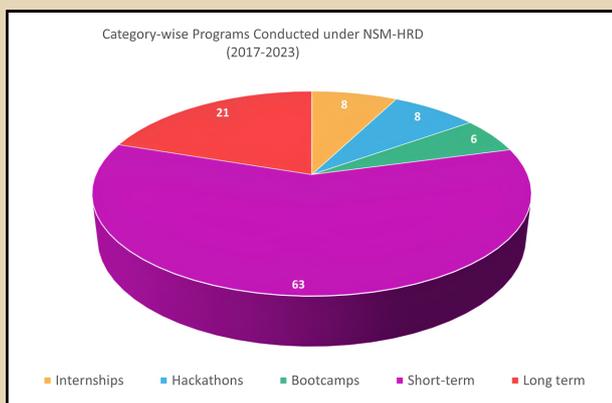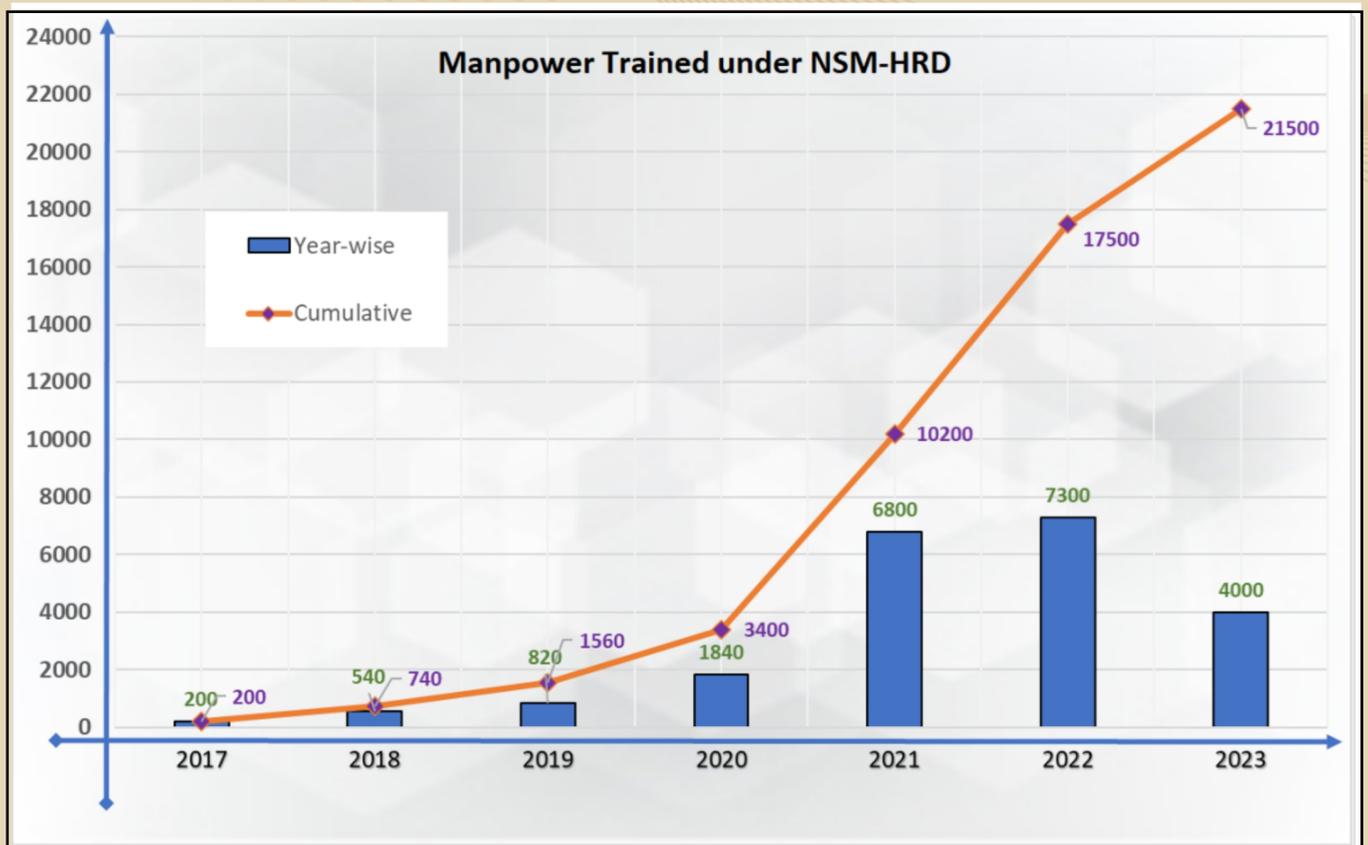
Our server, Rudra, built on the Intel Cascade platform, underscores our dedication to innovation and efficiency. Not only are these systems cost-effective, but they also boast superior power efficiency in operation. Together, these advancements will culminate in a substantial leap in computing power, with a total capacity of 64 PF. These groundbreaking supercomputers will comprise of the following:

- 3 PF HPC system at IUAC New Delhi
- 650 TF HPC system at SN Bose Kolkata
- 650 TF HPC system at IIT Patna
- 1 PF HPC system at GMRT-TIFR Pune
- 3 PF HPC system at IIT Bombay
- 3 PF HPC system at IIT Madras
- 650 TF HPC system at IIT Jammu
- 20 PF HPC system at C-DAC Bangalore
- 200 TF HPC system at C-DAC Delhi
- 1 PF HPC system at C-DAC Pune
- 250 AI PF System at IIT Delhi

# NSM Initiative in HRD

An equally important pillar of NSM is development of HPC aware and HPC skilled manpower to proliferate use of HPC for scientific and engineering research as well as to augment the workforce required to support HPC user community. More than 21,500 students, researchers and faculties have been trained towards generation of HPC aware manpower since year 2017. About 4,000 manpower has been trained in 2023.

The training programs offer different types and lengths of courses conducted by C-DAC, IITs and industry partners. The programs consist of long and short term courses, workshops, internships, hackathons etc. The long-term courses include three and six months courses. Workshops are one-to-two week training programs which include Faculty Development Programs (FDP), scientific domain specific workshops etc. Hackathons are majorly a 5-day program where teams work to solve a given problem statement or their own applications with the help of dedicated mentors.



Manpower Trained under NSM-HRD



Category-wise Programs Conducted under NSM-HRD (2017-2023)



Distribution by Training Domains (2017-2023)

# PARAM Supercomputers - NSM in News

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## 25+ Startups Onboarded to Use National PARAM Supercomputing Facility

Vardaan    Wednesday, January 17, 2024    0 Comments

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Over 25 Startups in AI domain have been onboarded by Centr... of Advanced Computing (C-DAC), India to leverage AIRAWAT-PSAI High P... Infrastructure.

AIRAWAT is ranked #75 among the World's TOP-500 Super... Linpack Performance in the 1st edition of TOP500 List publ... June 01, 2023.

The startups onboarded by C-DAC will get incentives of 1... support from C-DAC AI experts.

## THE TIMES OF INDIA

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THIS STORY IS FROM MAY 2, 2023

### IIT-Patna to get PARAM supercomputer by September this year

Madan Kumar / TNN / May 2, 2023, 21:22 IST

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The Indian Institute of Technology-Patna (IIT-P) is set to receive its first supercomputer, a PARAM system of 833 TF under the National Supercomputing Mission, which will be installed on the Bihta campus by September 2021. The infrastructure for the supercomputer will be based on Rudra server, which is indigenously manufactured in India, in line with the "Aatma Nirbhar Bharat" initiative.
Read Less

IIT Patna inks MoU with C-DAC on Tuesday for setting up supercomputer at IIT Patna by September this year

## IISc. commissions one of India's most powerful supercomputers

Param Pravega, commissioned under the National Supercomputing Mission, is the largest in any Indian academic institution

February 03, 2022 01:08 pm | Updated February 04, 2022 11:27 am IST – Bengaluru

STAFF REPORTER

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The Indian Institute of Science (IISc.) has installed and commissioned Param Pravega, one of the most powerful supercomputers in India, and the largest in an Indian academic institution, under the National Supercomputing Mission (NSM), in February 2022.

# 1PF supercomputing system based on C-DAC's Rudra servers to be installed at GMRT

By Jui Dharwadkar

Feb 03, 2023 11:49 PM IST

OPEN APP

Play to Win

The Centre for Development of Advanced Computing (C-DAC) and National Centre for Radio Astrophysics (NCRA) have come together to build a high-performance computing facility

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## THE TIMES OF INDIA

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NEWS / GADGETS NEWS / 9 More Supercomputers To Be Added Under Nation... | OnePlus Nord Ce 4

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Today ePaper

⏱ THIS STORY IS FROM AUGUST 17, 2023

# 9 more supercomputers to be added under National Supercomputing Mission, list of four current fastest machines in India

TIMESOFINDIA.COM / Aug 17, 2023, 08:22 IST

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The Indian government has approved a Rs 14,903 crore ($2 billion) expansion of the Digital India programme to enable digital delivery of services to citizens.

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# Avalon Technologies joins MeitY's RUDRA supercomputing mission

The partnership will add to the indigenous manufacturing capability of High-Performance Computing systems that are a part of the 'RUDRA' programme, said the company in an announcement



Ashutosh Mishra | New Delhi

2 min read Last Updated : Jan 12 2024 | 10:00 PM IST

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Home > News > Govt to set up 9 more supercomputers in Indian institutes, a push to meet higher computational demand

Supercomputer | Feb 24, 2022 | INDIA

# Govt to set up 9 more supercomputers in Indian institutes, a push to meet higher computational demand

The National Supercomputing Mission was launched to enhance the research capacities and capabilities in the country by connecting them to form a Supercomputing grid, with National Knowledge Network (NKN) as the backbone
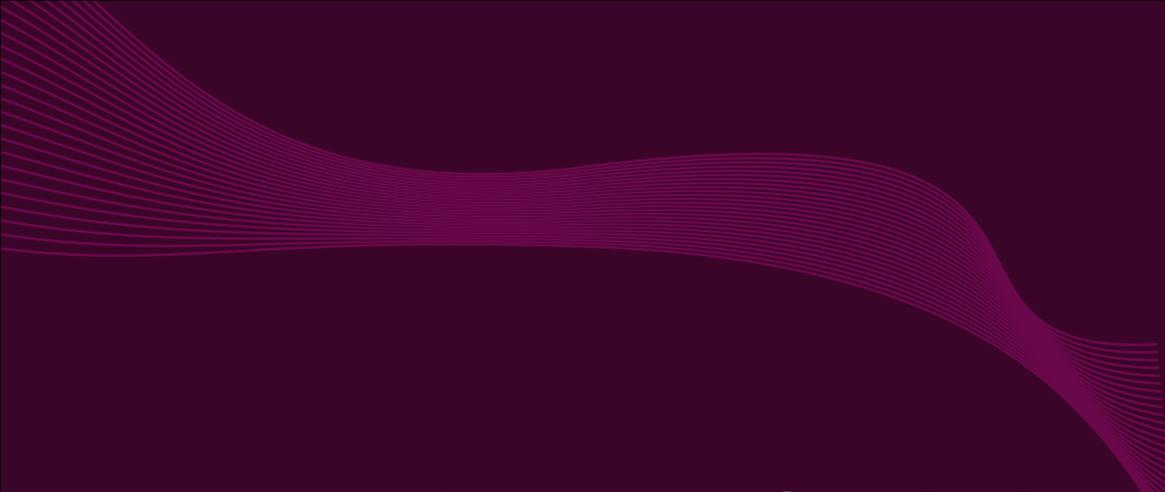
# How to Access NSM PARAM System

Recommended process for creating a user account to access the NSM facility:

1. Visit nsmindia.in

2. Navigate to the "How to access NSM HPC System" section, where you will find a link to the User Creation portal.

3. Click on the provided link to access the registration page.

4. Fill in all required information on the registration page.

5. Upload the necessary documents as instructed.

6. Once the form is complete, submit the details.

7. The NSM committee will review the submission.

8. If accepted, users will receive an email containing their user credentials and allocated cluster.

Note: For any inquiries, please contact - **nsmsupport@cdac.in**

Recommended process for creating a user account to access AIRAWAT-PSAI:

1. NPSF has implemented a Web Application which has completely digitized the user on-boarding process (Technical Affiliation Scheme) and it has made it available at **https://airawat-psai.cdac.in/tas/web**

2. The process requires Digital Signature to be executed by the applicant for which C-DAC's eHastakshar (eSign) services is integrated with the Web Application.

3. To begin the process, prospective users should navigate to **https://airawat-psai.cdac.in/** and fill out the online application form available at **https://airawat-psai.cdac.in/tas** with all the required details.

4. Once the form is filled out, prospective users proceed to finalize the eHastakshar (e-sign) process.

5. Upon successful completion of the TAS form and the e-signature (digital signing) process, the form is submitted to the National PARAM Supercomputing Facility (NPSF), C-DAC team via auto-generated email for thorough scrutiny and approval.

6. Following approval from the relevant authority, an account will be created for the user on the AIRAWAT-PSAI system as part of the onboarding process.

7. Users will then be notified about their account details and system access details via email, along with any required manuals and advisories for using the system effectively.

# NSM User's Feedback

> "PARAM Siddhi computing facility helped to train the AI model with the large dataset collected (side channel traces (power/EM) captured from the FPGA board when the cryptographic operation is executed). PARAM Siddhi helped us to train the model faster. The support team of PARAM Siddhi helped us whenever required for the successful execution of our program."
>
> — A Suganya,
> Senior Scientist, Society for
> Electronic Transactions and Security (SETS)

> "Param Seva helps me a lot to perform the DFT calculations for large supercells. Support team is also very helpful. I get support instantly when I face any problem. I owe the deepest gratitude to the Param Seva team."
>
> -Sukhanidhan singh,
> Indian Institute of Technology (ISM)
> Dhanbad

> "PARAM Ganga has helped me immensely for my Molecular Dynamics and Phonon studies. The helpdesk has also helped a lot in running the software and issues with different modules."
>
> Partha Pratim Paul,
> IIT Roorkee

> "The HPC system at PARAM SEVA has helped us to speed up our calculations. We used Quantum Espresso and ORCA software for our calculations. I really appreciate the help received very quickly from the support team. We are thankful to the Param Seva team for the wonderful job they are doing."
>
> -Prof. Ajay Chaudhari,
> Professor, Indian Institute of Science

> "Carrying out calculations, especially bigger simulations, was really difficult before the NSM facility. It used to take a huge amount of time since small clusters/workstations were used for this purpose. The calculations, which took 3 days to complete, are done within 12-13 hrs after the NSM facility. Now, we are able to simulate even big systems very quickly, and hence, our models are more realistic. This has helped us to move closer to experiments, and publishing complete theoretical papers has become easier now. We are highly indebted to CDAC Pune, Ganga support team, and Institute Computer Centre IIT Roorkee for this facility and for helping us to take full advantage of this huge machines"
>
> Sumangla Arora,
> Phd Scholar, IIT Roorkee

# NSM User's Feedback

"
We are working on problems on receptivity and transition of high-speed boundary layer, flow induced vibration and oscillations for bluff and streamlined bodies, and acoustic radiation from flows past streamlined bodies. Results are very promising and that has led to very good theoretical understanding of the problem. We plan to disseminate at least 5 manuscripts based on the obtained results so far in peer-reviewed and acclaimed journals. Our experience in using PARAM Kamrupa has been very good so far and we wish to continue the association.

- Dr. Swagata Bhaumik,
IIT (ISM) Dhanbad
"

"
PARAM Shakti has helped our research group immensely in conducting DFT calculations on a wide range of research problems. The helpdesk has responded promptly in installing different programs & modules required by us from time to time. In short, helpdesk has been remarkably supportive. We owe the deepest debt of gratitude to IIT Kharagpur and the support team of PARAM Shakti.

- Dr. Modhu Sudan Maji,
Associate Professor, IIT Kharagpur
"

"
The technical support team at PARAM Himalaya has always been helpful and supportive and it is due to their contribution that I was able to fully utilize the computational facilities. We owe the deepest gratitude to IIT Mandi and the support team at PARAM Himalaya.

-Mayank Chopra,
Student, IIT Ropar
"

"
PARAM Smriti is helping me immensely with the supercomputing facility on a wide range of research problems. The helpdesk has been notably swift and productive in setting up different programs & modules required from time to time. In short, the helpdesk has been remarkably supportive. We convey our deep appreciation to both NSM and the PARAM Smriti support team for their invaluable support.

- Harshita Seksaria,
PhD Scholar, Institute of
Nano Science and Technology, Mohali
"

"
The micromagnetic framework requires us to simultaneously solve the magnetization dynamics of several millions of magnetic spins associated with a magnetic structure. We are able to perform such a massively parallel task in a reasonable time frame through the use of Nvidia GPUs provided by the Param Ananta Cluster.

- Dr. Naveen Sisodia,
Assistant Professor, IIT Gandhinagar
"

"
PARAM Brahma has been of tremendous help in executing crucial memory intensive calculations. Without this support we would not have completed many key calculations that have led to some very important papers from our group. We are thankful to CDAC-Pune and the support team of PARAM Brahma.

- Dr. Sudipta Dutta,
Associate Professor, IISER Tirupati
"

# NSM User's Feedback

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We have used PARAM Pravega extensively during the development of the in-house solver as well as for the full simulations reported in our papers. We have used OpenMPI, HDF5 and Hypre modules available in the cluster for running the simulations. The installation and job submission systems in the cluster have worked seamlessly enabling us to focus on our simulations quickly without any start up time. The availability of such a cluster motivates and enables us to plan and study physical problems using numerical simulations which require considerable computational resources.

Kiran S.,
Indian Institute of Science Bangalore

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The access to PARAM Brahma has helped us to carry out computational calculations in a very efficient manner. We have made significant progress in our research works and completed several collaborative projects in the last six months due to the supercomputer's multiple job submission facility, owing to its highly competent queuing system. We must note that no data loss has been occurred so far, which is appreciable considering the massive number of users accessing the facility. We would also like to thank the PARAM Brahma support team, who have been very helpful in solving our queries and issues. Nonetheless, access to this fast and reliable supercomputing facility under the NSM, has boosted our research and helped us tremendously to compete in this fast-paced scientific era.

Dr. Kumar Vanka,
Senior Principal Scientist, NCL Pune

"

"

CDAC has been doing a wonderful job for many years in helping Computational Scientists across India in their active pursuit of research. The strong computational support provided by CDAC-Pune enables us to pursue good quality research. I would like to appeal to the Govt. of India to allocate substantial funds to CDAC-Pune to support the latter in their future endeavours, which includes upgrading their HPC systems. Any HPC system gets outdated in five years. Moreover, the usage of Param is really high. Param caters to users from all over India. CDAC-Pune is in dire need of a strong funding support from the Govt. of India. Integration of the latest computational resources into the current HPC system is the crying need of the hour.

- Prof. Joydeep Chowdhury,
Research Scholar, Jadhav University

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# Acknowledgements

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operating NSM systems and supporting users:

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