National Supercomputing Mission: Development of HPC Technologies through Indigenous Efforts

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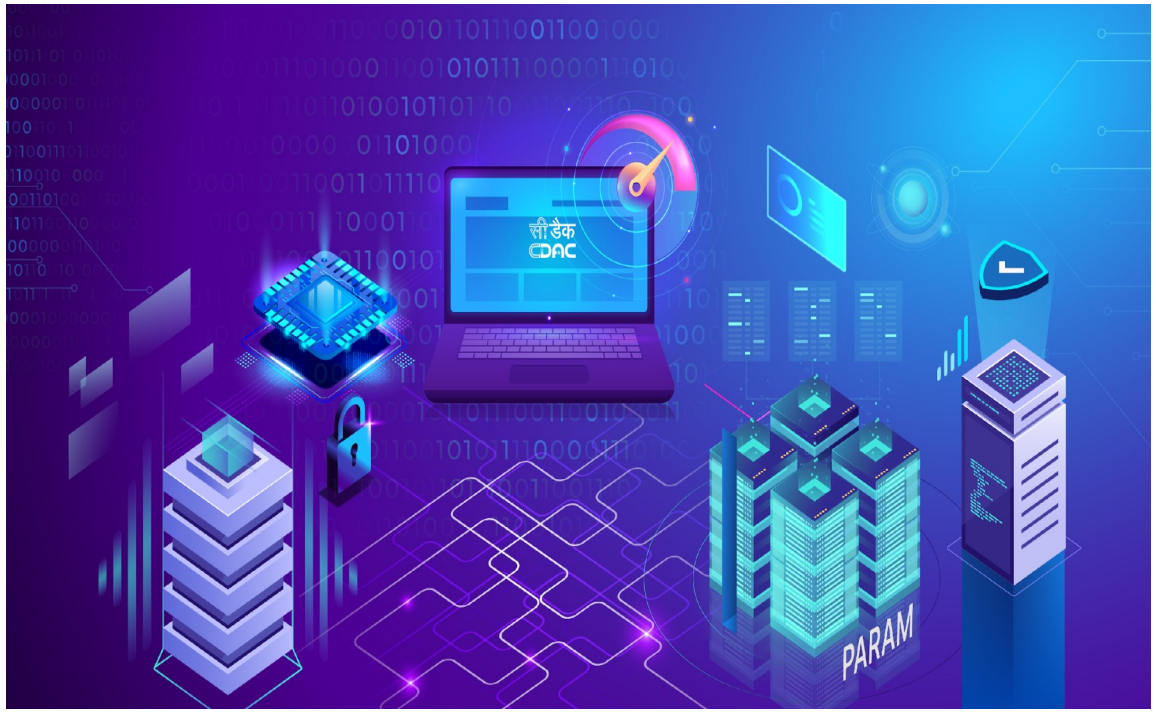
About C-DAC



Established in 1988

Presence at 12 locations

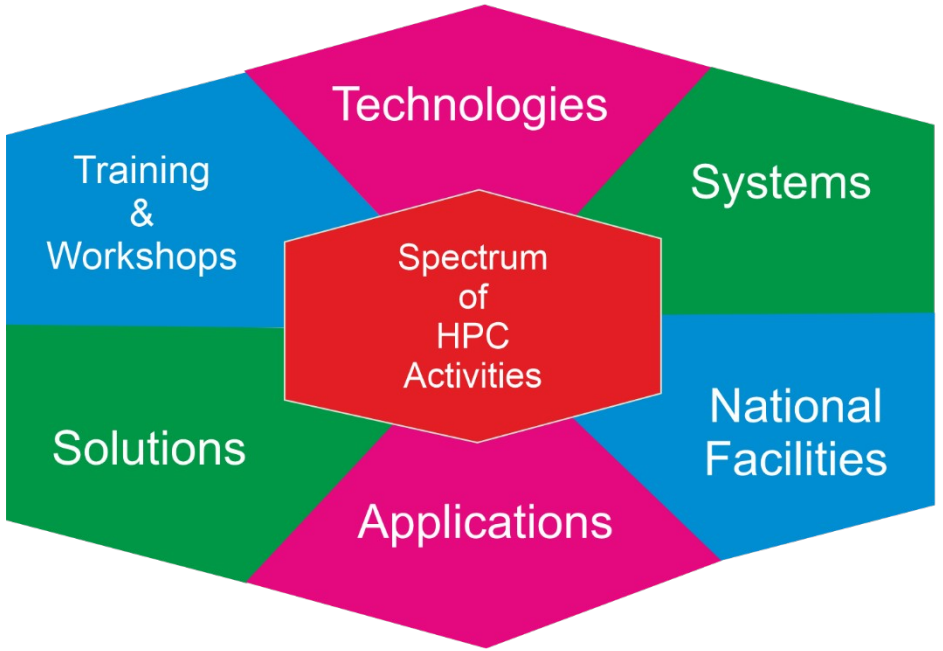
Key Areas

- HPC & Quantum Computing
- RISC-V and Strategic Electronics
- Software Technologies including FOSS
- Health Informatics
- Cyber Security & Cyber Forensics
- Multilingual & Heritage Computing
- Education and Training

Building indigenous supercomputing capability

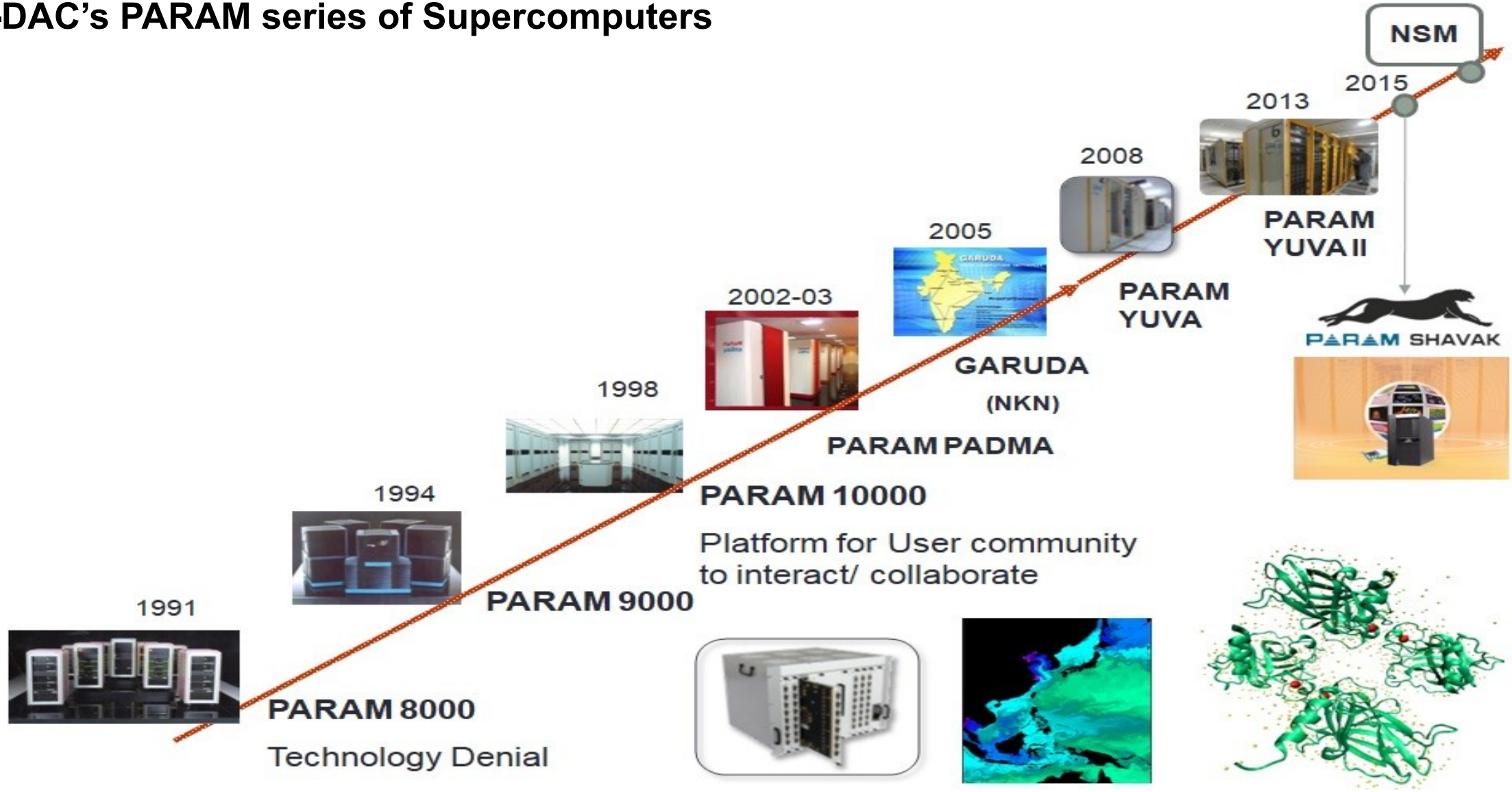
HPC at C-DAC

- National body for HPC in India for more than 30 Years
- Drives HPC activities of the country
- PARAM Series of Supercomputers
- Operates National Supercomputing facilities



Growth in HPC – 1988 onwards...

C-DAC's PARAM series of Supercomputers



National Supercomputing Mission (NSM)

One Vision One Goal...Advanced Computing for Human advancement...

National Supercomputing Mission

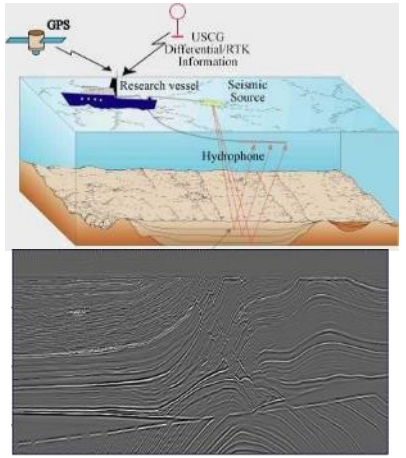
Creation of Supercomputing Infrastructure

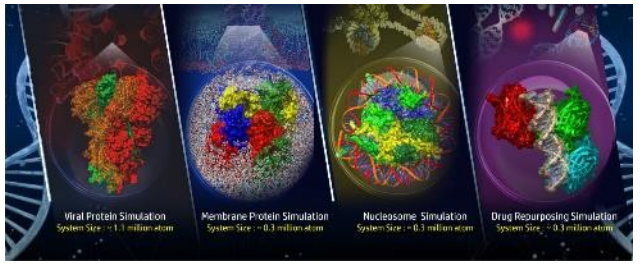
- Total capacity – 64 PF with phased build approach
- 17 Supercomputers with compute capacity of 28 PF established
- 8 more Supercomputers with compute capacity of 36 PF to be build in next 6-8 months – Includes a 20 PF National facility

Supercomputing Infrastructure usage till date:

- 9000+ HPC users from 200+ institutes across the country
- 95+ Lakhs HPC jobs executed
- 1000+ PhD students
- 1250+ publications

HPC Applications for National Need in 5 Domains





HPC Human Resource Development

- 22000+ HPC Human Resources trained

A Glimpse of NSM Systems

NSM followed a distributed model of HPC System deployment to reach wider scientific and R&D community, instead of building a large scale HPC system at one location . Also to cater to availability of power at a single location

Performance

13 PF

3.3 PF

1.8 PF

1.3 PF

838 TF

Years

13.2PF/410PF (AI)

PARAM Siddhi-AI

3.3PF

PARAM Pravega

1.7PF

PARAM Brahma

1.66PF

PARAM Shakti

1.8PF

PARAM Yukti

1.66PF

PARAM Sanganak

1.66PF

PARAM Ganga

838TF

PARAM Shivay

838TF

PARAM Seva

838TF

PARAM Smriti

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PARAM Utkarsh

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PARAM Ananta

838TF

PARAM Porul

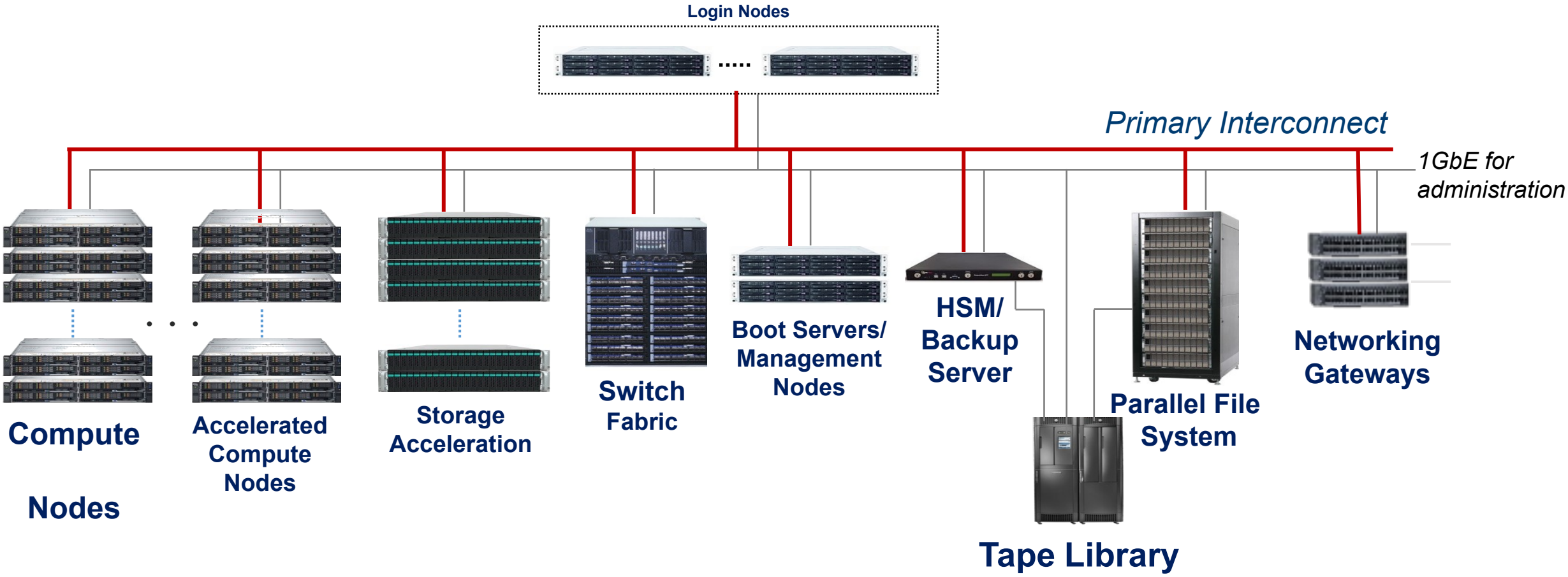
838TF

PARAM Kamrupa

838TF

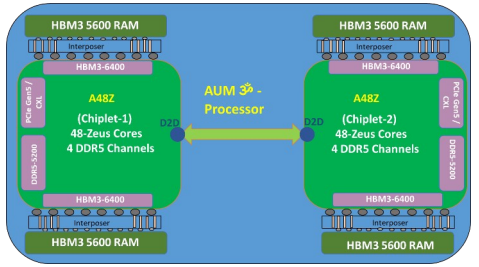
PARAM Himalaya

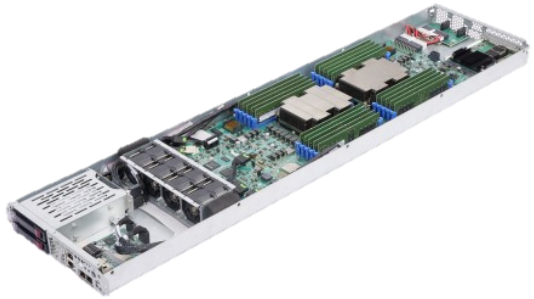
Typical HPC system Architecture

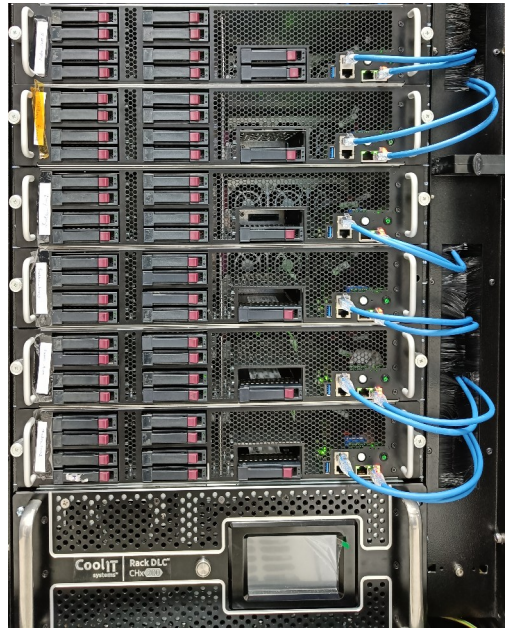


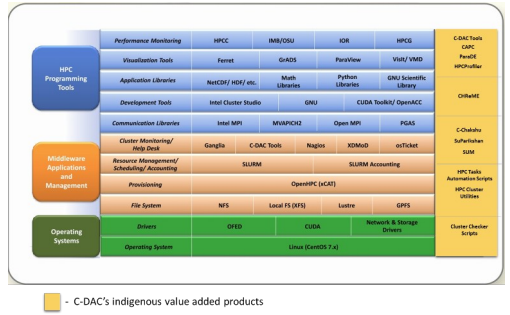
Indigenous Developments

- Rudra series of Servers
  - Liquid Cooling technology
- System Software Stack – HPC & AI
- Trinetra Scalable HPC Network
- AUM HPC Processor
- RISC-V Accelerator
- Storage – DAOS based Flash Storage
- Secure Grid



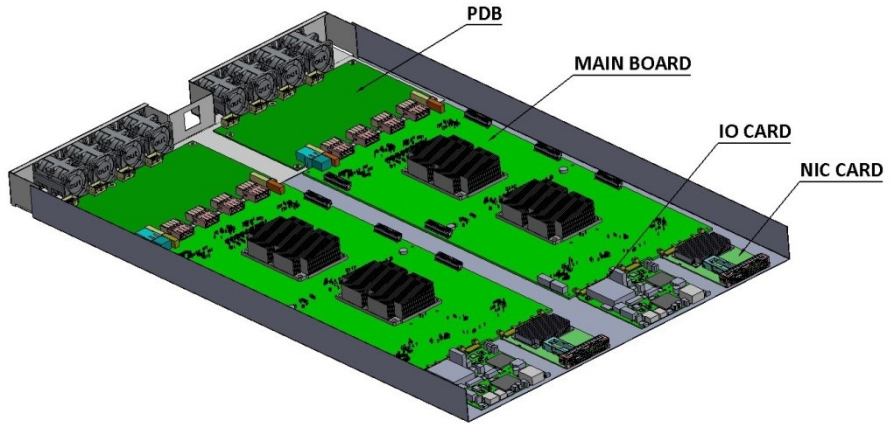




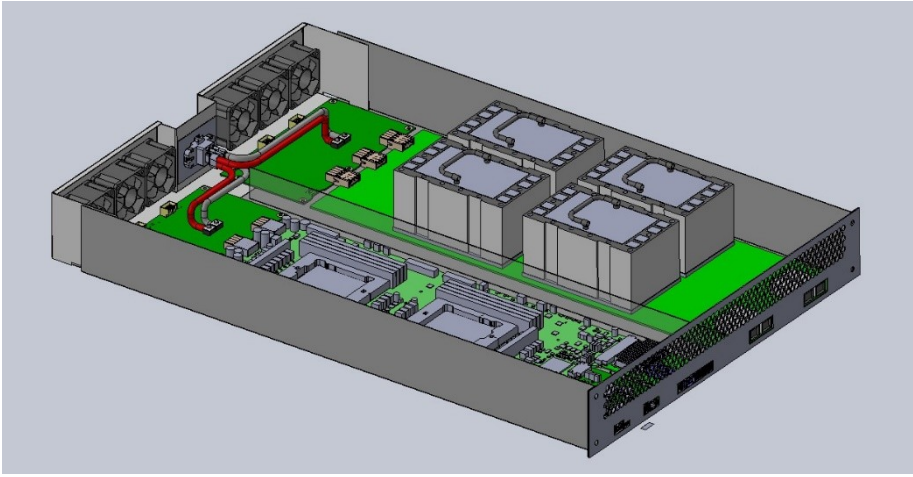


Rudra Server Development

- Open Compute Platform (OCP) compatible with 48V DC for Cloud/Data center and HPC market
- Dense form factor: > 60 KW per rack
- Option of both Liquid (better energy efficiency) and Air cooling



Rudra-SPX: CPU-CPU

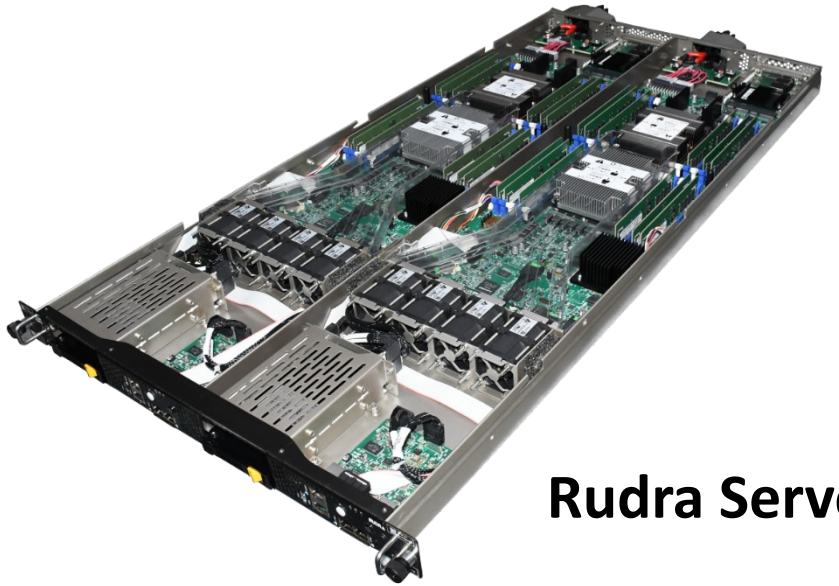


Rudra-SPX: CPU-GPU

Rudra Server

Variants

- 1 U & 2 U server with central Power supply
- 2 U server with standalone power supply
- 2 U Storage server with standalone power supply
- PARAM Shavak



Rudra Server 1U

Rudra Server
Standalone PS

Rudra Server Platform – Liquid Cooling

Rudra server with cold plates

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

30 kW panel water heat exchanger

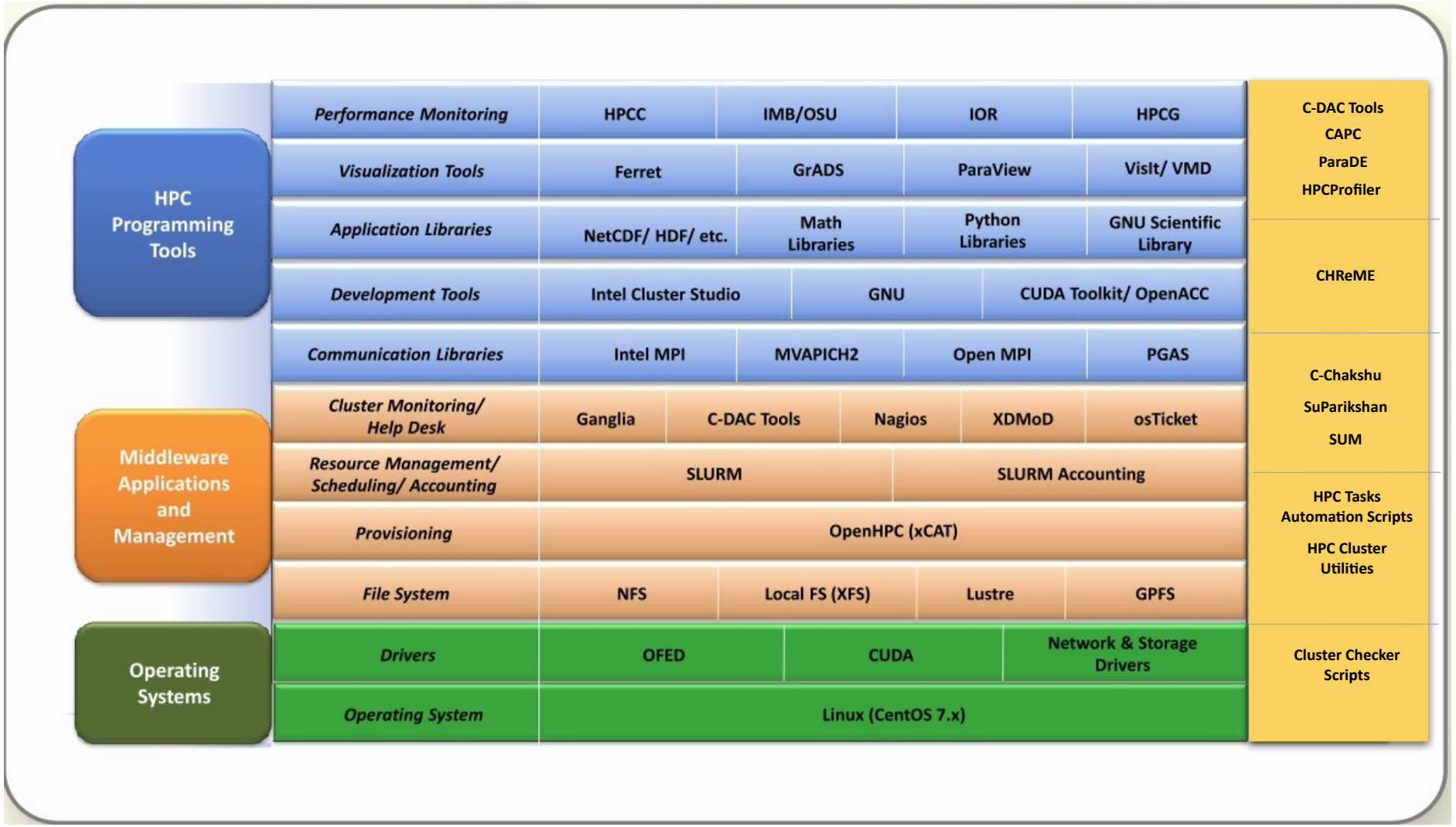
Impact

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

Software stack for Rudra series of servers

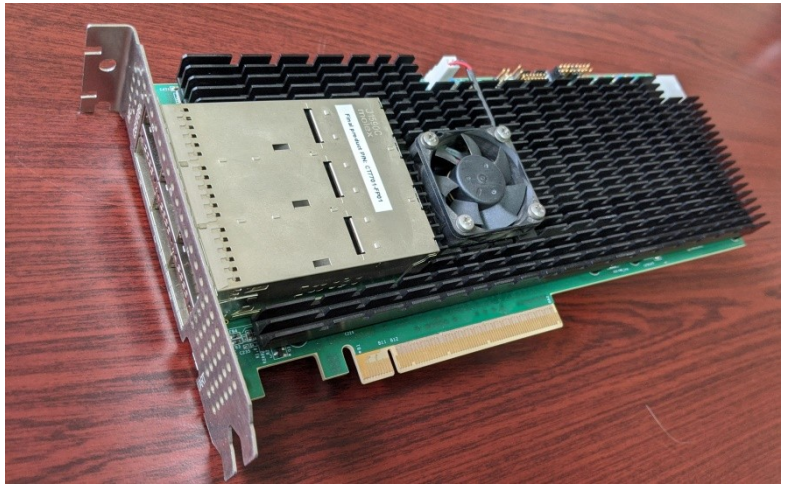
- Compiler/Toolchain
  - GCC and LLVM compiler
- BIOS
  - U-Boot
  - UEFI EDK2.1
- Operating System
  - Linux & Ubuntu - Full Linux BSP sources
  - Virtualization, Networking, Storage and PCIe support
- BMC:
  - OpenBMC – Board Management Controller software

HPC Software Stack



- C-DAC's indigenous value added products

Trinetra: Indigenous HPC interconnect



Low Latency, High Bandwidth, Scalable Network

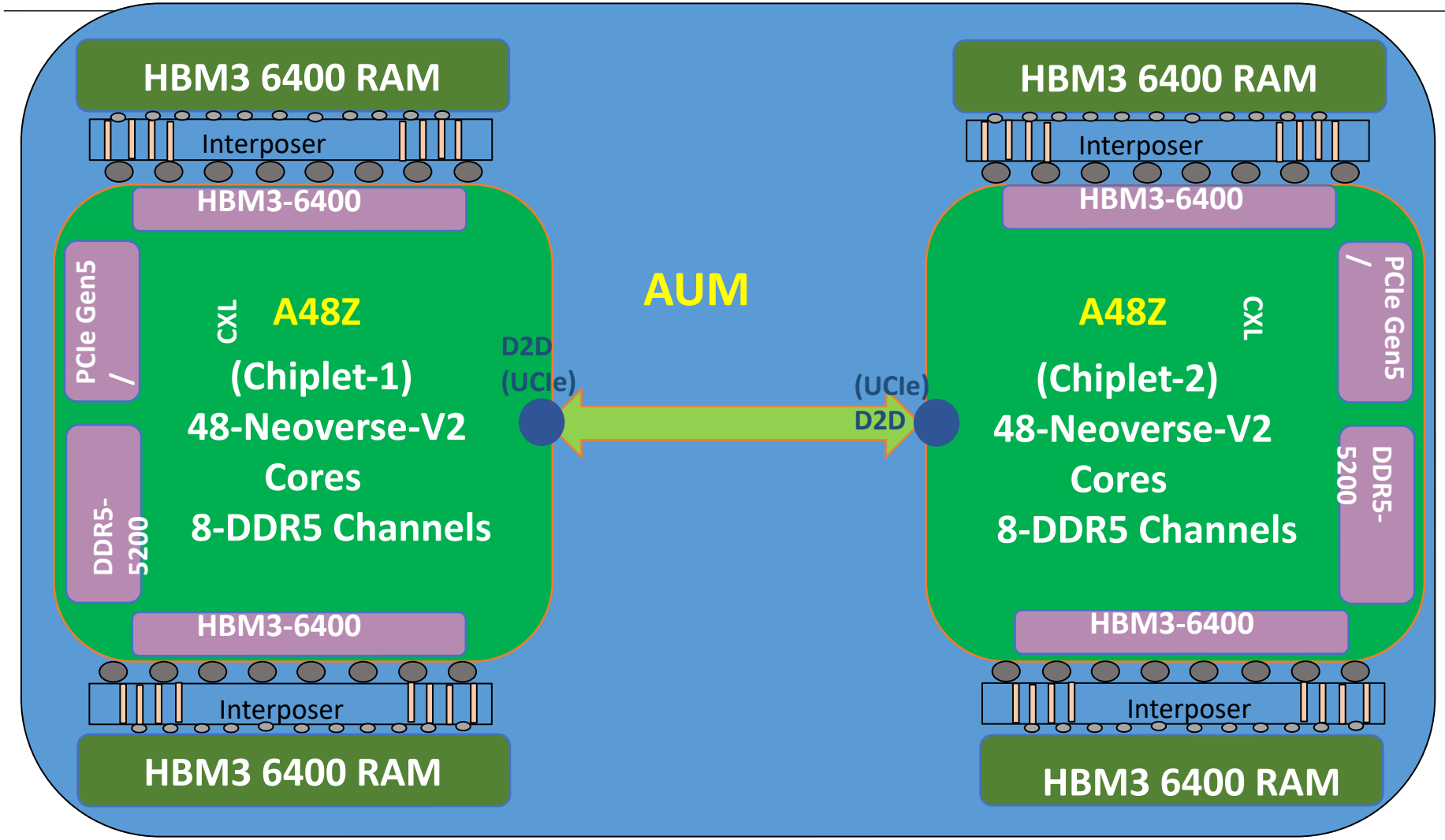
Trinetra-A

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

Trinetra-B

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

AUM Processor – 96 Cores



PHY

D2D Chiplet Interconnect

TSMC 5nm

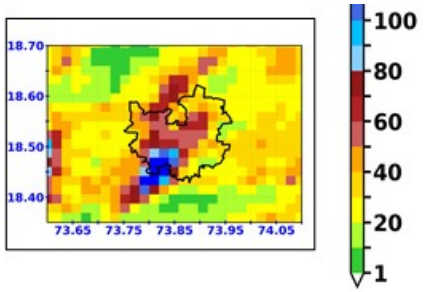
AUM Processor: Major Architectural decisions

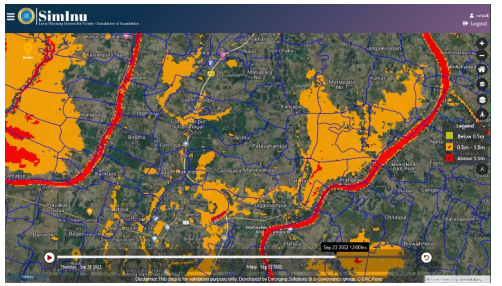
- Improved Efficiency
  - Memory Bandwidth
  - Easy to optimize (Vector Size)
  - Superior Application level performance / Watt
- Better I/O for Data Access
  - HBM and DDR
  - Many PCIe5 Lanes
  - CXL for Coherent accelerators
- Security Features Provision

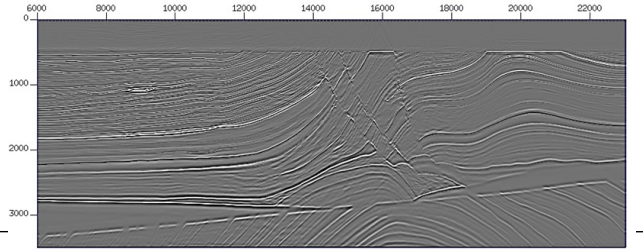
- Superior Application-level performance / Watt -> Increase Memory sub-system performance
- Need Much better Bytes/Flop performance – Target > 0.5 Byte/Flop

HPC APPLICATIONS FOR GRAND CHALLENGE PROBLEMS

- Genomics, Drug Discovery and Drug Repurposing
- Urban Weather, Flood and Air Quality Modelling and Decision Support Systems
- Flood Forecasting Systems
- Oil and Gas Exploration based on Seismic Data.
- Applications in Computational Chemistry and CFD.
- Applications in Astrophysics
- Special Purpose Machines for Optimization Problems







Bioinformatics

HPC Applications: Genomics & Drug Discovery

Supercomputing Clusters

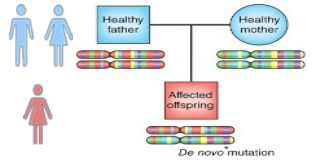
To provide high end dedicated computing facility to researchers

Bioinformatics Resources and Applications Facility (BRAF)

Computational Genomics

Mycobacterium Genomics

Population Genomics



Software Development (BigData/AI/Cloud)

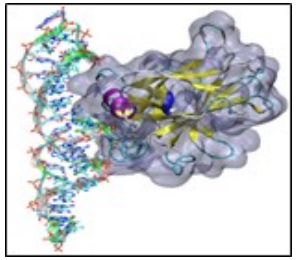
Molecular Modelling

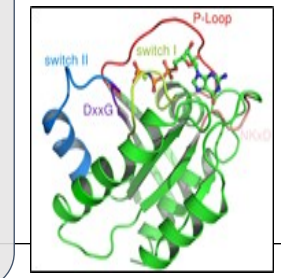
Cancer proteins

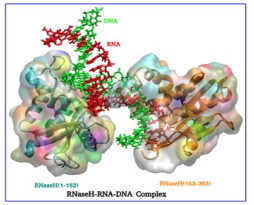
Protein misfolding

Antisense Technology

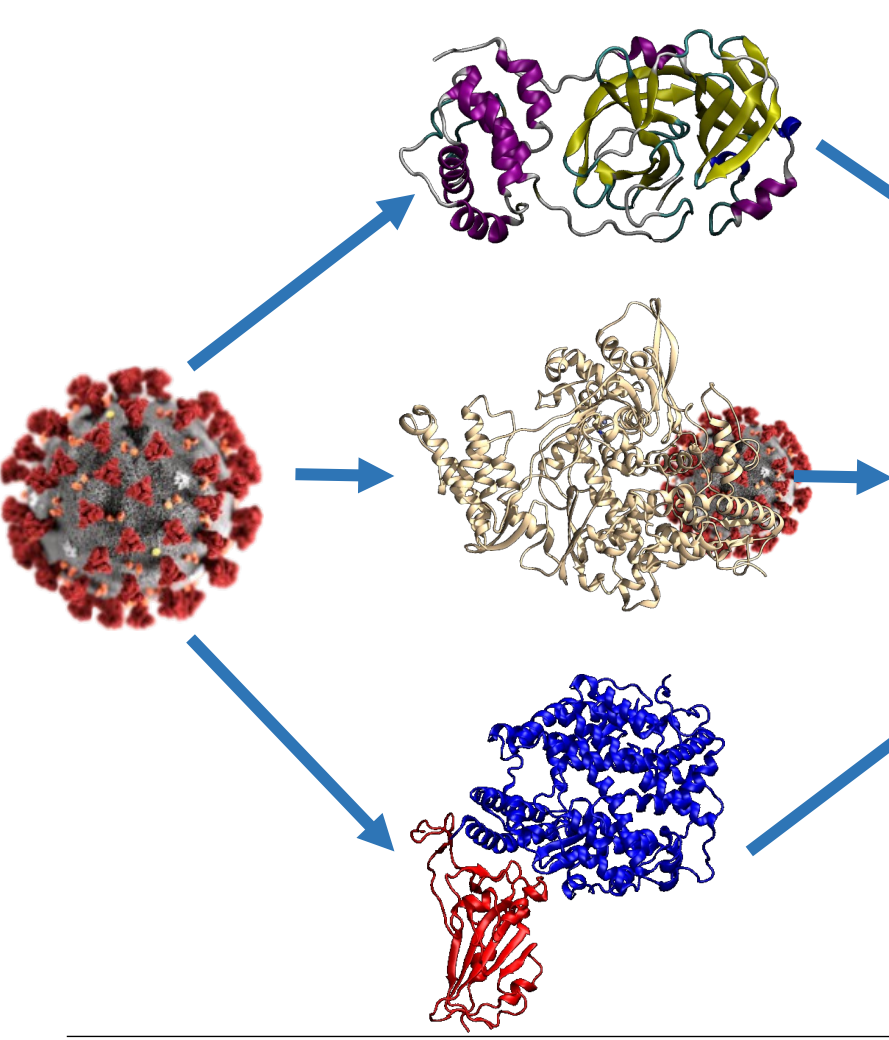
Membrane Proteins



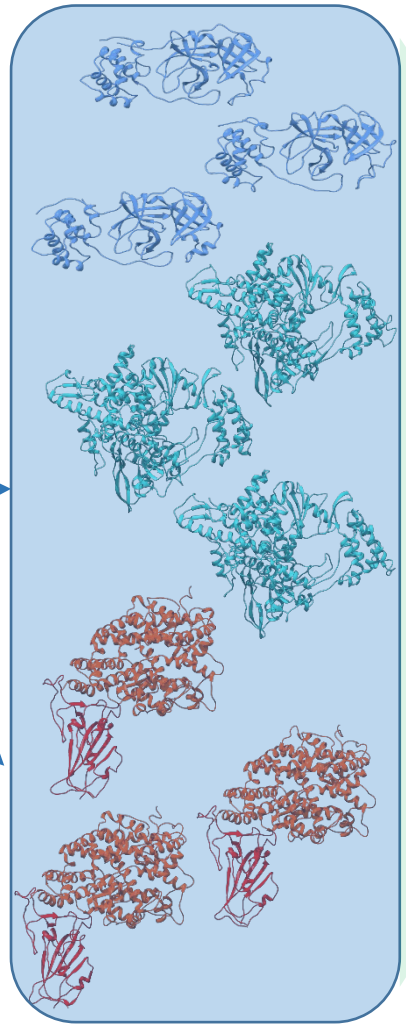




HPC-Driven Drug Repurposing @ C-DAC

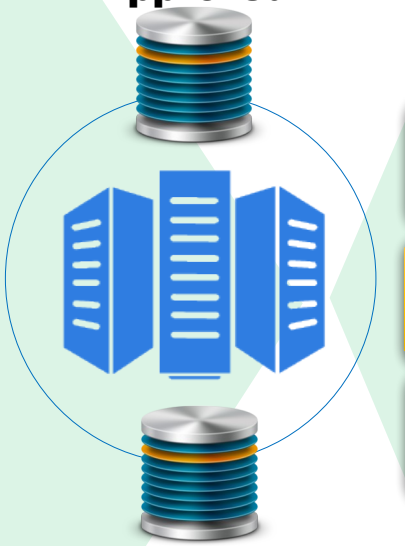


Molecular Dynamics on GPU/HPC Clusters



Ensemble Generation

FDA Approved



SWEETLE AD

Molecular Docking and simulations of > 9000 compounds on GPU/HPC Clusters

Predicted Drugs

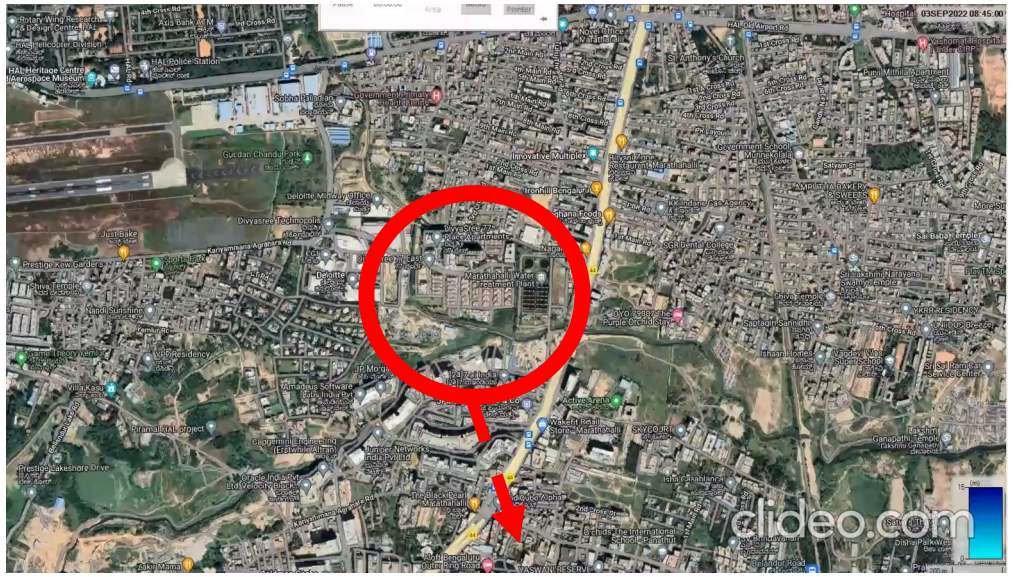
- Ivermectin
- Remdesivir
- Rutin
- DAB10

Prescribed by doctors

Weather, Climate and Environment Modelling

High Resolution Modelling: Met-AQ-Hydro

- Sensitivity analysis: physics, dynamics and LULC use parameterization schemes to study Heavy rainfall and Heatwave
- Integrated Coupled high-resolution met-hydro modeling system for extreme rainfall and urban floods
- Heat wave simulation



Pollutant Dispersion

- Chemical data assimilation for Delhi AQ – graded action plan underway
- Pune High-resolution Emission inventory and Air Quality Early warning system

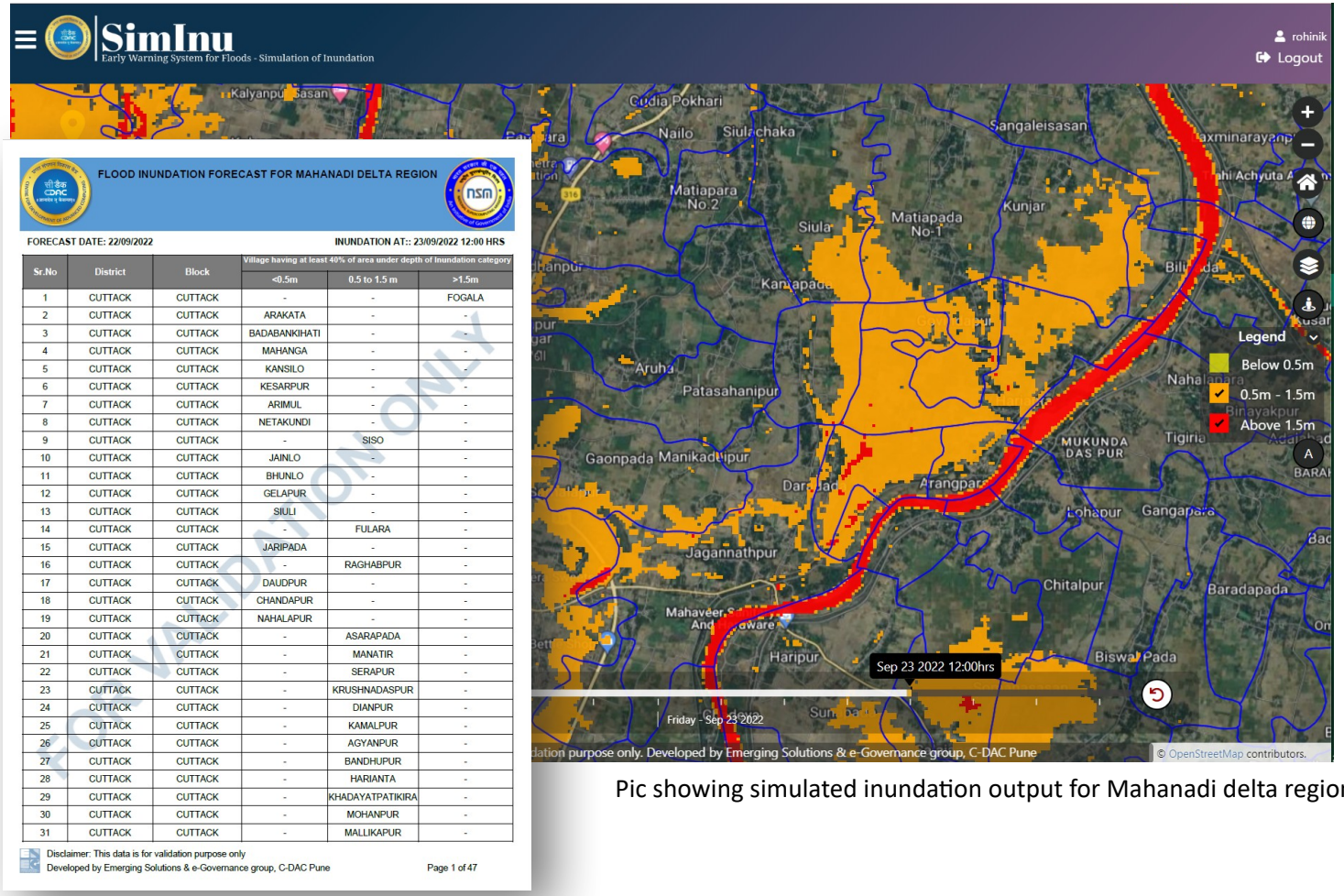
First-of-a-kind, OpenFOAM (CFD) modeling: pollution hotspot dispersion simulation

NATURAL HAZARDS
Risk Reduction & Management

Early Warning System For Flood Prediction In The River Basins Of India

- Develop Early Warning System for Flood Prediction, Sediment Transport model and Integrated Reservoir Operation tools
- Design geospatial portal for information dissemination on flood prediction

- 2-day inundation prediction for Mahanadi Basin under National Supercomputing Mission (NSM)
- Daily simulation was carried out for generating inundation forecast for Delta region of Mahanadi River Basin using HPC infrastructure of C-DAC from June till October, 2022. About 300 predictions were done during this period.
- Model is scalable to all river basins and can handle large river basins of the country.



Pic showing simulated inundation output for Mahanadi delta region

Users CWC, SWRD, SDMA | IISc, PEC, CWC Collaborators

Forest Fire Spread Simulation

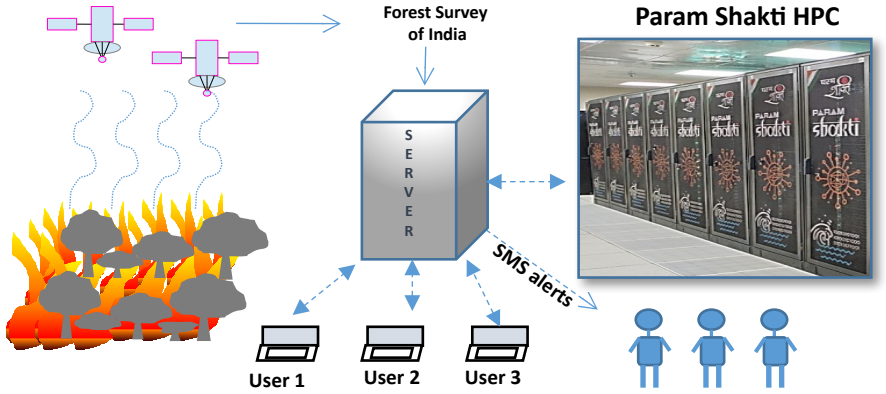
OBJECTIVE: Forest Fire Spread Forecasting

COLLABORATORS: Indian Institute of Technology, Kharagpur;
Department of Science and Technology, Sikkim

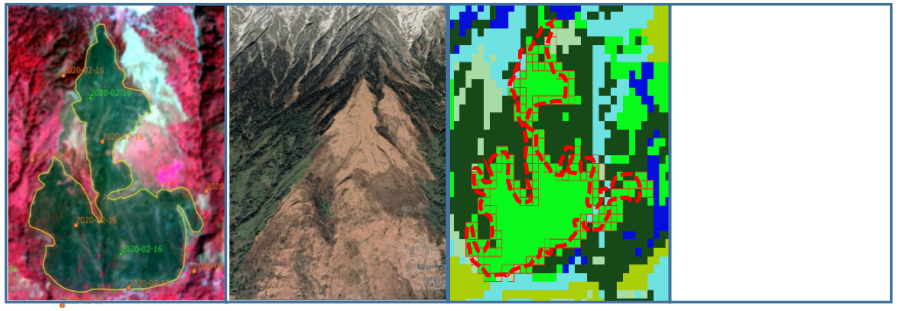
MODEL: Open Source – WRF SFIRE

COMPUTATION: Param Shakti High Performance Computing System

Conceptual Diagram

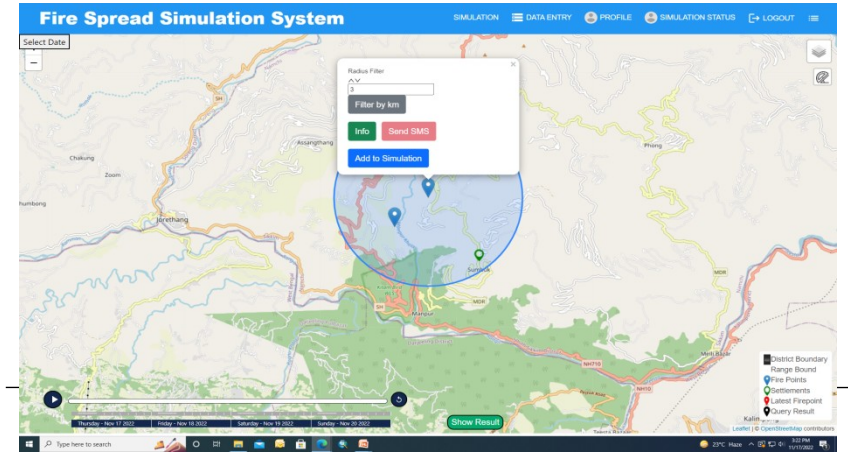


Validation

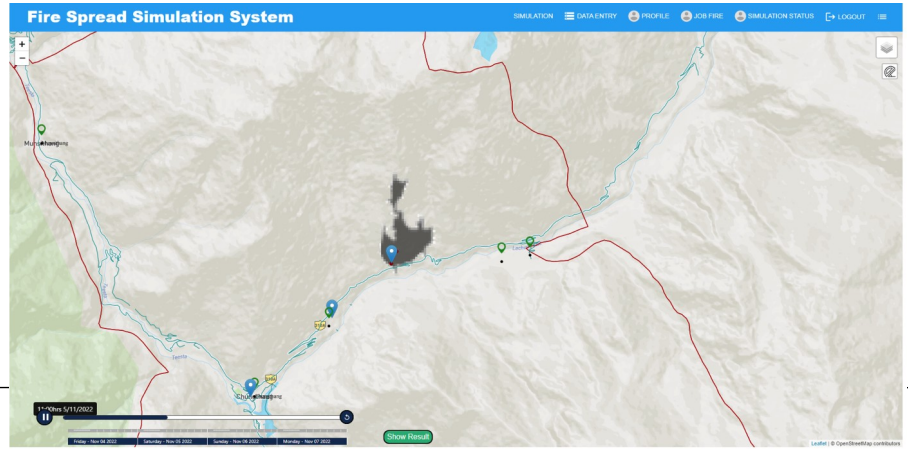


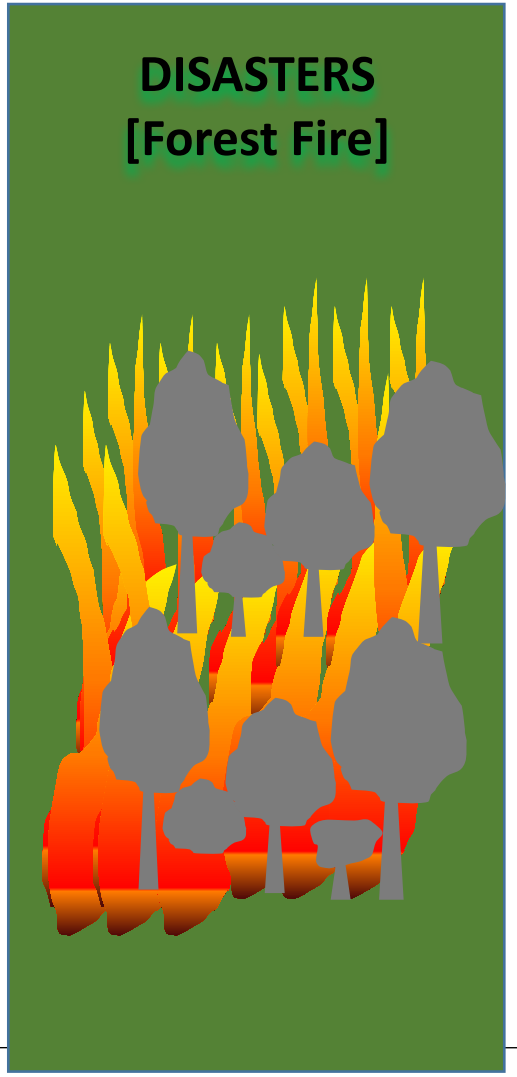
Satellite observed burnt area | Terrain view (Google earth) | WRF – SFIRE Simulation (operational) | FDS simulation (research)

SMS alert to stakeholders within specified buffers



Dashboard visualisation of Fire Spread





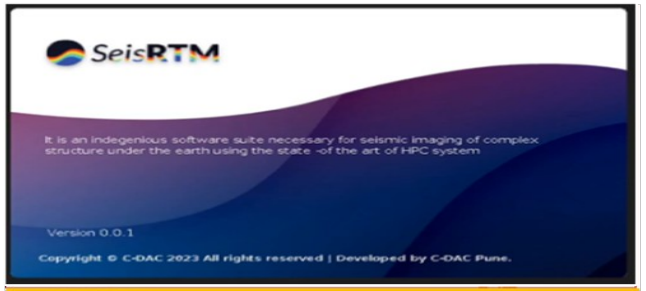
Oil and Gas Exploration based on Seismic Data.

Oil & Gas Exploration: Seismic Imaging

- Project Title : A HPC Software Suite for Seismic Imaging to Aid Oil & Gas Exploration
- Consortia Partners : CDAC Pune, ONGC GEOPIC and IIT Roorkee
- Objective : Development of HPC Software Suite for seismic imaging to provide enhanced image of complex subsurface geology
- End Users : ONGC, Oil India and Private Oil companies

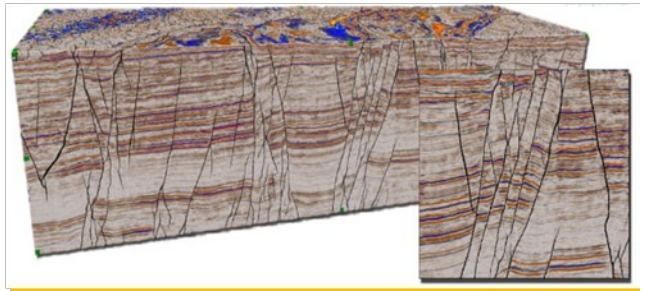
Input - Seismic Data & Earth Model

Shot Gather



"SeisRTM" - Seismic Image Processing

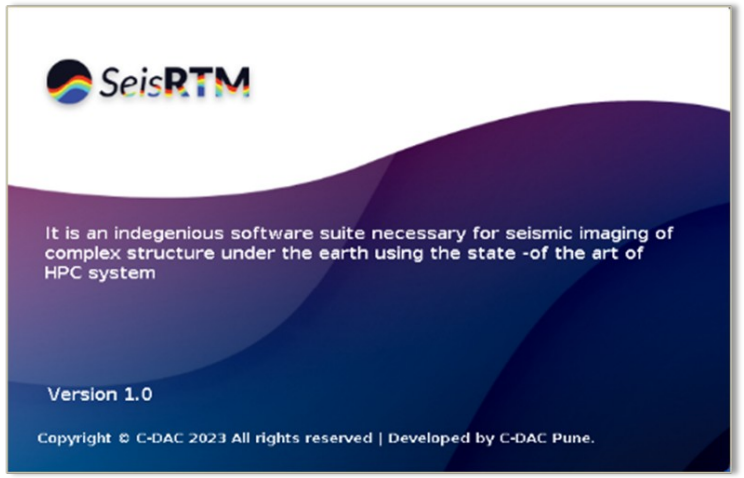
RTM Methodology



Outcome - Subsurface Image

RTM Output

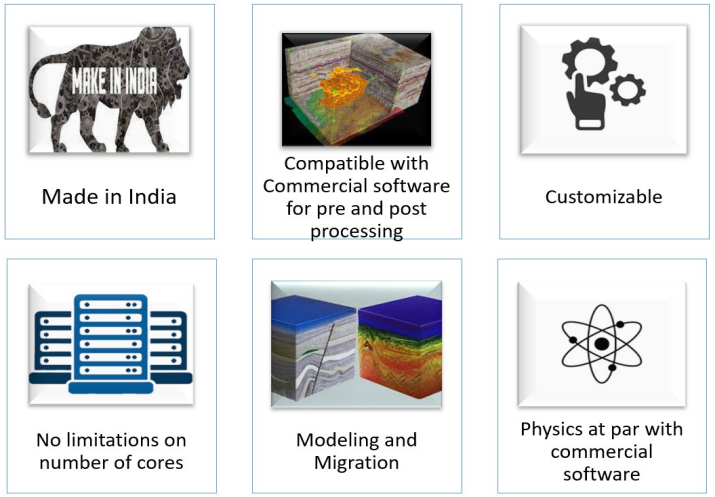
SeisRTM: Unique Features/Capabilities



SeisRTM

Advantages of SeisRTM:

- Seismic imaging algorithm in Isotropic and Anisotropic medium
- No dip limitation for seismic depth imaging
- Cost-effective and fast algorithm for depth imaging
- Command Line Interface (CLI) and Graphical User Interface (GUI) for RTM software
- Customizable solution for RTM



About SeisRTM

SeisRTM Capabilities

- 2D isotropic, VTI, TTI seismic modeling.
- 2D isotropic, VTI, TTI RTM
- 3D isotropic seismic modelling
- 3D isotropic seismic RTM
- Pre & Post migration processing tools
- GUI based 2D & 3D visualization

	Version 1	Version 2	Current Version
SeisRTM 2D Applications			
2D ISO Modeler	✓	✓	✓
2D ISO RTM	✓	✓	✓
2D ANISO VTI Modeler	–	✓	✓
2D ANISO VTI RTM	–	✓	✓
2D ANISO TTI Modeler	–	✓	✓
2D ANISO TTI RTM	–	–	✓
2D Utilities	✓	✓	✓
SeisRTM 3D Applications			
3D ISO Modeler	–	✓	✓
3D ISO RTM	–	✓	✓
3D Utilities	–	✓	✓
CLI	✓	✓	✓
GUI	–	–	✓
	2022	2023	2024

SeisRTM Versions

SeisRTM Features:

- Frequency up to 70 Hz
- Higher order Finite Difference implementation
- CPML Boundaries
- Conventional and Boundary saving RTM
- Imaging Aperture: Shot Centric & Fold Centric
- Choice on imaging conditions
- Shot Image gathers as RTM outcome
- Parallel on Shots using CPU Cluster
- Handles standard SEGY v1.0 headers
- Laplacian based image conditioning
- Tools for pre and post processing of seismic data
- CLI and GUI with self-documentation

спасибо

Thank You !

AUM HPC SoC (A48Z) Block Diagram (48-Cores)