



National Supercomputing Mission (NSM)

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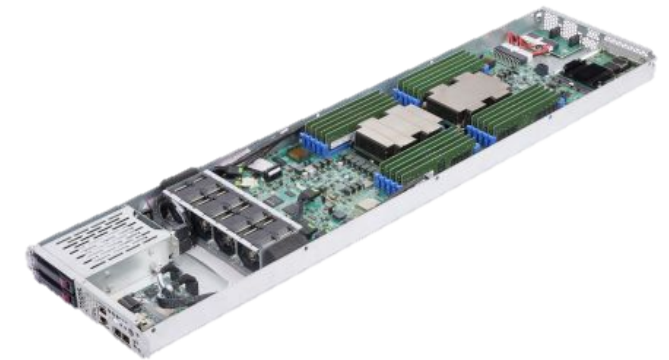
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National Supercomputing Mission (NSM)

Objectives of NSM

- **Supercomputing infrastructure** in the country
- **Indigenous Supercomputing ecosystem** in phased manner: From “Assembly” to “Manufacturing” to “Design and Manufacturing” of Supercomputers
 - Servers
 - HPC network
 - Software stack
 - HPC Processor
 - Liquid cooling technologies
- **Supercomputing Applications** of National interest
- **Human resources** for applications development and HPC maintenance



- Phase-1: Assembly in the country with Indigenous S/W Stack
- Phase-2: Manufacturing in the country with Indigenous S/W Stack
- Phase-3: Design & Manufacturing in the country
- Phase-1 and Phase-2: **15 systems** with compute power of **22PF** built at IITs, C-DAC, NIT, JNCASR and IISER
- Overall **28 Lakhs+ HPC Jobs** Executed on NSM Systems
- **2200 users** across the country from 85+ institutes
- Phase-3: Larger systems with compute power of more than **40 PF** planned



NSM Supercomputers across the Nation



IIT BHU, Varanasi
833 TF



IIT Kharagpur 1.66 PF



IISER, Pune 797 TF

NSM Supercomputers across the Nation



IIT Kanpur 1.66PF

IIT-H 833 TF

JNCASR 833 TF



NSM Supercomputers across the Nation

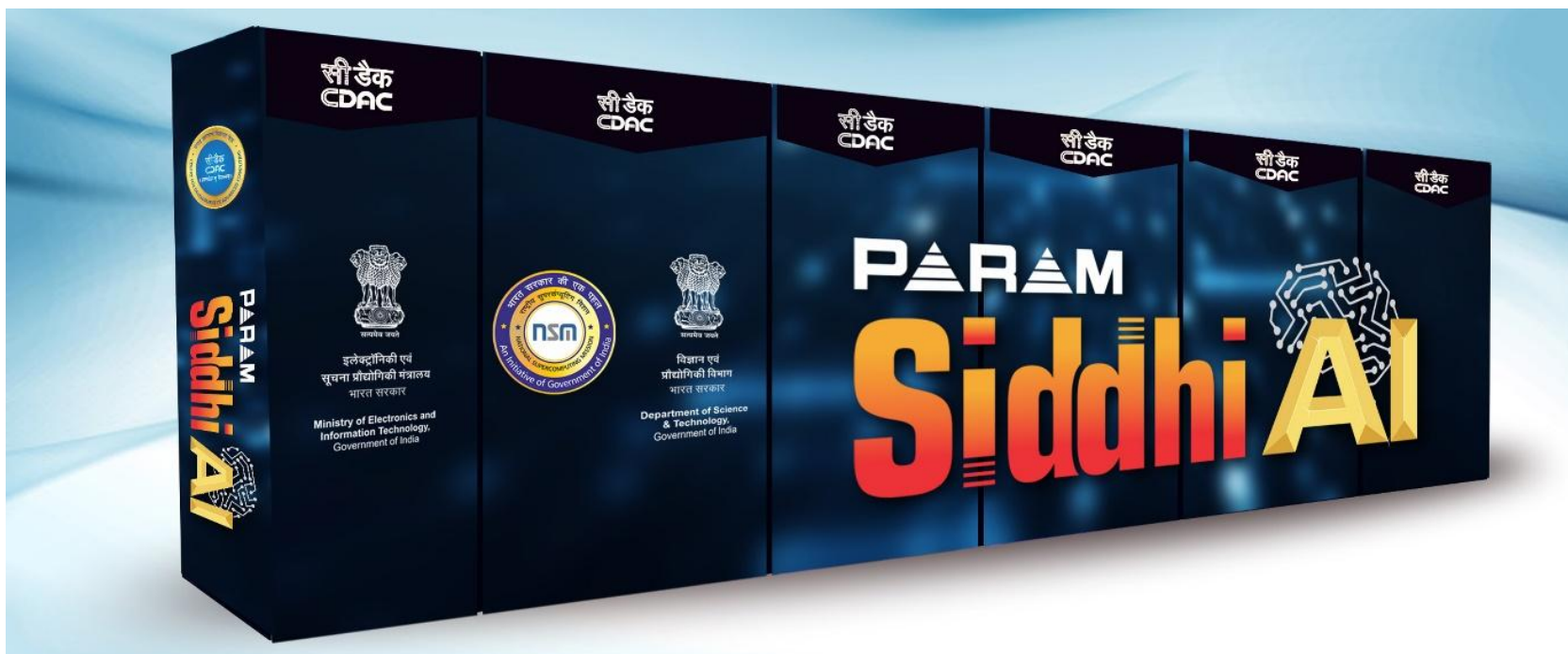


C-DAC B 833 TF

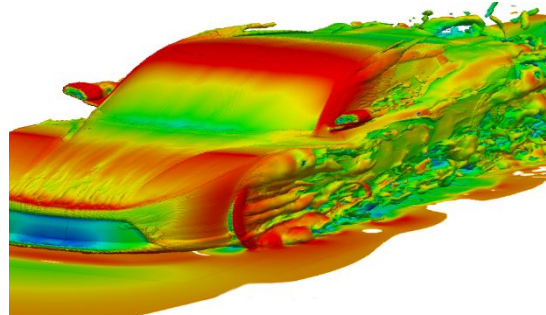
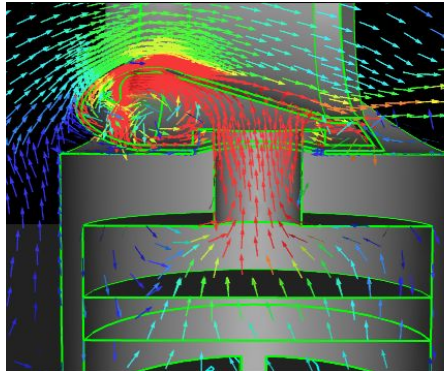
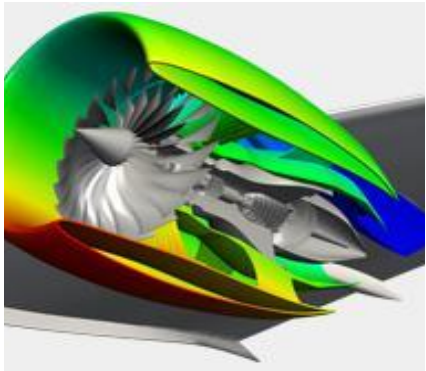
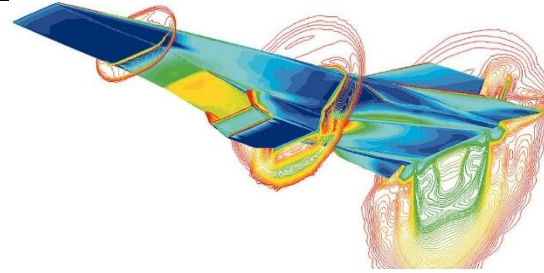
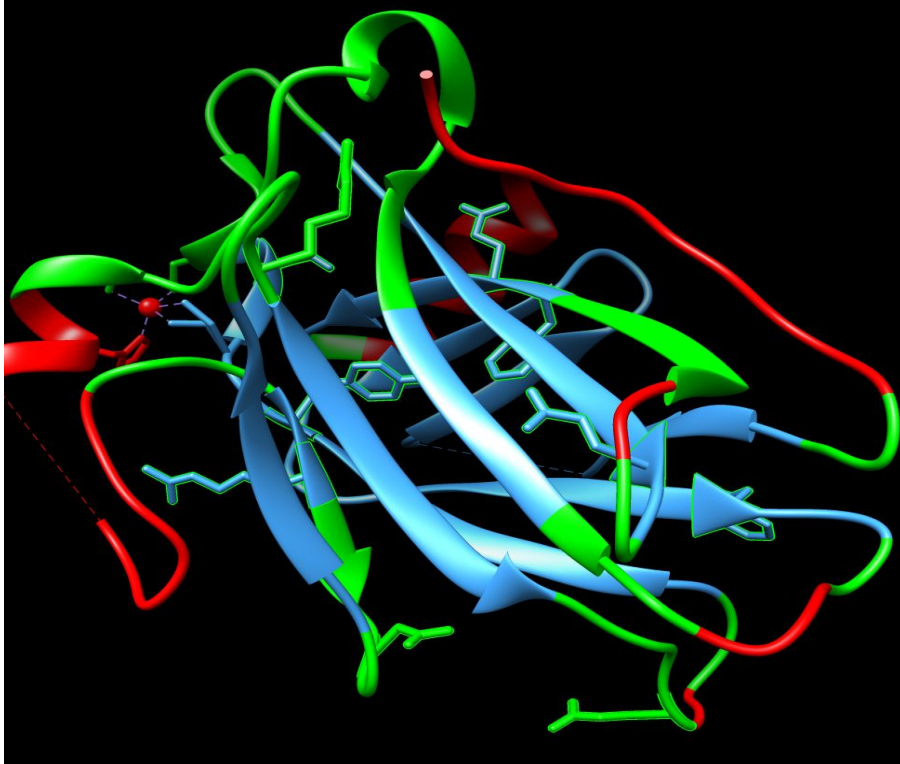
NABI Mohali 833 TF



PARAM Siddhi AI



- PARAM Siddhi - AI of **5.26 Petaflops (210 AI Petaflops)** is the fastest Supercomputer in India and **ranked at No. 62 position** in 'TOP500 Supercomputer List – November 2020' declared at Supercomputing Conference 2020 (SC 20) at United States.
- HPC-AI Convergence
- 139 Users from 19 institutes



Solving India Specific Real World Complex Problems

Aimed at Both HPC applications and training AI models using very large data sets, which then can be hosted at other data centre locations/edge devices for inference services

Connecting Start-ups, MSME, Academia, Researchers and Industry

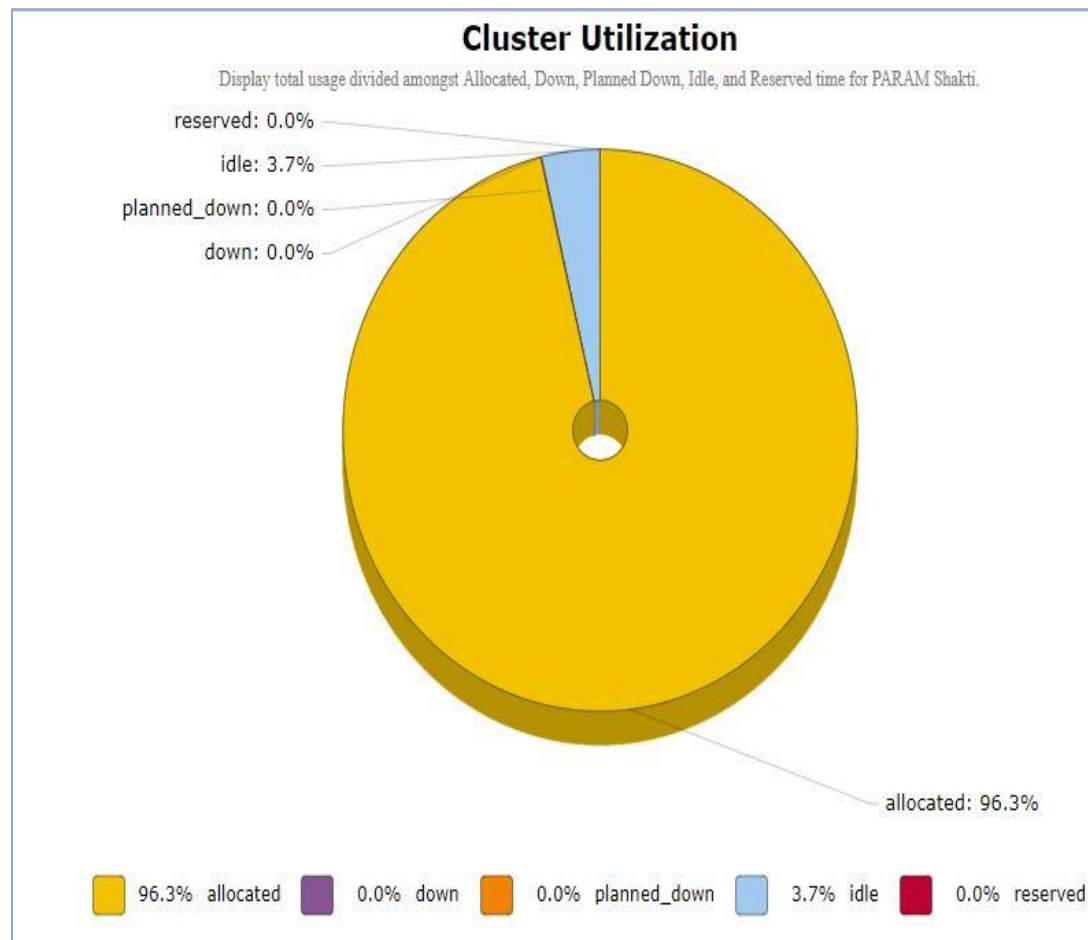
- Natural Language Processing
- Multi-lingual machine translation
- Text-to-Speech in Indian languages
- Image Processing
- Health Care
- Automotive industry
- Agriculture



NSM Clusters – Applications, Tools, Programming Models- AI & HPC

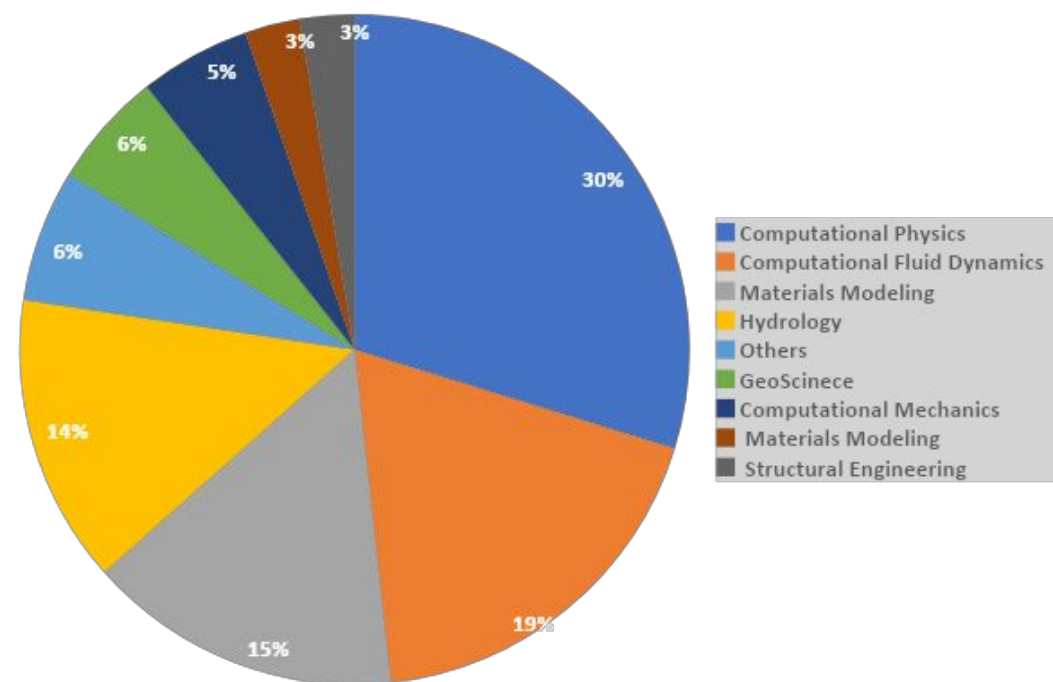
HPC Applications	Bio-informatics	MUMmer, HMMER, MEME, PHYLIP, mpiBLAST, ClustalW	Visualization Programs	GrADS, ParaView, VisIt, VMD
	Molecular Dynamics	NAMD (CPU & GPU), LAMMPS(CPU & GPU), GROMACS	Dependency Libraries	NetCDF, PNETCDF, Jasper, HDF5, Tcl, Boost, FFTW
	Material Modeling, Quantum Chemistry	Quantum-Espresso, Abinit, CP2K, NWChem,	Programming Models	MPI, OpenMP, OpenACC, CUDA, PGAS, Pthreads
	CFD	OpenFOAM, FDS, SU2	Installed additional applications, libraries, tools on different NSM systems as per requirements from users of respective systems	
	Weather, Ocean, Climate	WRF, RegCM, MOM, ROMS		
	Disaster Management	ANUGA Hydro		
AI/ ML/ DL Tools/ Technologies		DL Frame work: TensorFlow , keras, theano, pytorch, scikit-learn,scipy, cuDNN		
		Data Science: Numpy , RAPIDS		
		Distributed DL Framework: TensorFlow with Horovod		
		Container Technology: enroot		
		JupyterHub: DL application development platforms and web based IDE		

Typical System Utilization (IIT Kharagpur)



Shakti

PARAM Shakti Domain Wise Utilization

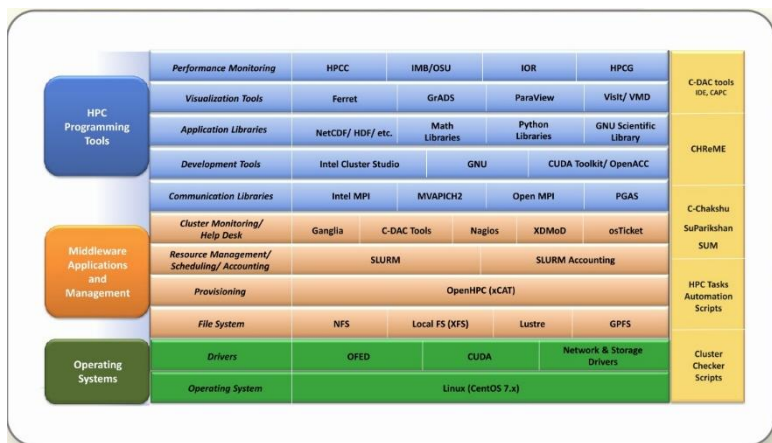
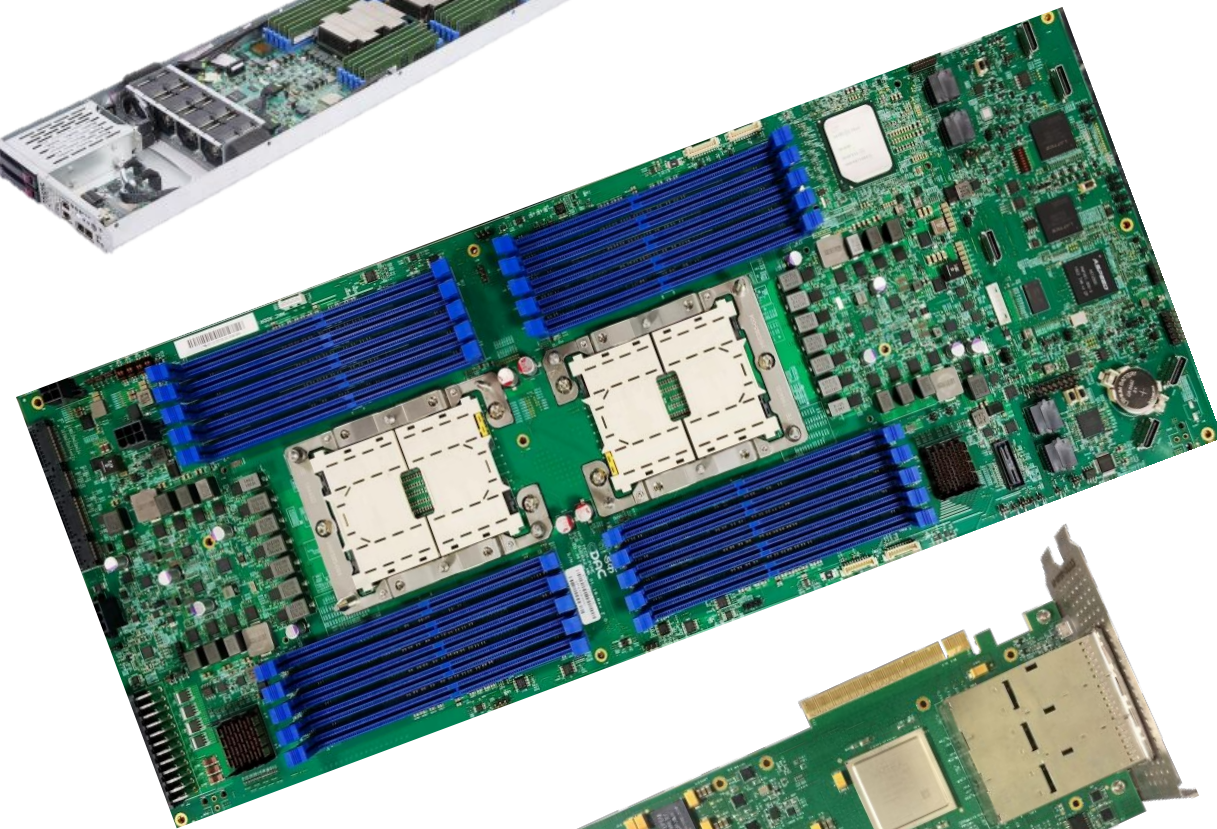
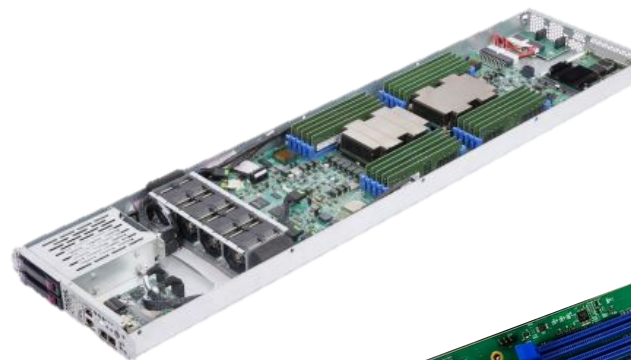


Domain-wise Usage

NSM R&D (Build Approach)

Indigenous Developments

- Rudra Server Platform
- HPC interconnect (Trinetra) -100 Gbps x 6 and 200 Gbps x 10
- HPC system software stack
- Liquid cooling technologies
- AUM-HPC processor development initiated – 96 Cores – An advanced step towards more than **90% indigenous** server Design & Manufacturing



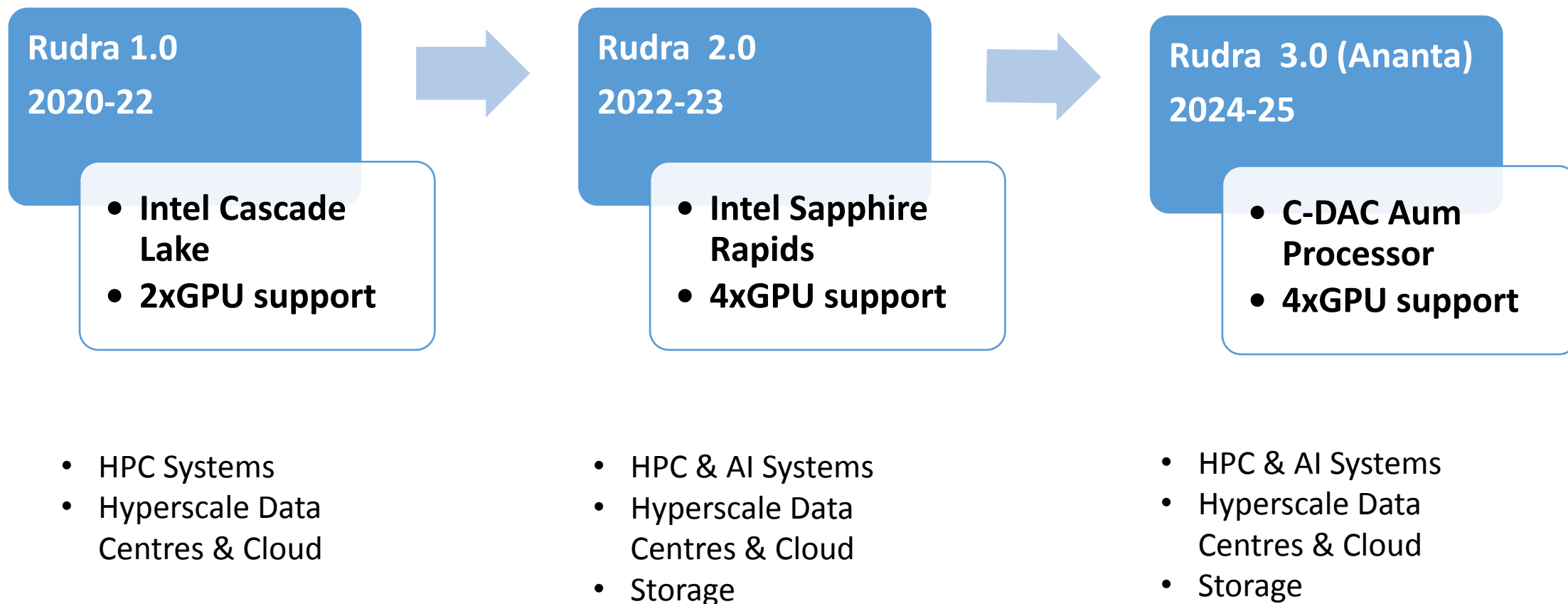
Rudra Server Platform

- C-DAC's indigenous Server Platform design – a step towards ATMANIRBHAR BHARAT
- **Complete control over Firmware and hardware design – Secure server**
- **Very dense, space saving, ½ width 1U/2U design – up to 64 servers in one rack - Up to 40KW load in a single rack**
- Up to 16 Blades with centralized power supply and Hot-swap feature
- Dual Socket Intel Xeon 2nd Gen scalable processor (Cascade lake) up to 24 cores each
- **Supports two GPUs/Accelerators**
- OCP 3.0 NIC with choice of Network connectivity (25/50/100 Gbps) or 100/200 Gbps HPC network
- On-board 2x 10Gbps Ethernet
- Two NVMe/SATA SSDs on U.2 connector
- **Targeted for both HPC and Cloud market**



Application		Rudra (@ 2.4 GHz)	Brahma (@ 2.9 GHz)
	No. of Nodes	Minutes	Minutes
NAMD v2.12	1	75.7	72.6
	2	39.2	38.5
	4	20.3	20.6
WRF v3.8.1	1	93.8	92.3
	2	48.4	48.1
	4	24.7	25.5
OpenFOAM v4.1	1	149.1	149.55
	2	70.3	71.91
	4	33.1	35.18
GROMACS v5.1.4	1	74.2	69.85
	2	35.6	36.16
	4	19.1	19.5

Rudra Server Roadmap





C-DAC Roadmap on Server Development

- Phase-3 systems based on Rudra 1.0
 - 32 PF compute Power
 - Requirement of around 5000 servers
 - In the process of shortlisting EMS vendors for manufacturing
- Development of Rudra 2.0 Server based on Next Generation Intel Processor Sapphire Rapids is in progress
- **Industry collaboration for development, Technology Transfer to OEMs/ODMs, Manufacturing and Support**
- Looking for suggestions for server design from industry for Data center requirements

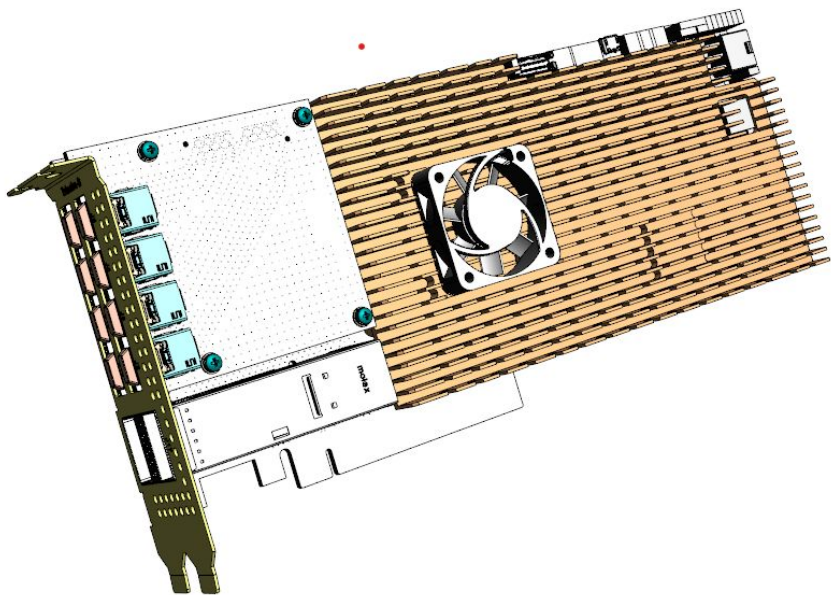
Trinetra: Paving way for Indigenous Exascale Systems



Low Latency, High Bandwidth, Scalable Network

Trinetra-A

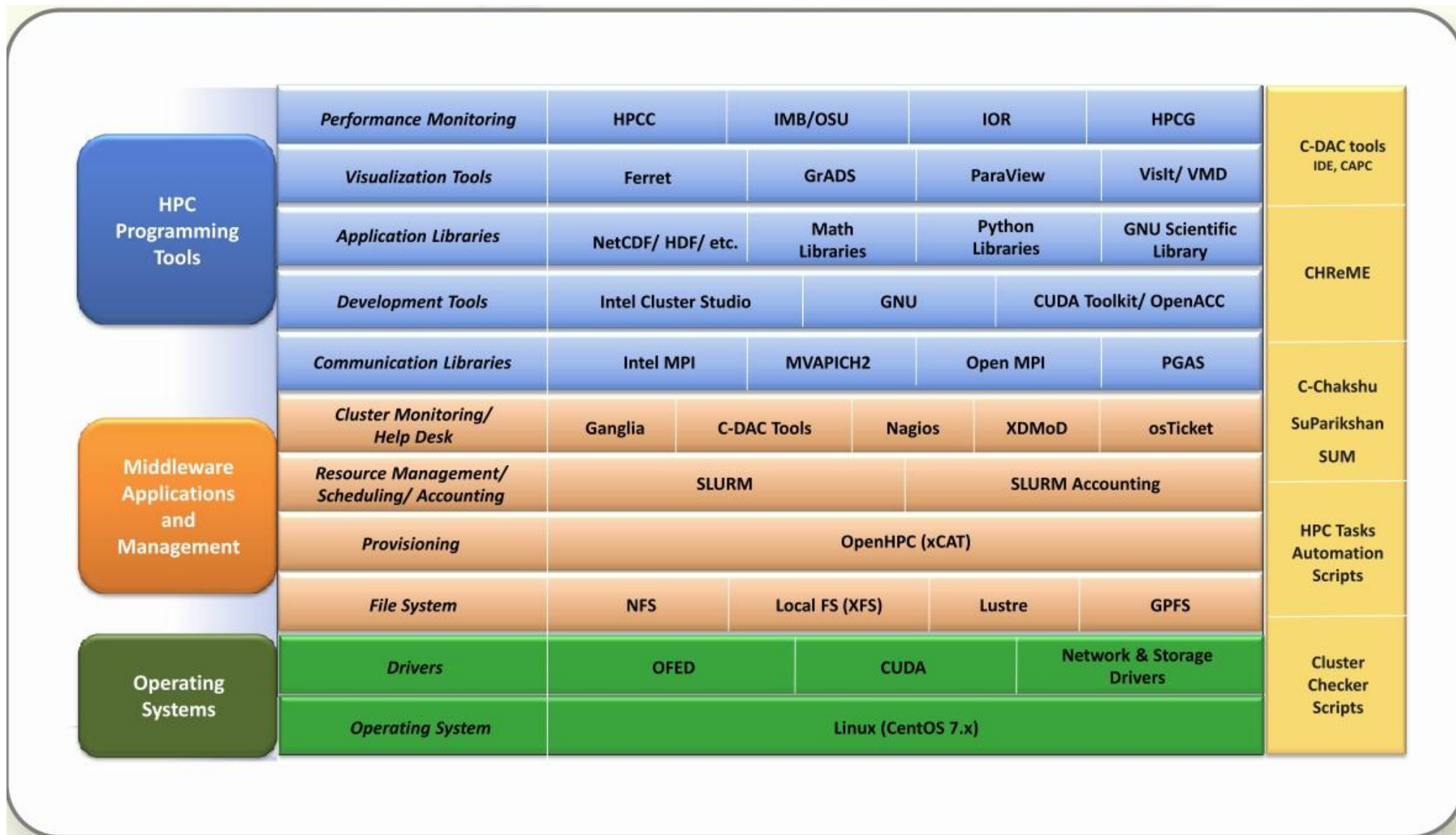
- 6*100Gbps full duplex interfaces
- PCI-e GEN3x8 host interface
- 3D Torus topology
- NCC-I Co-processor



Trinetra-B (under development)

- 10*200Gbps full duplex interfaces
- PCI-e GEN3x16 host interface
- Cascaded Hypercube topology
- NCC-II Co-processor

C-DAC HPC Software Stack





AUM - HPC Processor Development



- Planned to be available in 2024
- 96 core HPC Processor
 - ARM 8.4 architecture
 - 96MB L2 cache, 96MB System cache
 - 8 channel 5200 Mhz DDR5 memory
 - 64 GB HBM3 5600Mhz memory
 - PCIe5 64 Lanes – CXL support for coherent Accelerators/ NIC
 - SMP support up to 2 sockets
 - Security Features - Secure boot and Crypto support
 - TSMC 5nm Technology Node, Chiplet based architecture, 2-Chiplets, 96-Cores and up to 96-GB HBM3 memory in a socket
- Dual socket Server design with up to 4 Industry standard GPU accelerators – Both HPC and AI applications (CPU Only node ~ 10 TF/Node)
- Indigenous Software eco-system for Aum Processor leveraging open source eco-system
- Targeted for both HPC and Cloud market

Design & Development of DCLC Based Cooling System

IIT Bombay and C-DAC

Outcome

1. Development of a 30 kW Panel water heat exchanger with evaporative cooling
2. Development of a 360 W chip cooler for cooling processor using liquid (water)



Chip cooler

Impact

1. Development of an efficient external cooling system for HPC
2. Indigenization of liquid cooling of a HPC server



30 kW panel water heat exchanger

- Technology Partners
 - Intel
 - Mellanox, NVIDIA
 - DDN
- Phase-1, Phase-2 Manufacturing OEM – ATOS
- Data Centre Infrastructure building – IBM, Schneider, Nikkom
- PCB Design Service Providers
 - Q-Wave
 - Sienna Design
 - Coreel
- EMS partners in EOI – Flex, VVDN, InfoPower, Kaynes, Velankani, Foxconn
- Fabless SoC design houses – in process



NSM HRD



- Training of **more than 11000** students, researchers and faculties toward generation of HPC aware manpower is accomplished
- Through Faculty Development Programs (FDP), online courses, Workshops, Bootcamps, and Hackathons.
- **Course curriculum development** – Short Term, M.Tech and for undergraduate – Some of the IITs and NITs started HPC courses
- **4 Nodal Centres** established at IIT madras, IIT Kharagpur, IIT Goa, IIT Pallakad
- **Online courses** on basics of **HPC, ML and DL** were conducted by NSM nodal centres along with C-DAC
- **Mission Target 20000 HPC aware manpower**

Early Warning and Flood Prediction for River Basins of India

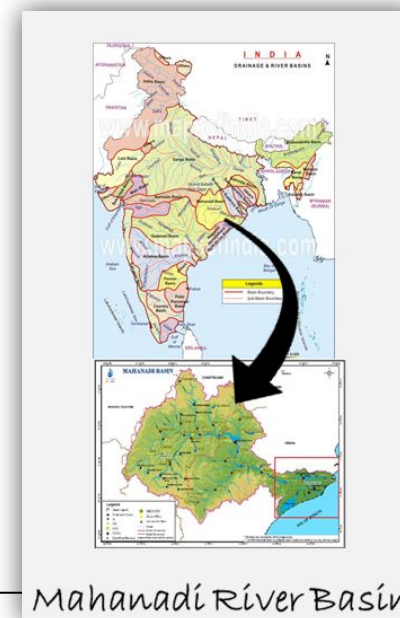
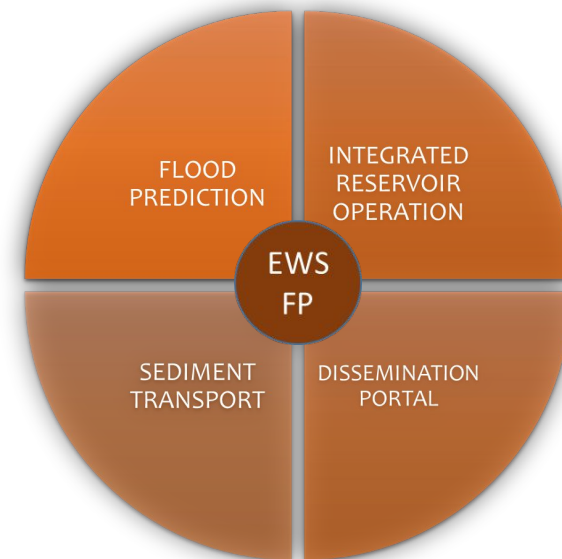
USER AGENCY: CENTRAL WATER COMMISSION, ODISHA STATE WATER RESOURCES DEPARTMENT,
ODISHA STATE DISASTER MANAGEMENT AUTHORITY

OBJECTIVE

- Design, develop and deploy a user- friendly and comprehensive Early Warning System for Flood Prediction (EWS-FP) in the River Basins of India on HPC system

CURRENT STATUS

- Model setup customized and completed for Mahanadi river basin
- Daily simulation being carried out for generating **3-days forecast for Mahanadi Delta region** using NSM HPC resources
- Outputs of daily simulation being sent to User Agency (CWC)
 - Simulation result of 3-days forecast
 - Inundation maps, Water level and Village level percentage inundation information





HOME PAGE OF WEB PORTAL



EWS for Flood Prediction

Logout

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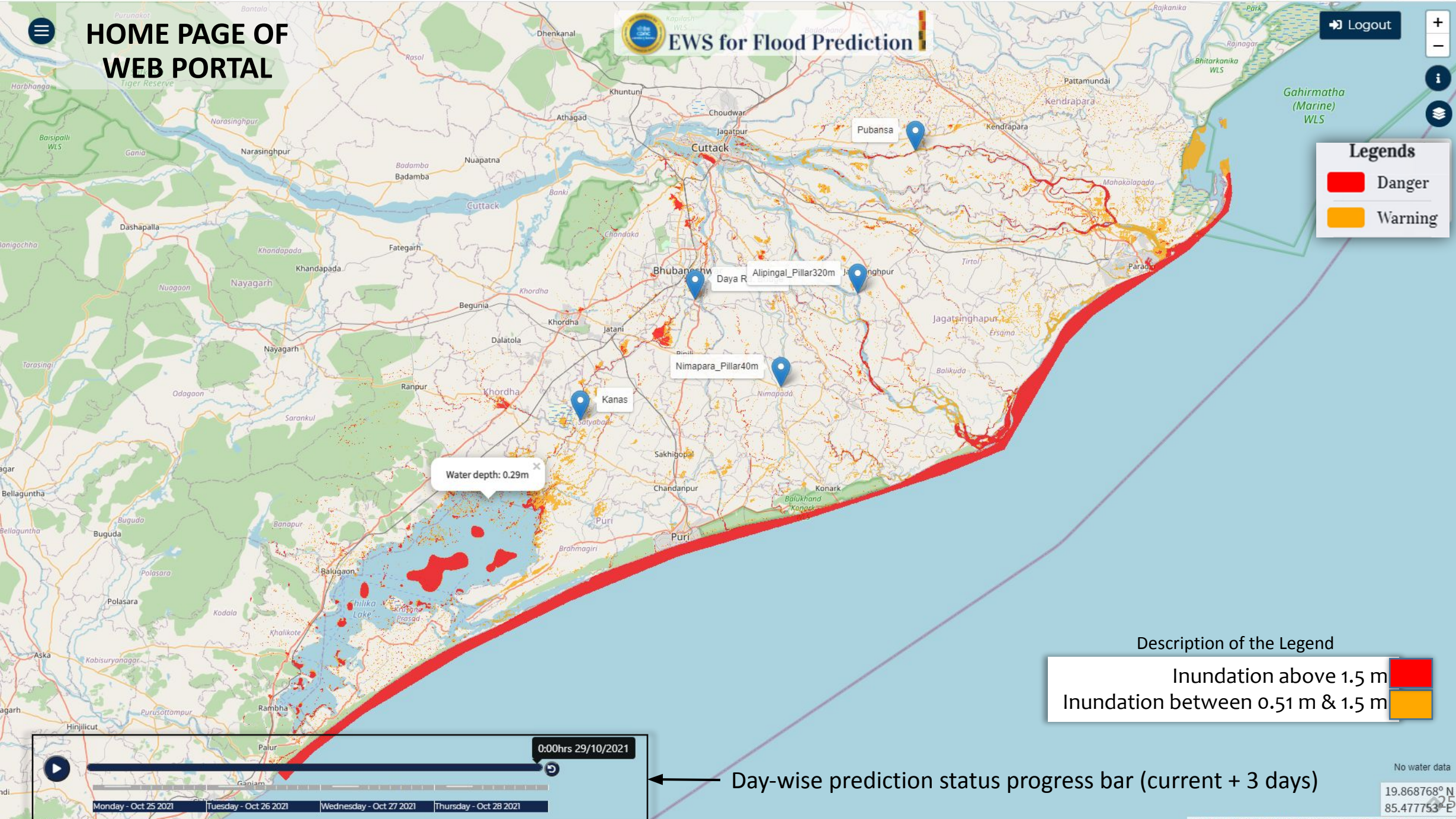
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Layers

Legends

Danger

Warning



Description of the Legend

Inundation above 1.5 m

Inundation between 0.51 m & 1.5 m

0:00hrs 29/10/2021

Monday - Oct 25 2021 | Tuesday - Oct 26 2021 | Wednesday - Oct 27 2021 | Thursday - Oct 28 2021

Day-wise prediction status progress bar (current + 3 days)

No water data
19.868768° N
85.477753° E

A HPC Software Suite for Seismic Imaging to Aid Oil & Gas Exploration

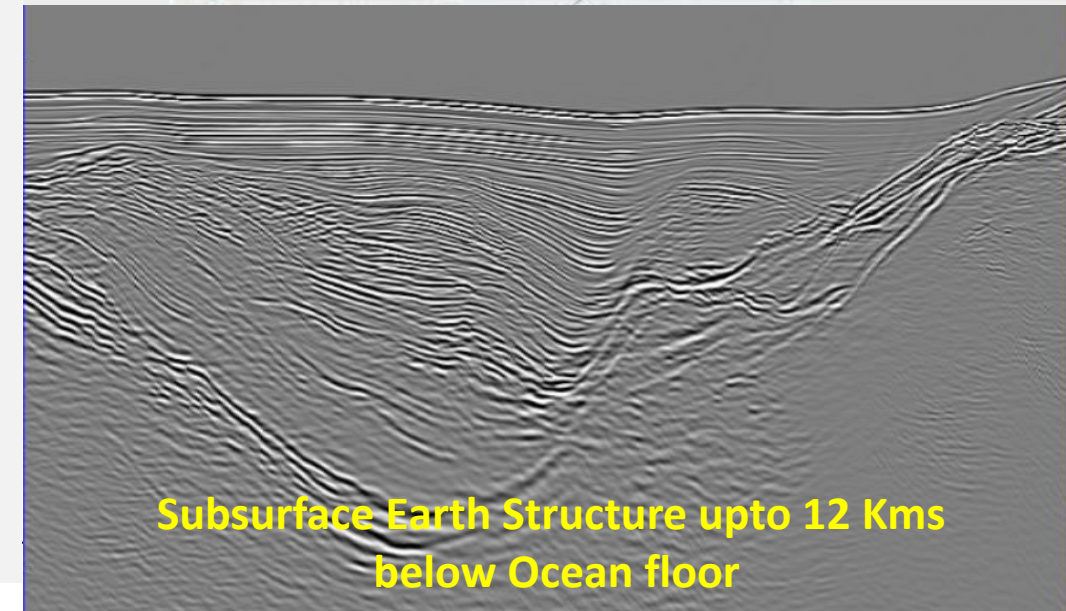
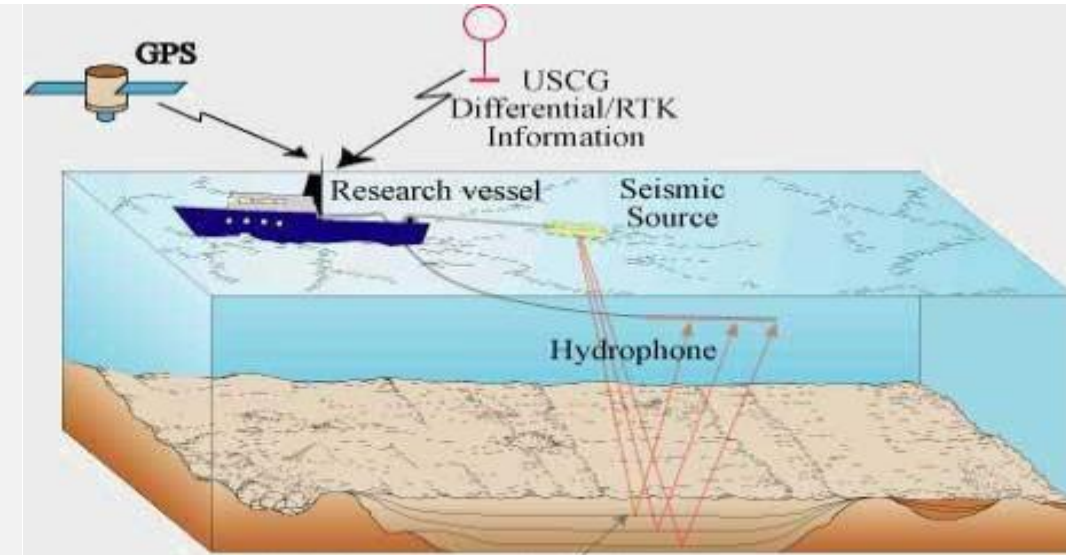
Consortia Partners: CDAC Pune, IIT Roorkee, ONGC GEOPIC, CSIR-NGRI and Osmania University

• Objective

- To develop an efficient parallel 2D & 3D customizable isotropic RTM and 2D anisotropic application with capabilities to provide accurate subsurface imaging for complex geological structure.
- To study seismic signatures of unconventional hydrocarbon source.

• Users

- ONGC, Oil India Ltd.
- Agencies involved in oil and gas exploration.
- Research organization for deep crustal studies.
- Academia for teaching advance seismic processing.



Outcome:

- Real time forecasting system for extreme weather, flash floods & air quality/pollution.
- GIS based Urban Decision Support System
- Urban environment data & information Portal

Impact:

- City Decision makers, researchers and citizens can analyze information related to city level weather, flood and air pollution for planning and rescue incase of disaster
- Weather, Hydrology & Air quality/pollution Forecast will be available in single platform.

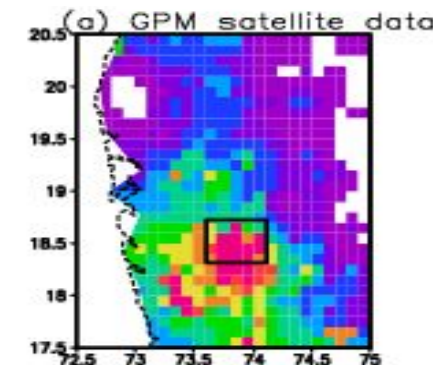
Users:

- City environmental engineers, Local and national environmental policy makers
- Urban disaster management agency, Municipal corporations
- Citizens

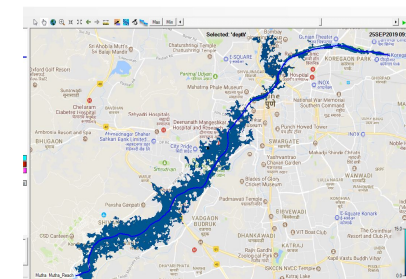
Cities:

- Pune (flood, weather), Delhi (air quality), Bangalore (weather, flood), Bhubneshwar (weather)

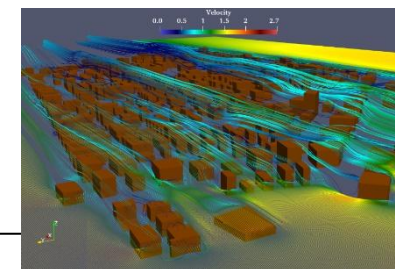
Heavy rainfall simulation over Pune



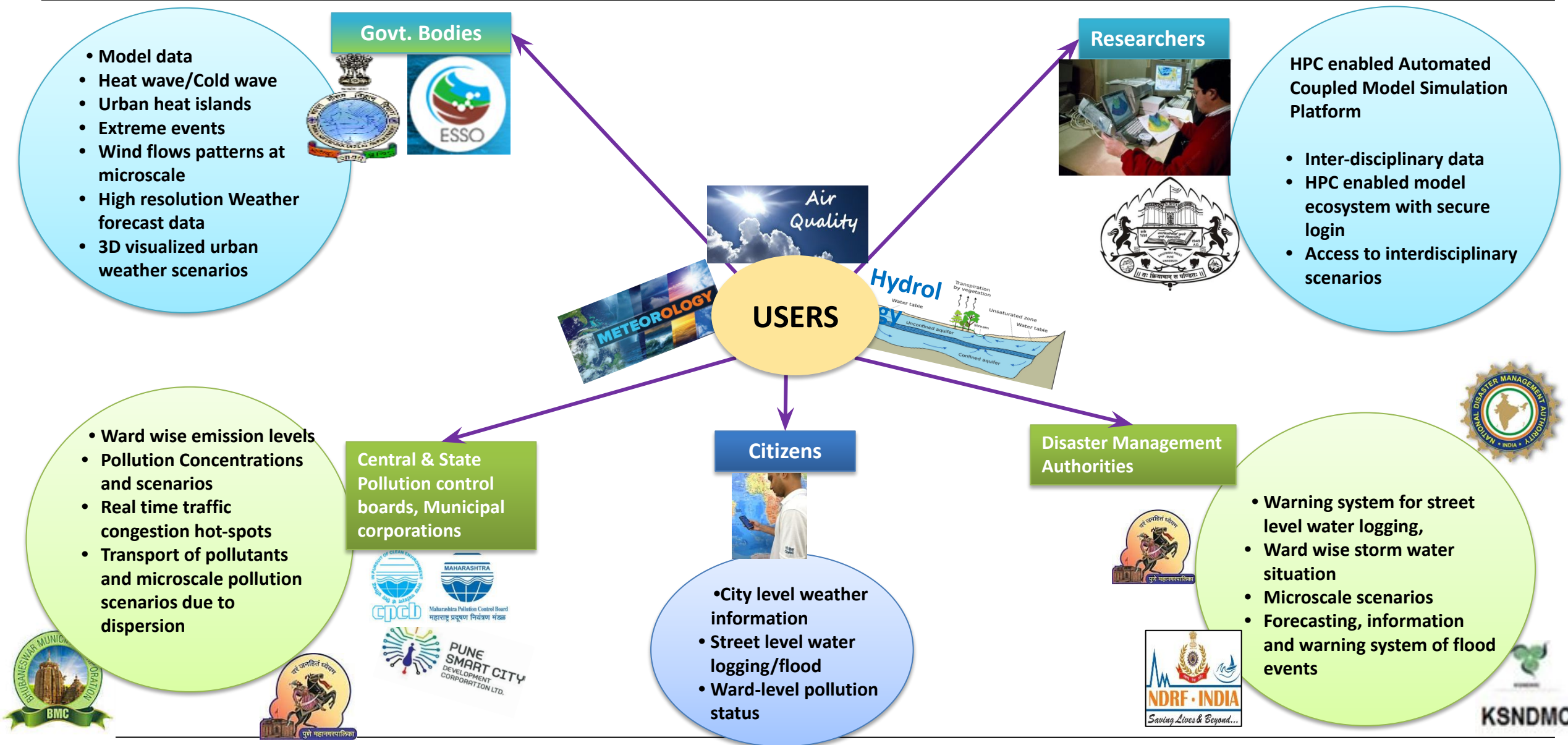
Flood Simulation over Pune



Pollution flow over the residential area

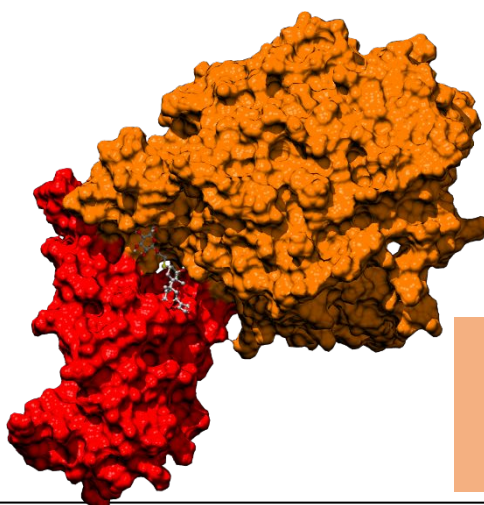


Services and its associated Stakeholders

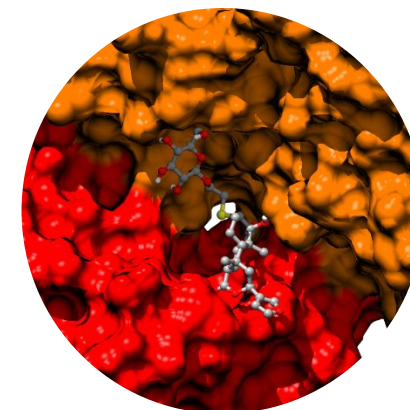


NSM Platform for Genomics and Drug Discovery (NPGDD): Outcome

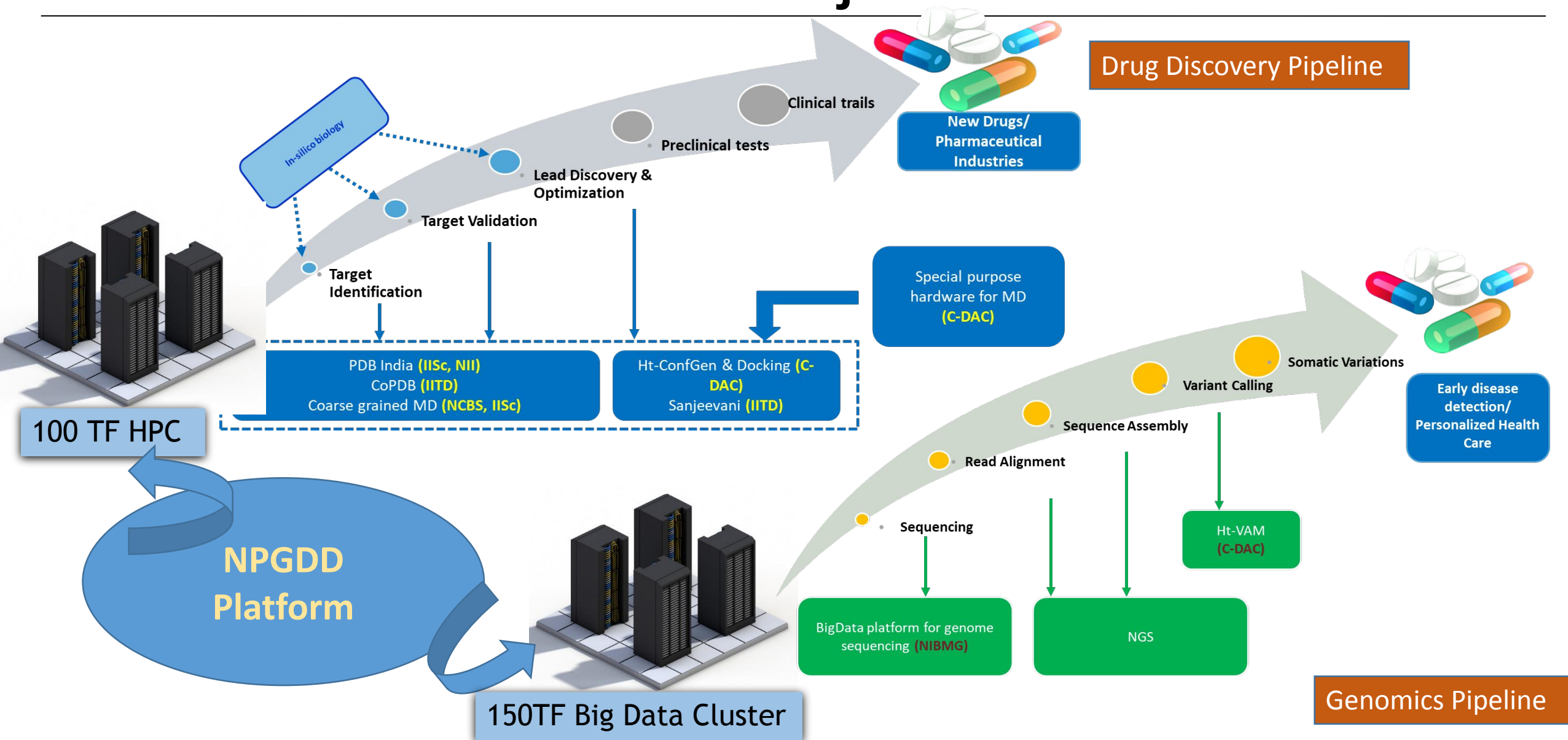
- 100 TF HPC and 150TF Big Data facilities with bioinformatics software for the life sciences community
- Tools available on BRAF: Drug Docking and Genome analysis tools
- High throughput docking and simulations studies on various SARS_CoV2 Virus proteins(Covid 19)
- The mechanism of action of phytochemicals from Ayurvedic plants is also explored for COVID 19 treatment using HPC
- IPR Generation:
 - Research on alzheimers, cancer and tuberculosis using supercomputer
 - Collaborative research with academic and pharmaceutical industries
- Computational tools are being developed under this project



HPC-driven Drug repurposing of
COVID-19 drug targets using
Ayurveda molecules



NPGDD: Objective



Outcome Summary of NSM till Date

- Building of 15 Supercomputing facilities with 22PF of compute power under Phase-1 and Phase-2 – 9 systems operational and 6 systems are at site
 - Phase-3: 6 systems including national facility with total compute power of ~ 40 PF – To be built
 - Total compute Power planned ~ 60+ PF
 - Efficient Data Centre design for all facilities – Liquid cooled
- Supercomputing Infrastructure usage till date
 - 2200 HPC users from 85+ institutes across the country
 - 28 Lakhs + HPC jobs executed
- Indigenous technologies/ knowhow developed
 - System Building – architecture, design and Integration of building blocks
 - Supercomputing Software eco-system
 - Rudra Server
 - Trinetra HPC network
 - Cooling Technologies
 - Ready for building of Phase-3 indigenous systems
- HPC applications under development in 6+ domains
 - 11000+ HPC manpower trained

NSM Summary

- Supercomputing eco-system Development
 - Supercomputing Infrastructure for Research and Development
 - Strategic Indigenous Supercomputing technology capability
 - Manpower development in Supercomputing domain
- Beneficiaries of NSM Infra: Academic and Research Institutes, Start ups, MSMEs
- Industry: Catalysis for High end Electronics Manufacturing and design capability in the country
- Design and manufacturing of High end bi-products– Servers, Cooling technologies for other markets
- Development of Supercomputing applications of National importance
 - Disaster management – Flood forecast, Extreme weather events, urban floods
 - Urban pollution
 - Health care – Drug discovery tools
 - Exploration of Oil & Gas
- Partners in App Development: IITs, IISc, IITM, Universities, R&D Labs, User agencies- Municipal corporations, CWC, ONGC

Thank You

- **Accelerators GPUs, FPGAs, special accelerators – Ease of programming, Availability of applications**
- Network – Topology, engineering and scaling
- **Data movement – Time taken to move the data to/from CPU to/from memory.**
 - High b/w and fast storage – Local node storage usage (Distributed high b/w storage) which can scale as system scales.
- Addressing HPC, Data Analytics and AI (Training, inference) in single system
- **Parallelism – 10s of thousands of nodes, Millions of CPU cores**
 - Programming environments which can scale to Millions of CPU cores
- Management and operations of System
- **Reliability**
- **Power consumption < 40 MW**
- Efficient cooling – Liquid Emersion cooling, DCLC

Exascale Software Challenges – Cont..

Programming Models, Languages and Libraries:

- Parallel programming models (such as MPI Threads) are low level tools and are not adequate for composing application at high levels of abstraction.
- **New generation of programming models which allow higher level of abstraction are required**
- Development of standard libraries and frameworks will make it easier to write reusable code and reuse other people's codes.

Tools:

- Modern tools for scientific software development are still relatively immature.
- **Requires improved compilers, performance analysis** and other tools that will make it easier to develop high performance codes.

NSM Infrastructure

Phase-1 and Phase-2: Systems Installed & Commissioned		Phase-2: Systems at Site, but to be commissioned Expected to be completed by March 2022	
1. IIT Varanasi	833 TF	10. IISc B'luru	3.332 PF
2. IIT Kharagpur	1.666 PF	11. IIT Roorkee	1.666 PF
3. IISER Pune	833 TF	12. IIT Guwahati	833 TF
4. IIT Kanpur *	1.666 PF	13. IIT Gandhinagar	833 TF
5. JNCASR, B'luru *	833 TF	14. IIT Mandi	833 TF
6. C-DAC, B'luru *	833 TF	15. NIT Trichy	833 TF
7. National AI Facility Param Siddhi AI (210 AI PF), C-DAC, Pune *	5.267 PF		
8. IIT Hyderabad *	833 TF		
9. NABI Mohali *	833 TF		
Phase1 and Phase2 Total compute Power ~ 22 PF (15 systems)			



NSM Infrastructure



Infrastructure built for R&D in C-DAC itself and SETS CHennai		List of HPC systems to be installed in Phase-3 (Calendar Year 2022 and 2023)	
1. Bioinformatics R&D Fac.-	230 TF	1. IIT Bombay	3.332 PF
2. HPC Hardware Lab	120 TF	2. IUAC Delhi	3.332 PF
3. HPC System SW Lab -	100 TF	3. IIT Madras	3.332 PF
4. Intel Skylake cluster	100 TF	4. National HPC Facility at C-DAC, Pune	20.0 PF
5. IBM Power9 cluster (SETS)	100 TF		
6. ARM A64Fx cluster	100 TF		
		Phase-3 Total compute Power	~ 32 PF

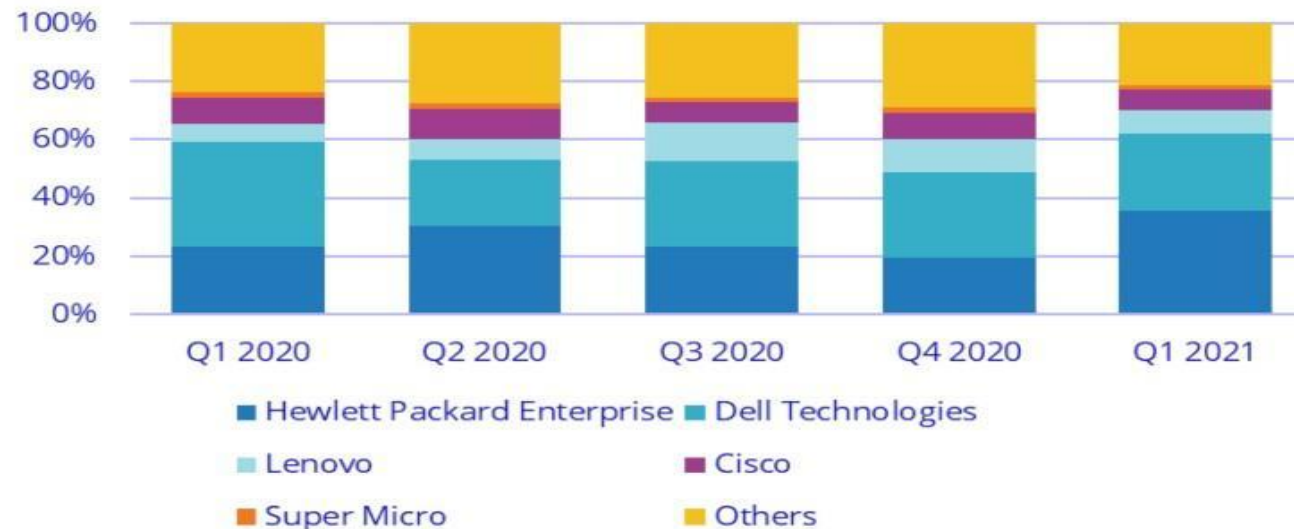
Phase1+Phase2+Phase3 Total = 54 PF

Indian Market Landscape

Overall server market in India witnessed a 33.8% year-on-year (YoY) growth in terms of revenue to reach \$310.6 million in the first quarter of 2021



India Top 5 x86 Server Companies, Q1 2021
Revenue Market Share



Source: IDC 2021

INDIAN SERVER MARKET

Overall server market in India for the year 2020-25

	2020	2021	2022	2023	2024
Units	1,29,313	1,94,454	2,23,399	2,47,652	2,72,251
INR (Cr)	7582	10896	12546	14032	15680