SENAI CIMATEC

Tecnologia, Inovação
e Educação para a Indústria

Sistema FIEB | SENAI CIMATEC

PELO FUTURO DA INOVAÇÃO

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SENAI CIMATEC

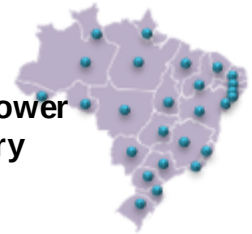
SENAI & CIMATEC Overview

SENAI CIMATEC

National Service of Industrial Training (SENAI)

Private and Non-profit
Created by decree of law in 1942

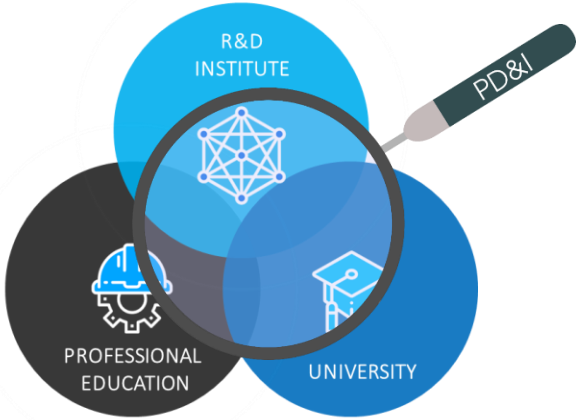
Mission: provide the Manpower training to Brazilian Industry

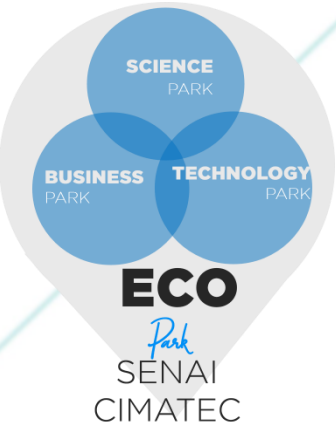


SENAI is present in all 27 states in Brazil
Represent all the sectors of the Brazilian industry

Over the years the industry needs change focusing in increasing sustainability and new ways of innovation.

Located at Bahia State





Manufacturing and Technology Integrated Center
SENAI CIMATEC created in 2002

CIMATEC Park created in 2019

SENAI CIMATEC Salvador

- 4 Buildings
- 35.000 m²
- US$200 mi in investments
- 40 areas of competence
- 900 employees

Integrated Model

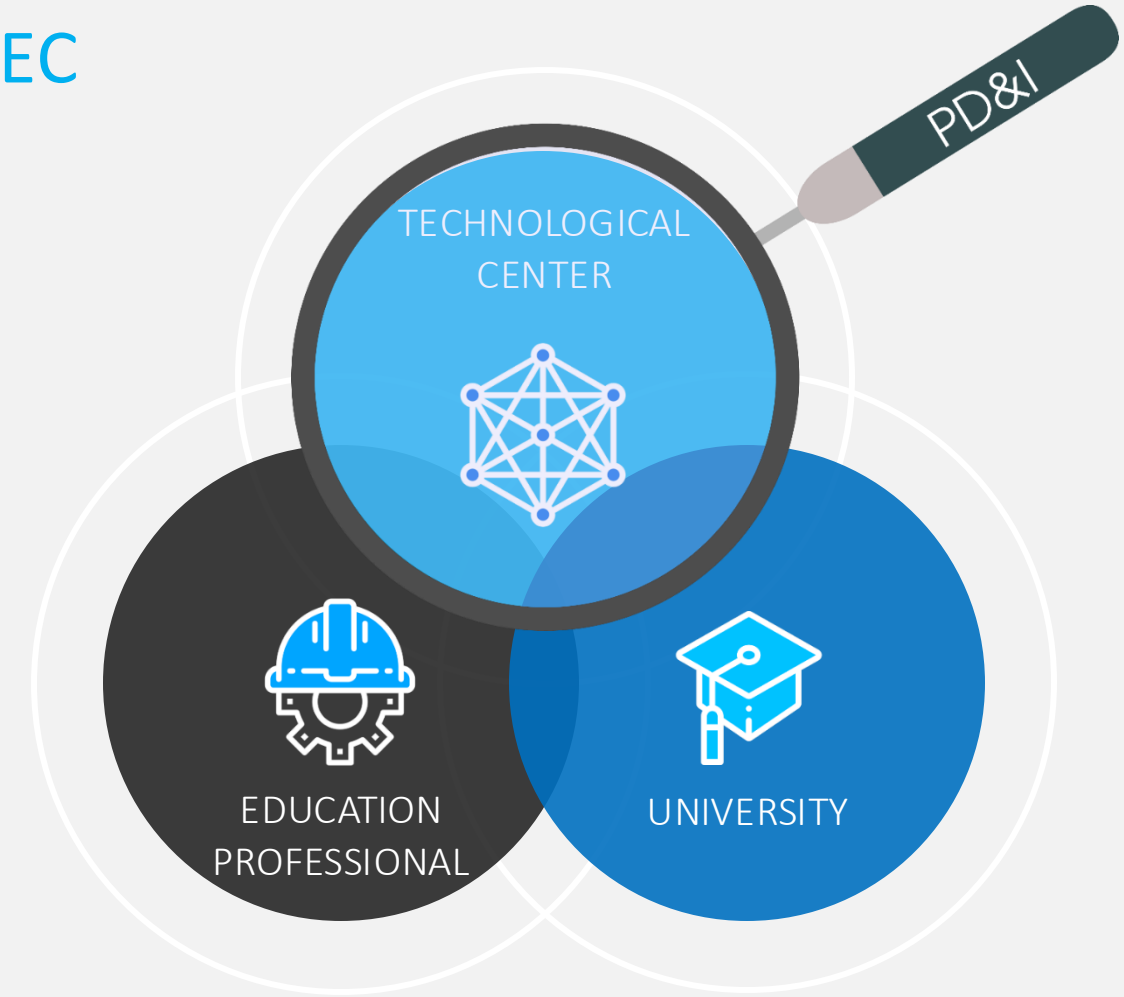
CIMATEC

180 PhDs and Masters

420 Engineers and Experts

31 Engineers in Training

New talents



Requests in Patents 83 INPI
07 **PCT/WIPO**

\+

Record in Software **61**

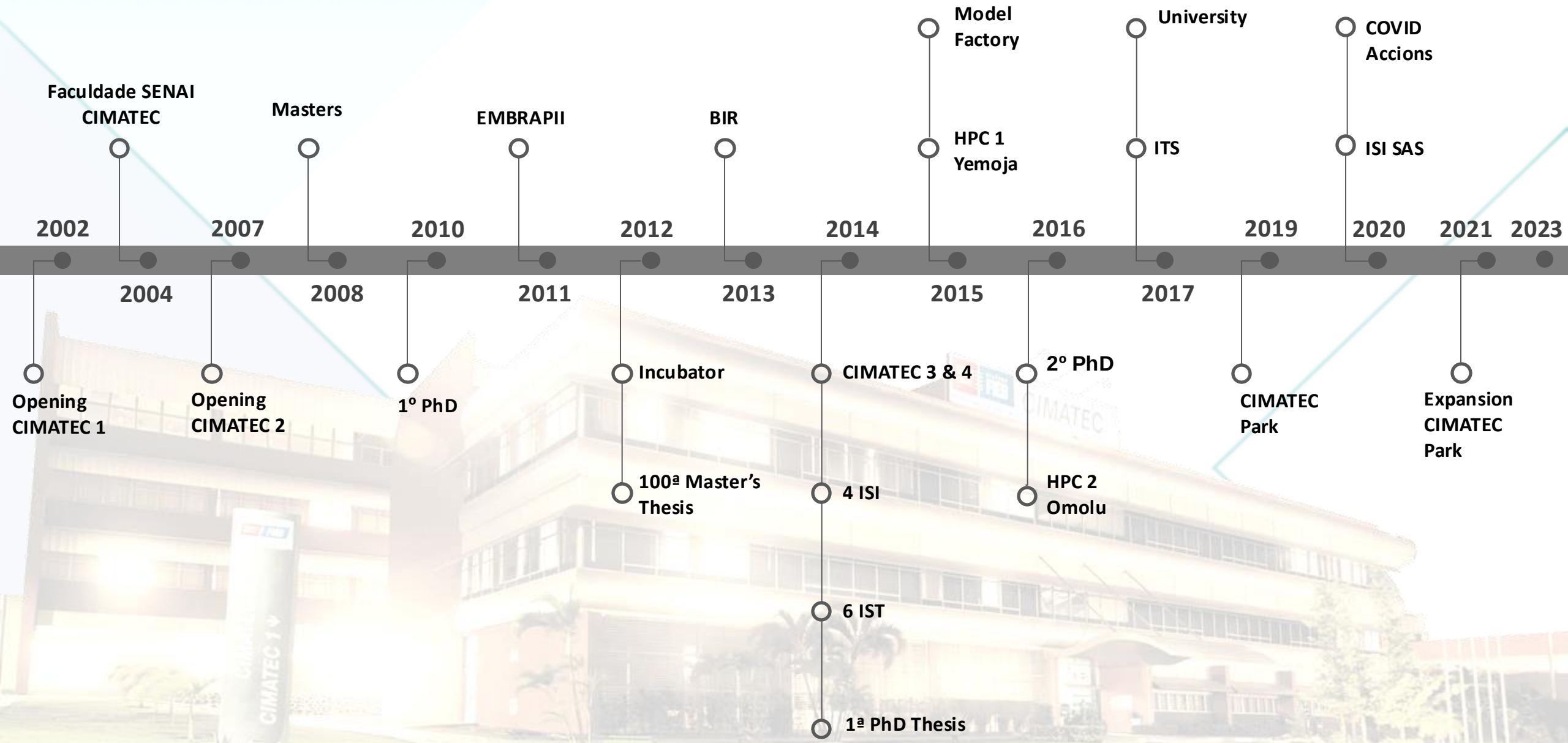
\+

Record in Brand 37

\+

Design Industrial 04

Total Assets Property Intellectual **192**



CIMATEC Timeline

Ecosystem CIMATEC

Sistema FIEB | SENAI CIMATEC | SENAI CIMATEC PARK
PELO FUTURO DA INOVAÇÃO

Entrepreneurship and Innovation

ACELERA CIMATEC

EMBRAPII

EMBRAPII
Empresa Brasileira de Pesquisa e Inovação Industrial

Partners Industrial

McKinsey&Company

intel

ISIs and ISTs

INSTITUTO SENAI DE INOVAÇÃO

INSTITUTO SENAI DE TECNOLOGIA

Technology Centers

Areas of Competence

RI&D - Operating Model

Institutions
Partners

RI&D

Companies

CIMATEC – Collaboration in the World

.TEC	.EDU	.ORG	.COM
International cooperation for technology development	International academic cooperation	Government cooperation abroad	Support for Brazilian industry abroad

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HPC

Code Portability and Optimization

Methodology

1 GEOPHYSICS MODELING

2 MATHEMATICS MODELING

3 COMPUTATIONAL MODELING

1 APPLICATION PERFORMANCE ANALYSIS

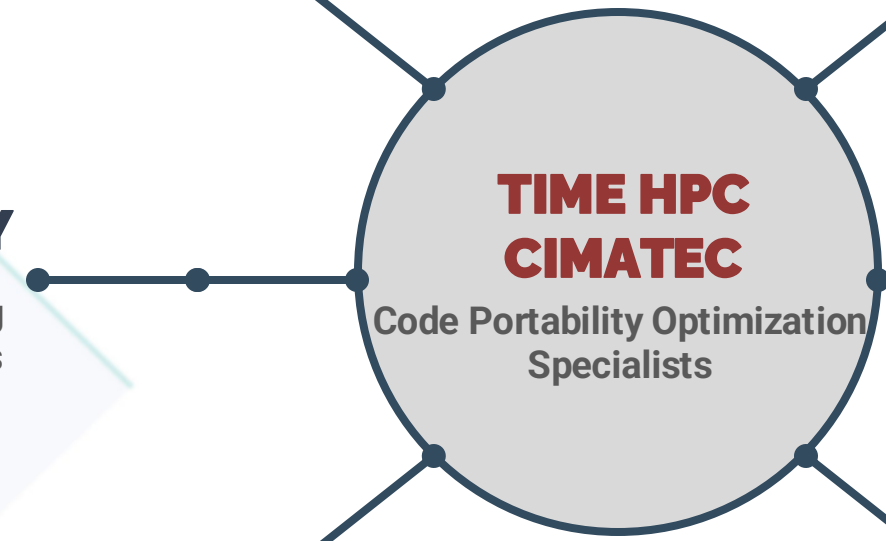
2 DOMAIN SPLITTING STRATEGIES

3 PARALLEL AND DISTRIBUTED SOLUTION DESIGN

4 PERFORMANCE METRICS

5 RESULTS ANALYSIS

STRUCTURE



APPLICATION
Mapping of Computational Costs

PORTABILITY
Adaptation to New Computing Architectures

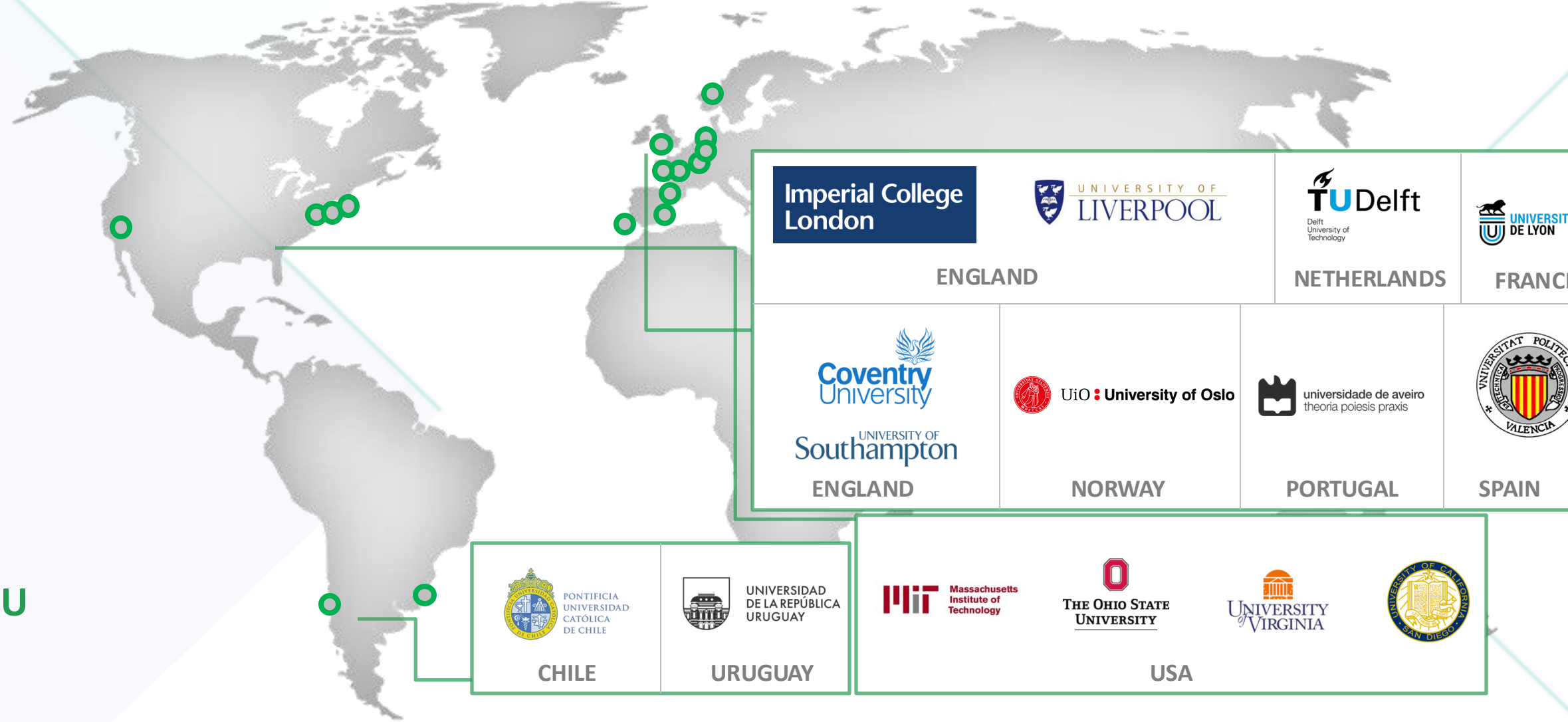
OPTIMIZATION
Decomposition, Distribution and Task Assignment Processes

ANALYSIS
Variables such as Latency, Granularity, Response Time, ... are evaluated

PARALLELISM
Implementation of Computational Models

PERFORMANCE RESULTS
Monitoring the methodology based on the results obtained

CIMATEC – Collaboration in the World



.EDU

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CIMATEC – Collaboration in the World

Fraunhofer
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung
DFKI
RWTH AACHEN UNIVERSITY
GERMANY

universidade de aveiro
theoria poiesis praxis
inegi driving innovation
PORTUGAL

TNO innovation for life
NETHERLANDS

Ciemat
Centro de Investigaciones Energéticas,Medioambientales y Tecnológicas
SPAIN

PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE
CHILE

LATU
URUGUAY

Massachusetts Institute of Technology
The Ohio State University
University of Virginia
University of California San Diego
IDRI
ELUCIDA RESEARCH HARVARD MEDICAL SCHOOL
McKinsey&Company
USA

.TEC

Brazilian Research and Development Institute

SENAI CIMATEC Supercomputing Center

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SENAI CIMATEC Supercomputing Center

SENAI CIMATEC Supercomputing Center

SENAI CIMATEC

Supercomputing Center Timeline

SENAI CIMATEC

PhDs

Researchers

Masters

Specialists

0. Cloud (Datacenter)

1. Yemoja - Oil & Gás

405 TeraFlops

2. Fiocruz OMOLU

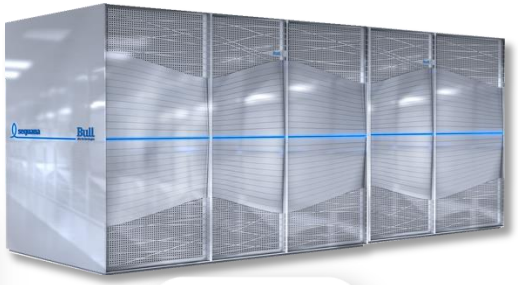
50 TFlops

3. HPC FINEP

180 TFlops

4. HPC Oil & Gas (CPU)

800 TeraFlops



5. HPC Oil & Gas (GPU)

1.8 PetaFlops

312 V100

6. Quantum Computing

7. HPC CIMATEC Park

Researches Lines

Services

Projects

Innovation

Models

2012 2015 2016 2018 2019 2020 2025

PÚBLICO PUBLIC

anp
COMPROMISSO COM INVESTIMENTO EM
PESQUISA & DESENVOLVIMENTO

HIGH PERFORMANCE COMPUTING

OG3ON

SENAI CIMATEC - CENPES PETROBRAS

BR PETROBRAS

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PÚBLICO
PUBLIC

OGBON Supercomputer Specification

OGBON

PETROBRAS

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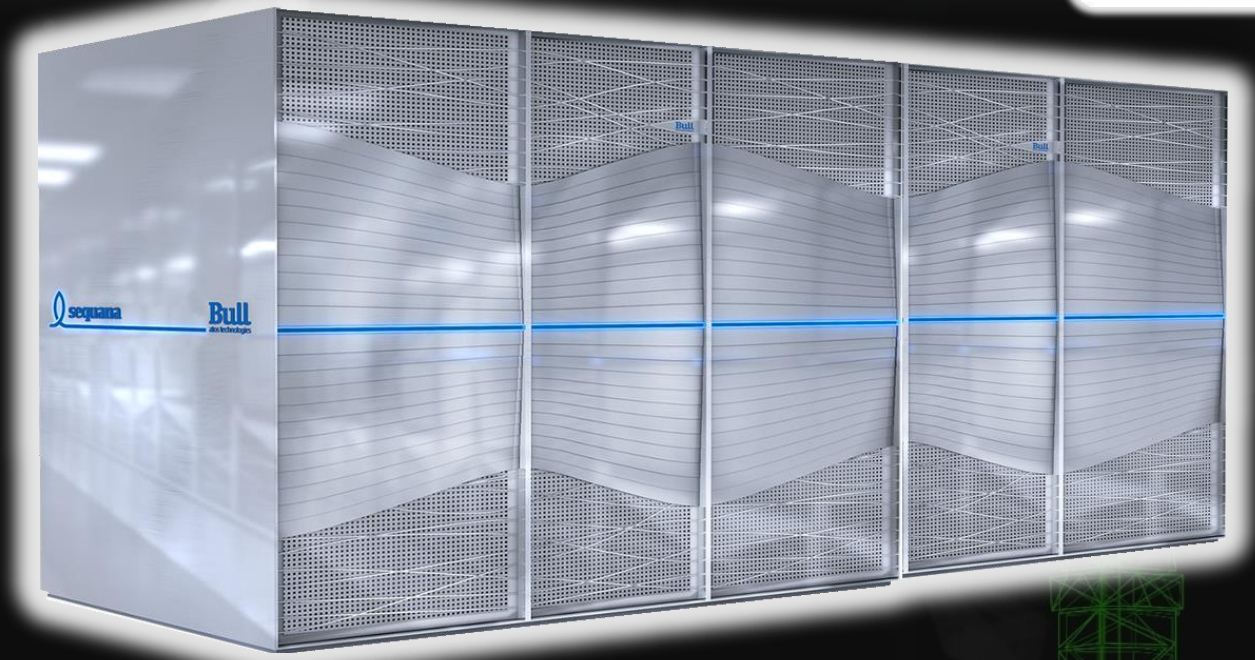
PELO FUTURO DA INOVAÇÃO

anp
COMPROMISSO COM INVESTIMENTO EM PESQUISA & DESENVOLVIMENTO



100% Cool Water Technology
Direct Cooling at 5 Racks

TOP 500
The List.

#347

312 GPUs
78 Nodes
4 x NVIDIA V100 32 GB
1605 Peta Flops (RMAX)
384 GB RAM per node

210 CPUs
204 Tera Flops (RMAX)
2 x Intel Cascade Lake
384 GB RAM

1 PB Parallel Lustre
26 GB/s IOR
500 TB Storage
100 Gbps Infinband
8 Login Nodes

PÚBLICO
PUBLIC

Code Optimization Projects

CIMATEC

SENAI CIMATEC carries out research and development of complex projects, integrating them into customers' production systems.

Timeline HPC

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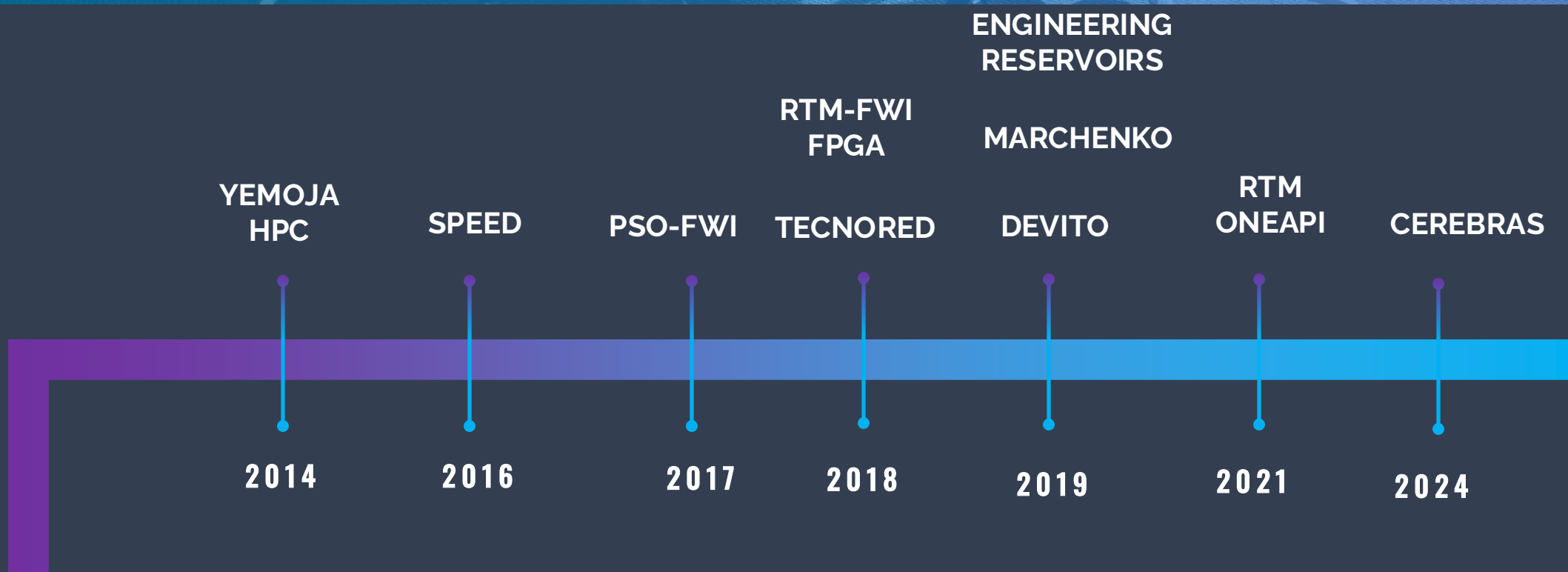


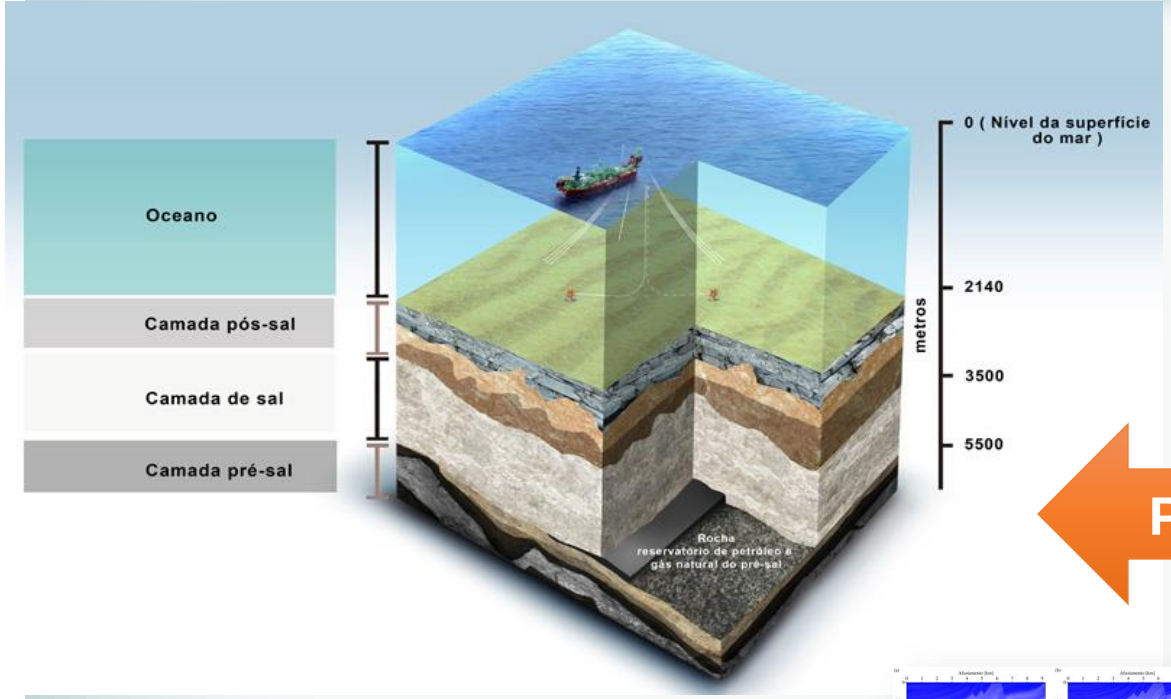
PROJECT

YEMOJA HPC

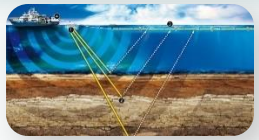
GOAL

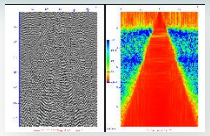
The first project of the SENAI CIMATEC supercomputing center aimed to process images of the Brazilian pre-salt oil reserve layer. And only through the processing of seismic imaging of this layer was it possible to measure the values of barrels of oil produced.

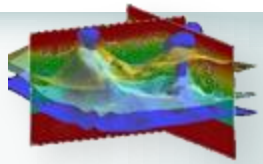
PROJECT
YEMOJA HPC



Pre-Salt







Acquisition

- Raw Data

Pre-Processing

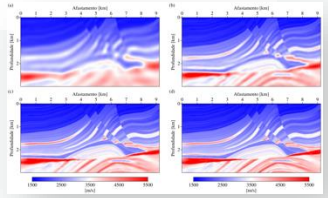
- Filtering
- Regularization
- Edition

Processing

- Parallelization
- Optimization
- Execution

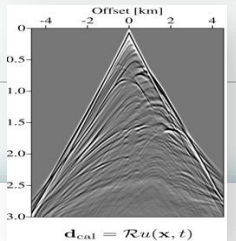
Interpretation

- Seismic Image



Seismic Pre-Salt Challenges:

- High Impedance Contrasts
  - High P-wave velocity in salt layer
- Complex Propagation Trajectories
  - Internal Multiples
- Complex structural configurations
- Low Amplitudes in pre-salt layer



Two new machines

- FINEP - Industrial
- Fiocruz - BigData for Health

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PROJECT

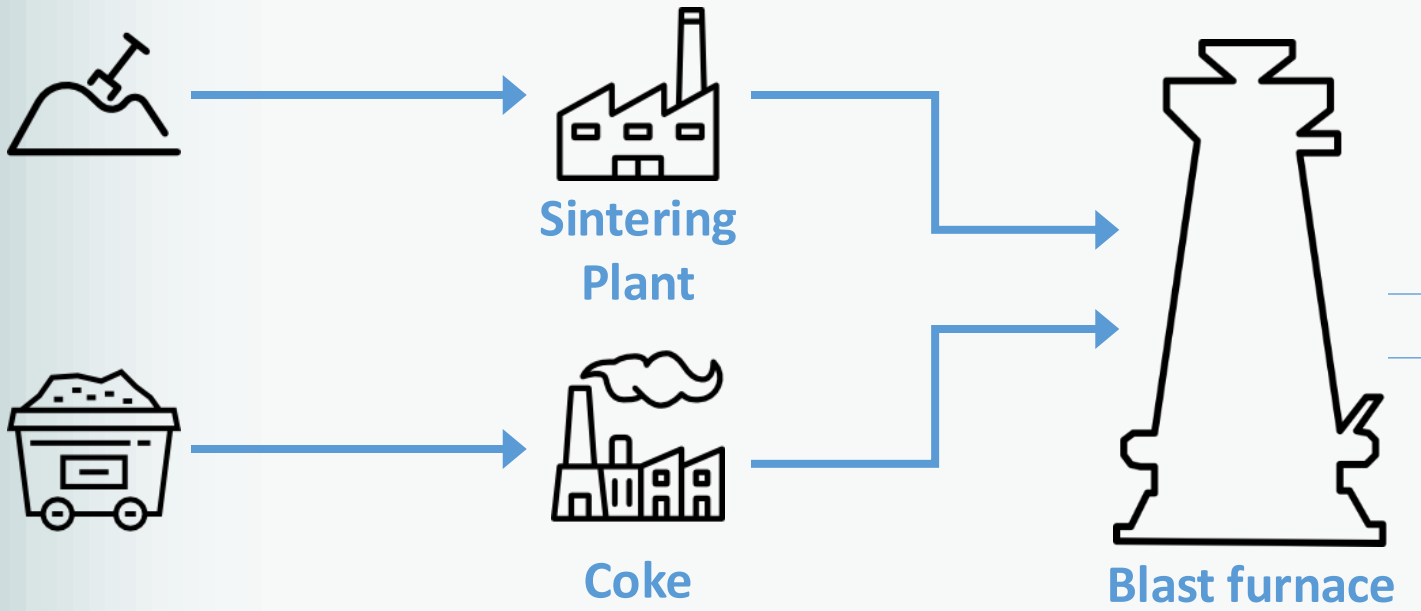
TecnoRed-CFD

GOAL

This project aimed to study and experiment with heterogeneous computing techniques in supercomputing environments, which intended to describe the processes for parallel optimization of the TECNORED-CFD software using GPUs.

PROJECT
TecnoRed-CFD

CONVENTIONAL REDUCTION PROCESS



CO_2 Emission	2 ton / ton steel
Implementation and operation cost	
Iron specifications	
Process duration	8h
Inputs	Expensive and complex
Performance	

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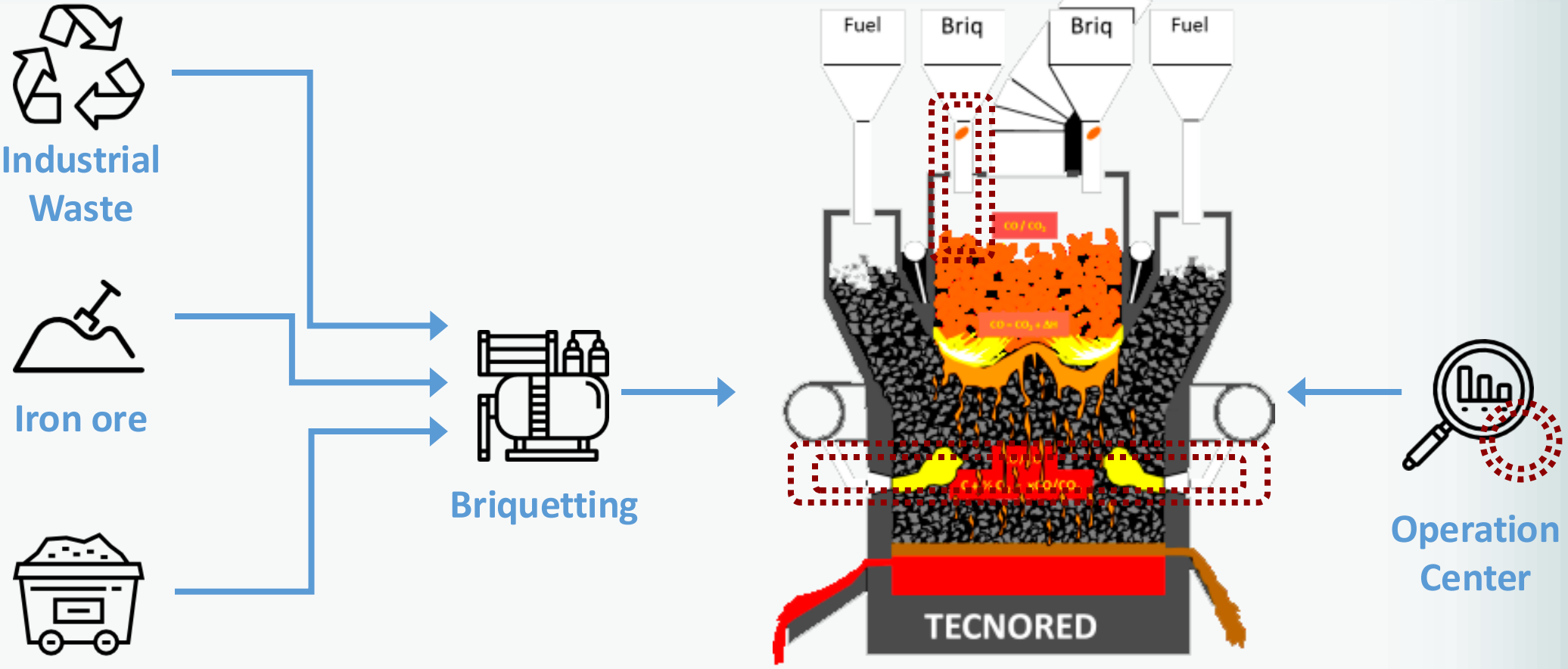
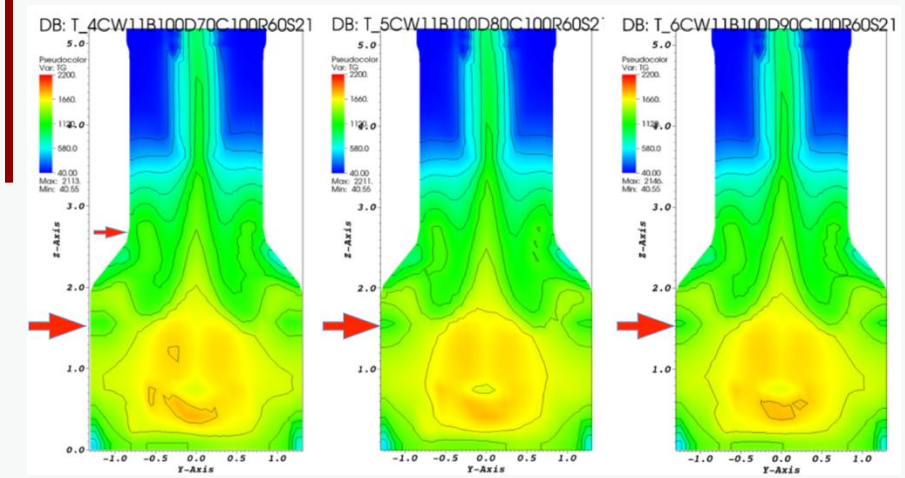
PROJECT
TecnoRed-CFD



Processing of Fuel and Self-Reducing Briquettes

PROJECT
TecnoRed-CFD



Research project

HPC

Computational Fluid Dynamics

Process

Outcomes

M 1

M 2

M 3

Etapas

- ✓ Informational
- ✓ Conceptual
- ✓ Performance analysis
- ✓ Parallelization
- ✓ Experimental Tests C1
- ✓ MD Software Simulation V0
- ✓ Validation/ Performance Tests/ Parameter Simulation

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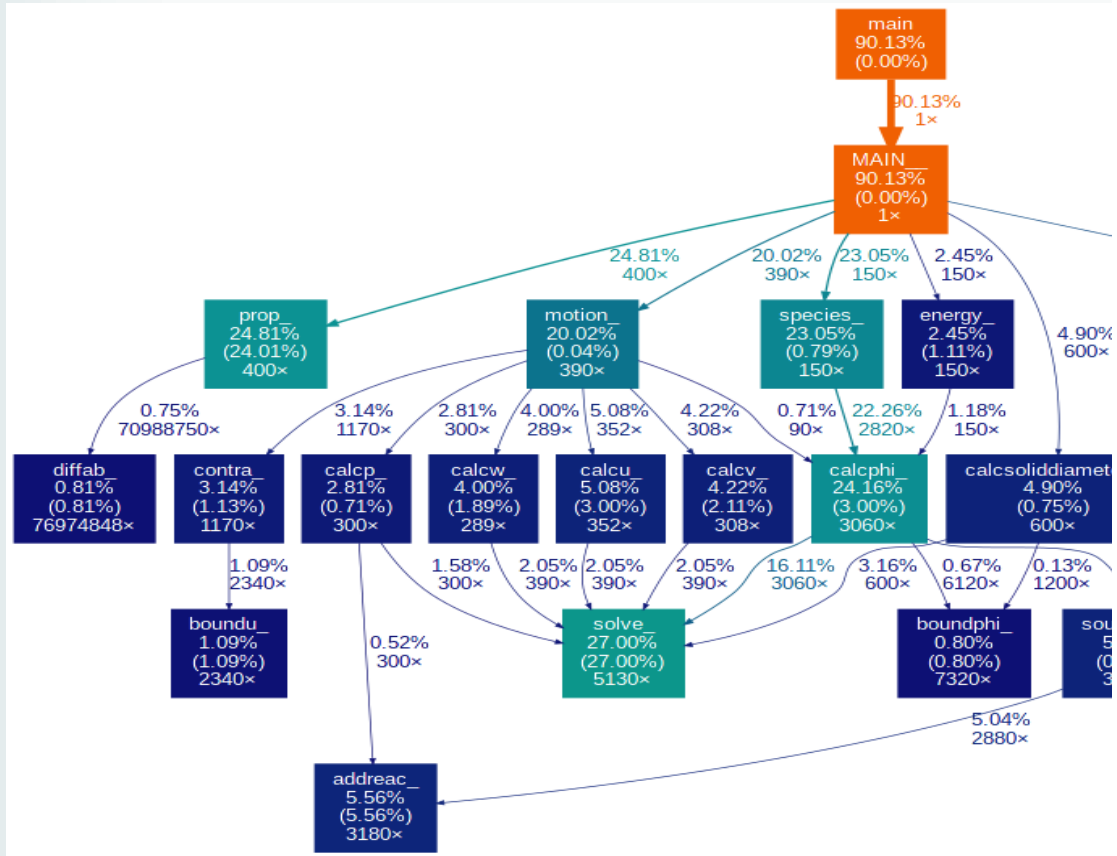
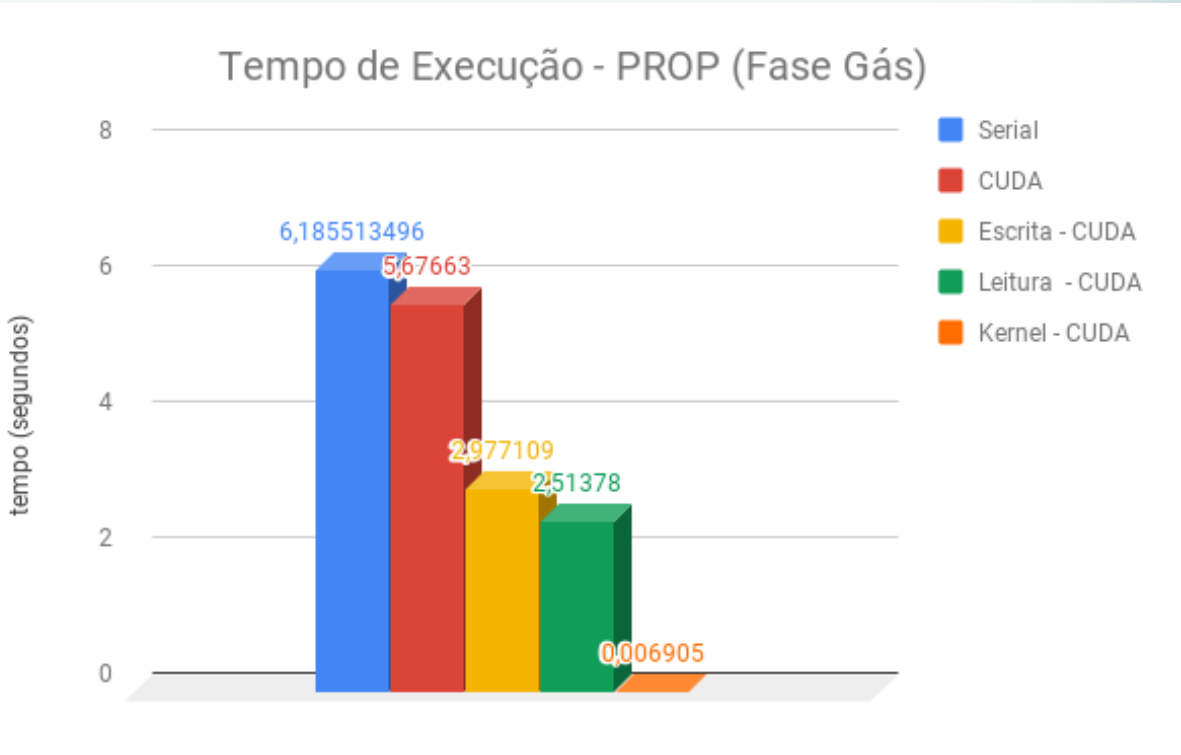
PROJECT
TecnoRed-CFD





PROJECT

Engineering of Reservoirs

GOAL

This project aimed to develop and improve the computational codes developed by CENPES for use in the area of reservoir engineering.

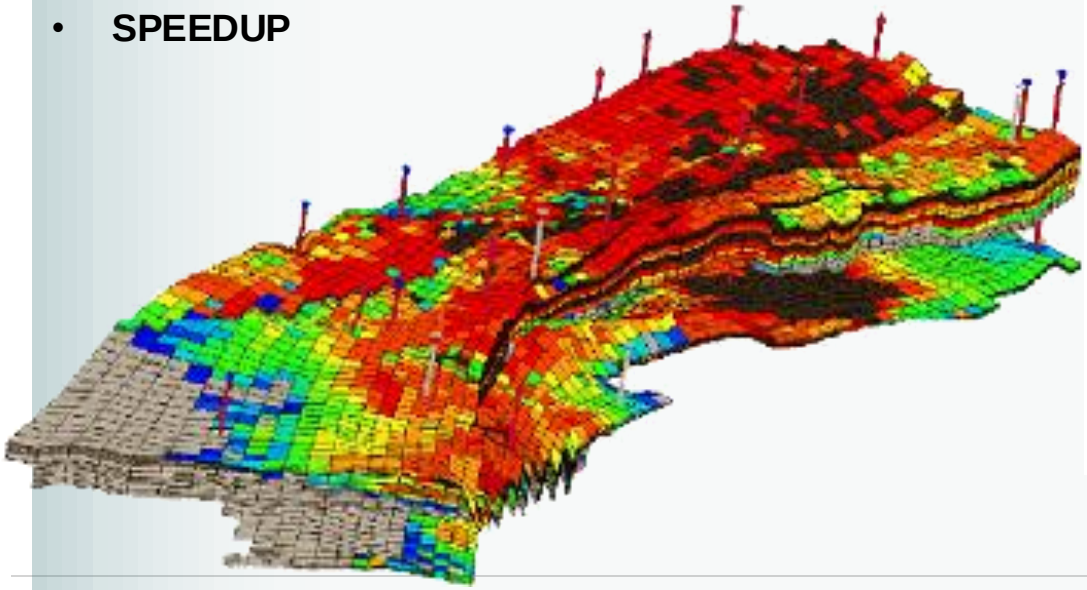
PROJECT
Reservoir Engineering

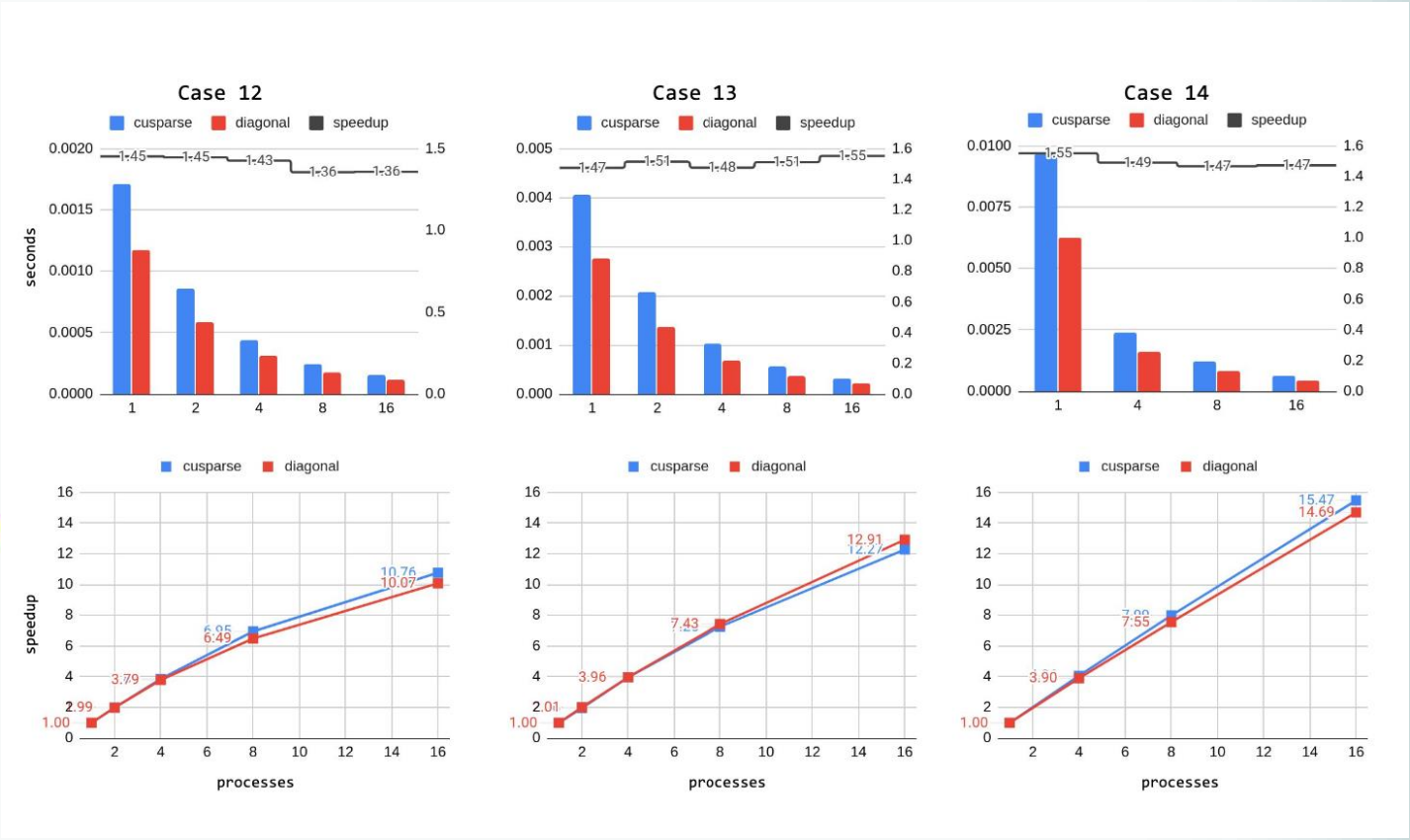
Code Optimization and Portability:

Adaptation to new Architectures
- **SOLVERBR**

Performance Analysis
- **PETSc**

Performance Metrics
- **SPEEDUP**





PROJECT

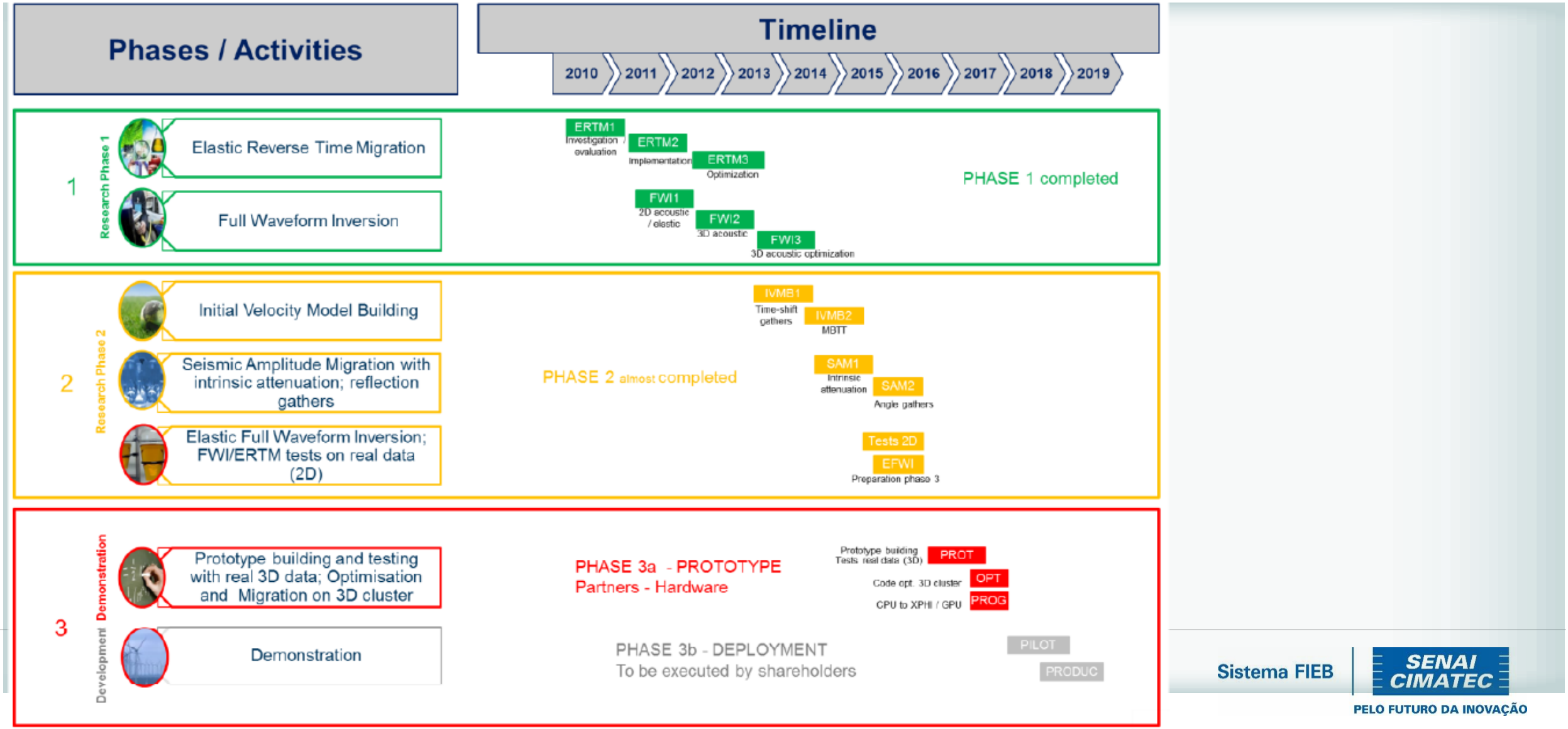
SPEED

GOAL

Development and validation of the prototype of a scalable and specific computational model for execution on supercomputers for the generation of seismic images with 3D data.

PROJECT

RSB SPEED: Computational Model intended for 3D Seismic Imaging for execution on Supercomputers



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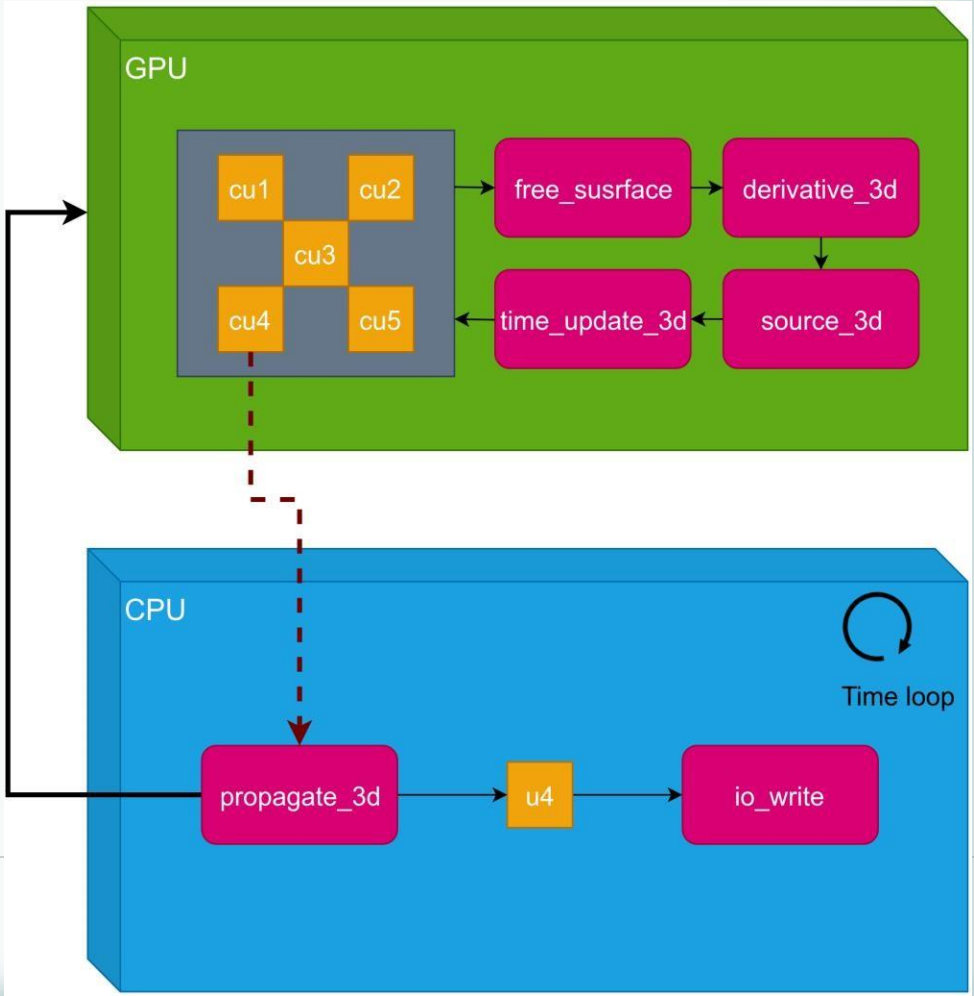
RSB SPEED: Computational Model intended for 3D Seismic Imaging for execution on Supercomputers

RESULTS OF RESEARCH AND CODE DEVELOPMENT (OUTCOME 5)

Speed GPU VERSION 2

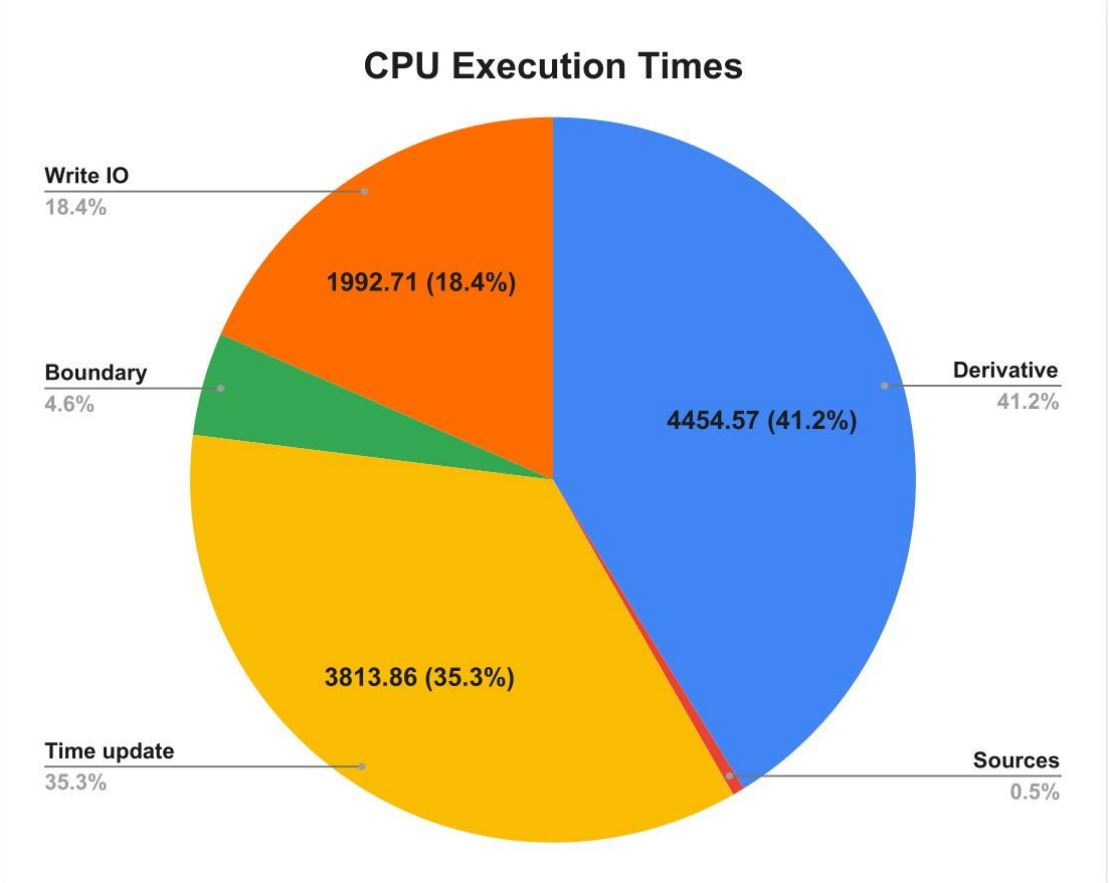
- The implementation of other kernels made it possible for the temporal loop to be done within the GPU;
- Development of methods to improve the relationship between host-device communication for data transfer and model computation time;
- The u[1-5] structures are now inside the GPU.

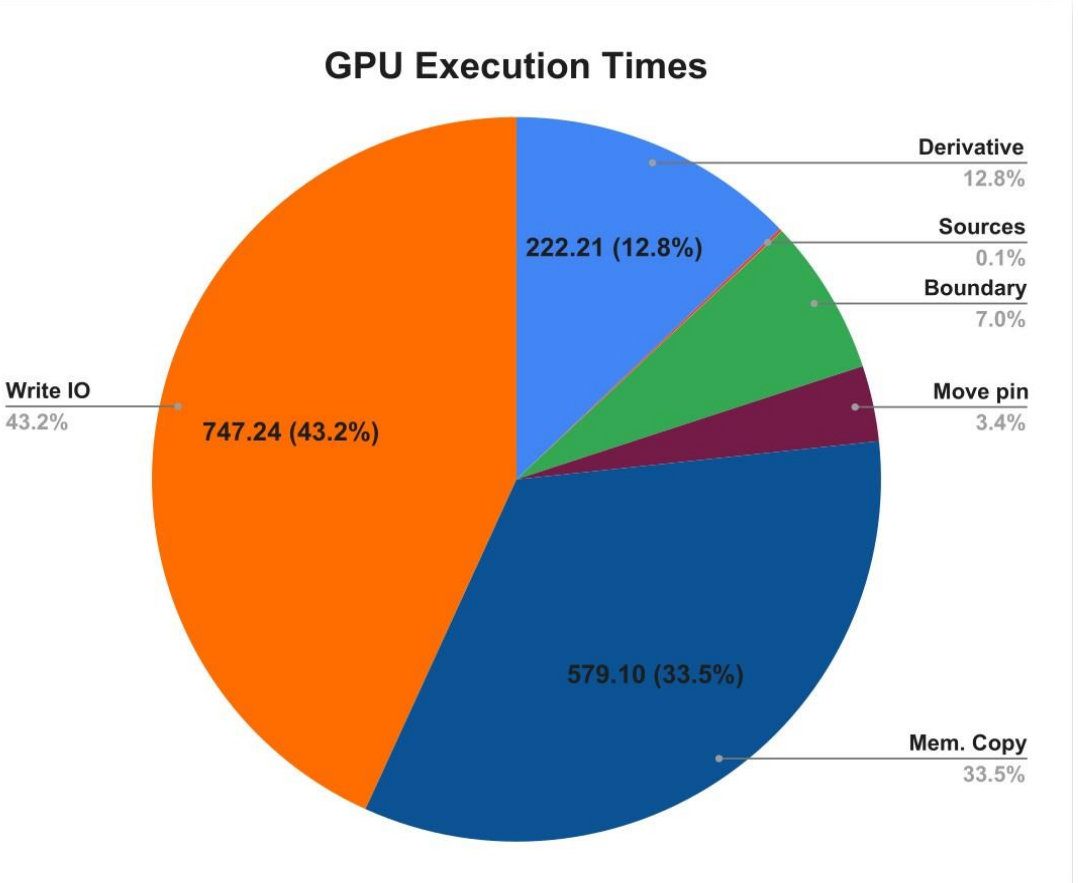


PROJECT

RSB SPEED: Computational Model intended for 3D Seismic Imaging for execution on Supercomputers

RESULTS OF RESEARCH AND CODE DEVELOPMENT (OUTCOME 6)





PROJECT

RSB SPEED: Computational Model intended for 3D Seismic Imaging for execution on Supercomputers

RESULTS OF RESEARCH AND CODE DEVELOPMENT (OUTCOME 6)

	Average Model CPU	Average Model GPU	Real Model CPU	Real Model GPU
Propagation	1060.26	105.00	10807.07	1302.51
Speedup	**10X**		**8X**	
Image	212.51	153.04	2424.19	2058.86
Total (S)	1272.77	258.04	13231.26	3361.37

PROJECT

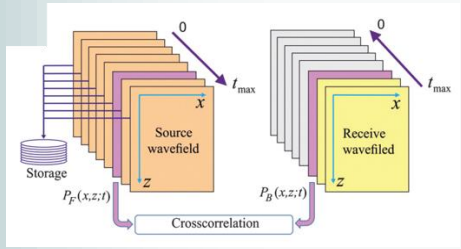
RTM-FWI FPGA

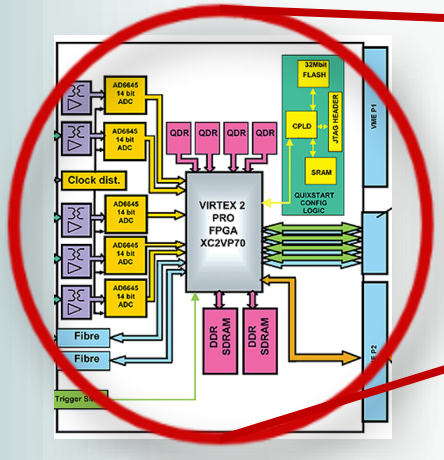
GOAL

This project aimed to perform a comparative analysis of accelerators based on RTM/FWI hardware implemented in FPGA and GPGPU.

PROJECT
RTM-FWI FPGA

FPGA to accelerate RTM, FWI and Seismic Imaging Algorithms



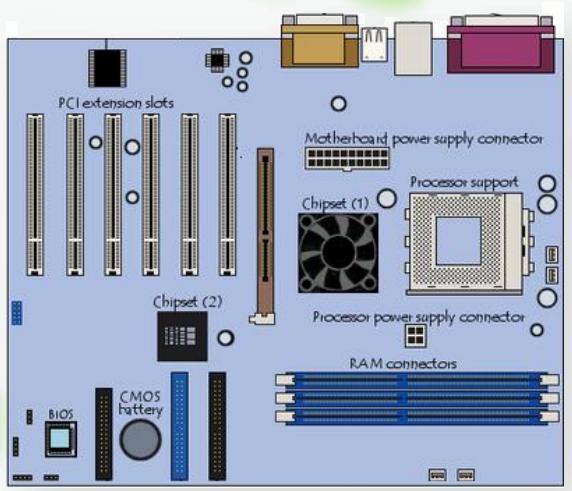


Seismic Co-Processor

FPGA

PCI-Express

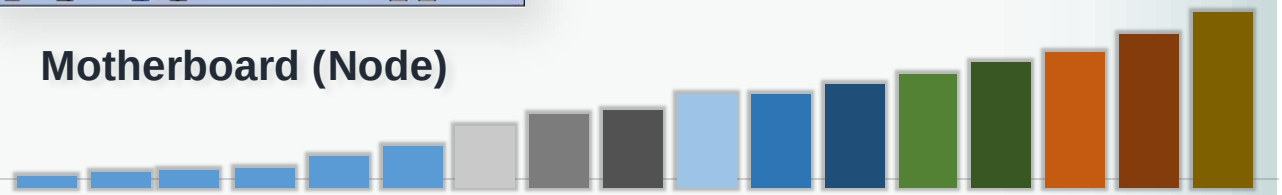
Operation System (OS)



Motherboard (Node)

HPC Scalable Processing

Clusters



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PROJECT

Marchenko

GOAL

This project aims to research, validate and apply the Marchenko iterative scheme in the attenuation of multiple reflections and in the construction of 2D/3D seismic images on real seismic data in a high-performance computing environment.

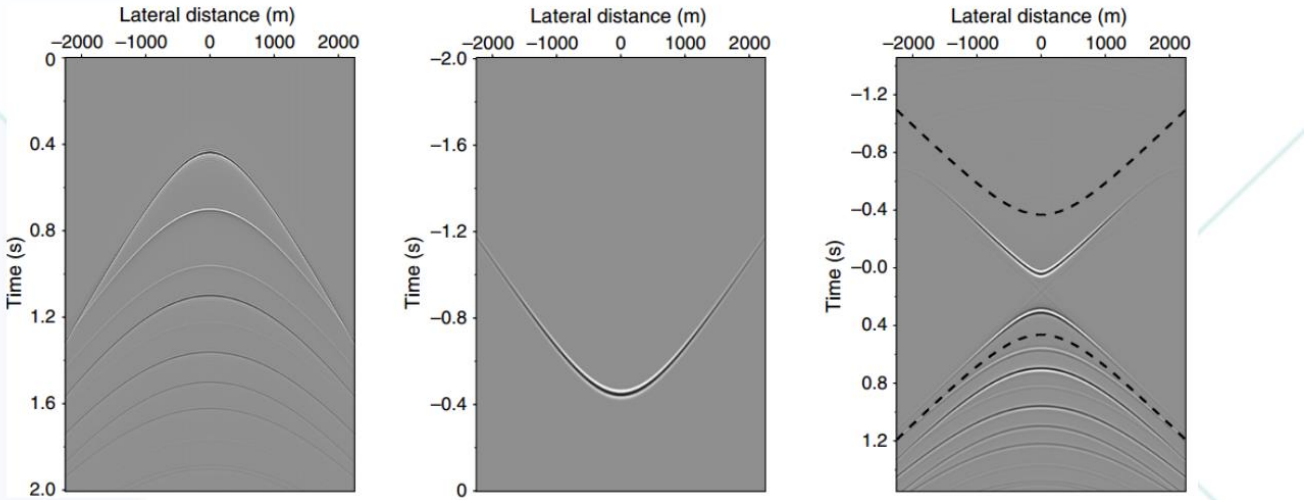
PROJECT

Marchenko Imaging

What is the Marchenko Method?

Marchenko's iterative scheme allows calculating Green's up and down functions using as input data the complete acquisition at the earth's surface and a smoothed velocity field to calculate the initial focusing functions.

Equation (Thorbecke, et al, 2017):



$$\theta_t \int_{\partial \mathbb{D}_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') N_{i-1}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x} = N_i(\mathbf{x}_R, \mathbf{x}_F, -t)$$

PROJECT

Marchenko Imaging

Consiste em modelar a função de focalização inicial (N_0) com diferenças finitas ou a equação Eikonal e iniciar o processo de cálculo dos seguintes fatores:

Paso 0

$$N_i(\mathbf{x}_R, \mathbf{x}_F, -t) = \theta_t \int_{\partial\mathbb{D}_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') N_{i-1}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

Paso 1

$$p_{min}(\mathbf{x}_R, \mathbf{x}_F, t) = \sum_{i=0}^{M} N_i(\mathbf{x}, \mathbf{x}_F, -t)$$

$$f_{1min}(\mathbf{x}_R, \mathbf{x}_F, t) = -\sum_{i=0}^{M_{l2}} N_{2i}(\mathbf{x}, \mathbf{x}_F, -t)$$

$$f_{1plus}(\mathbf{x}_R, \mathbf{x}_F, t) = -\sum_{i=0}^{M_{l2}} N_{2i+1}(\mathbf{x}, \mathbf{x}_F, t) + G_d(\mathbf{x}_R, \mathbf{x}_F, -t)$$

$$f_2(\mathbf{x}_R, \mathbf{x}_F, t) = -\sum_{i=0}^{M} N_i(\mathbf{x}, \mathbf{x}_F, t) + G_d(\mathbf{x}_R, \mathbf{x}_F, t)$$

$$G(\mathbf{x}_R, \mathbf{x}_F, t) = f_2(\mathbf{x}_R, \mathbf{x}_F, -t) + p_{min}(\mathbf{x}_R, \mathbf{x}_F, t)$$

Paso 2

$$G(\mathbf{x}_R, \mathbf{x}_F, t) = f_2(\mathbf{x}, \mathbf{x}_F, -t) + \theta_t \int_{\partial\mathbb{D}_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') f_2(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

$$G_{min}(\mathbf{x}_R, \mathbf{x}_F, t) = -f_{1min}(\mathbf{x}, \mathbf{x}_F, t) + \theta_t \int_{\partial\mathbb{D}_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') f_{1plus}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

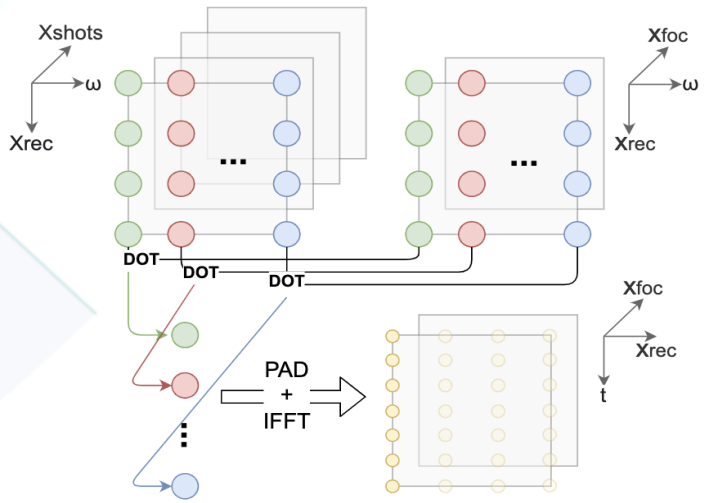
$$G_{plus}(\mathbf{x}_R, \mathbf{x}_F, t) = f_{1plus}(\mathbf{x}, \mathbf{x}_F, -t) - \theta_t \int_{\partial\mathbb{D}_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') f_{1min}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

Imageamento

$$I(x_F) = \sum_{ir}^{nrec} (G_{min}(\mathbf{x}_R, \mathbf{x}_F, t) * f_{1plus}(\mathbf{x}_R, \mathbf{x}_F, t))|_{t=0}$$

or

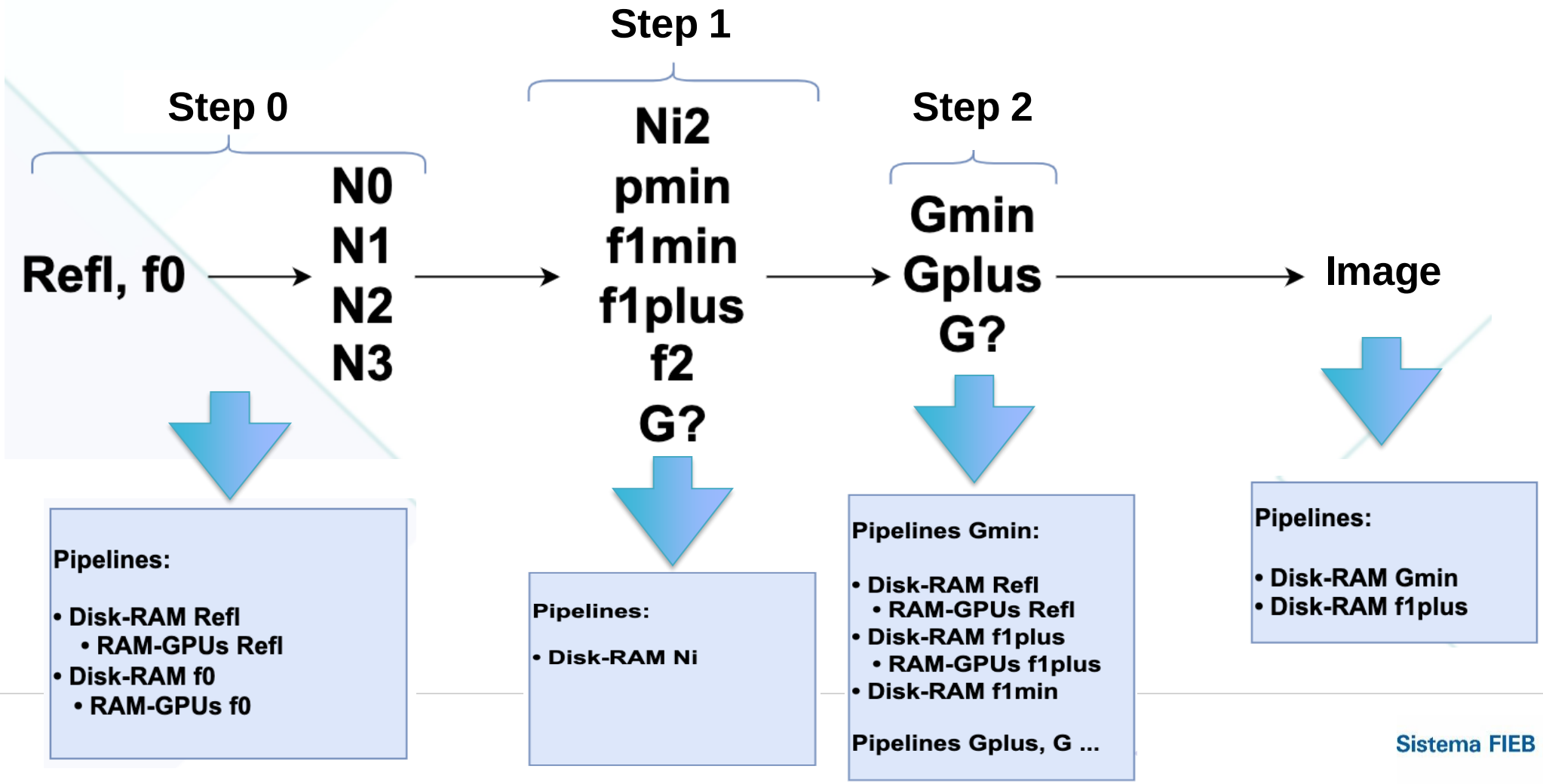
$$I(x_F) = \sum_{ir}^{nrec} (G_{min}(\mathbf{x}_R, \mathbf{x}_F, t) * G_{plus}(\mathbf{x}_R, \mathbf{x}_F, t))|_{t=0}$$



Kernel cross-correlação

PROJECT
Marchenko Imaging

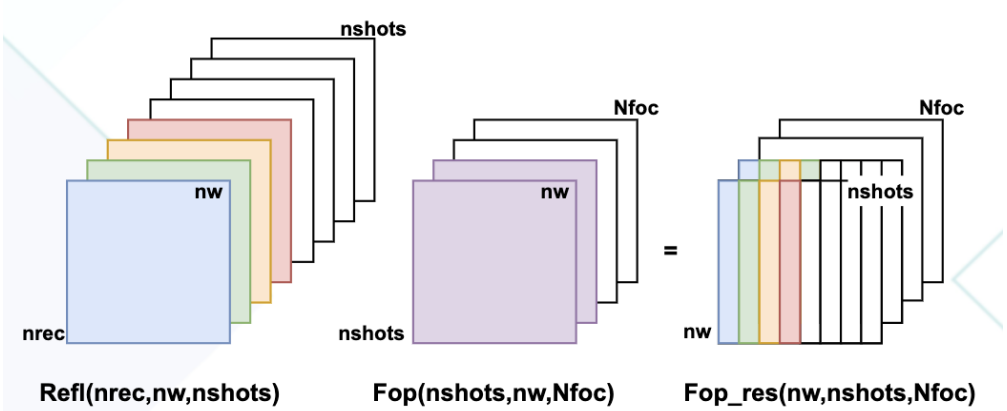
Pipelines on GPU



PROJECT
Marchenko Imaging

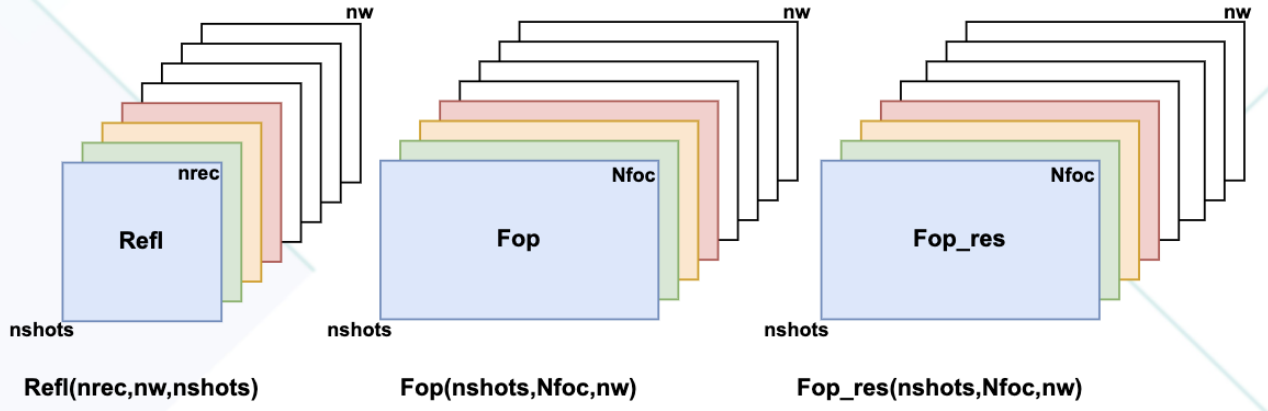
Data distributions on the GPU : Thorbecke, et al. 2017 vs Ravasi, et al. 2020

Thorbecke

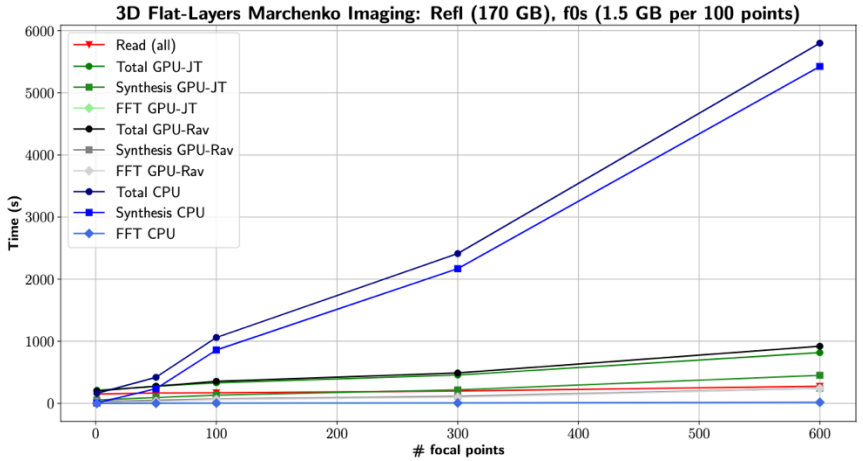


GPU0 GPU1 GPU2 GPU3 ALLGPUS

Ravasi



GPU0 GPU1 GPU2 GPU3 ALLGPUS



Node Specifications

CPU

- 2 Intel (R) Xeon (R) Gold 6240 CPU @ 2.60 GHz with 18 cores each node;
- 376GB.

GPU

- 4 TESLA V100 com 32GB de memória global cada nó.

Numeric example specifications

3-layer flat model
Refl (shots): 201*61=1261 shots/receptors, 286 frequencies, total 170GB;

- f0s (initial focusing functions): 201*61 receivers, increase step 50. Each 100 points have 1,5 GB.

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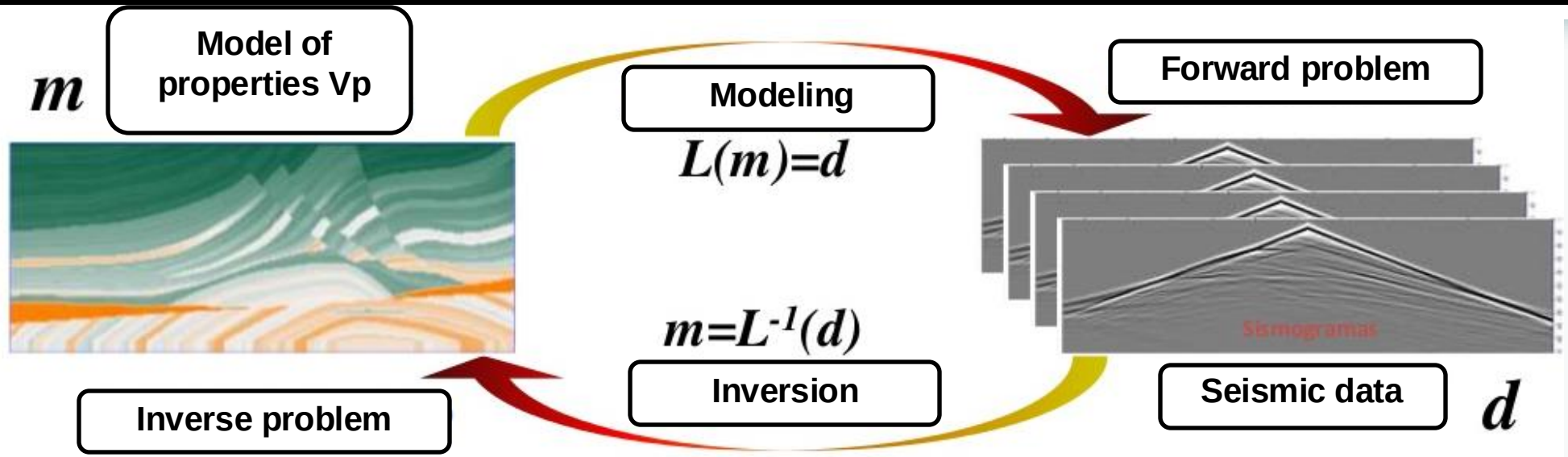
PROJECT

PSO-FWI

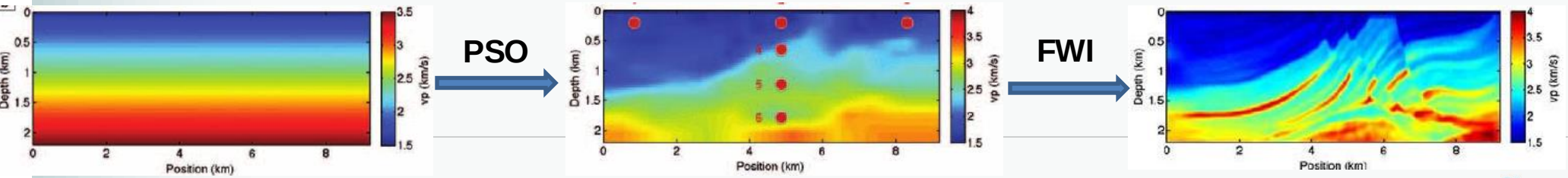
GOAL

This project aimed to obtain estimates of 2D acoustic macromodels using PSO-FWI (Particle Swarm Optimization - Full-Waveform Inversion).

PROJECT
PSO-FWI



Goal: Improvement of the velocity field >>>>> improve the quality of the seismic image in depth



Higher resolution

PROJECT

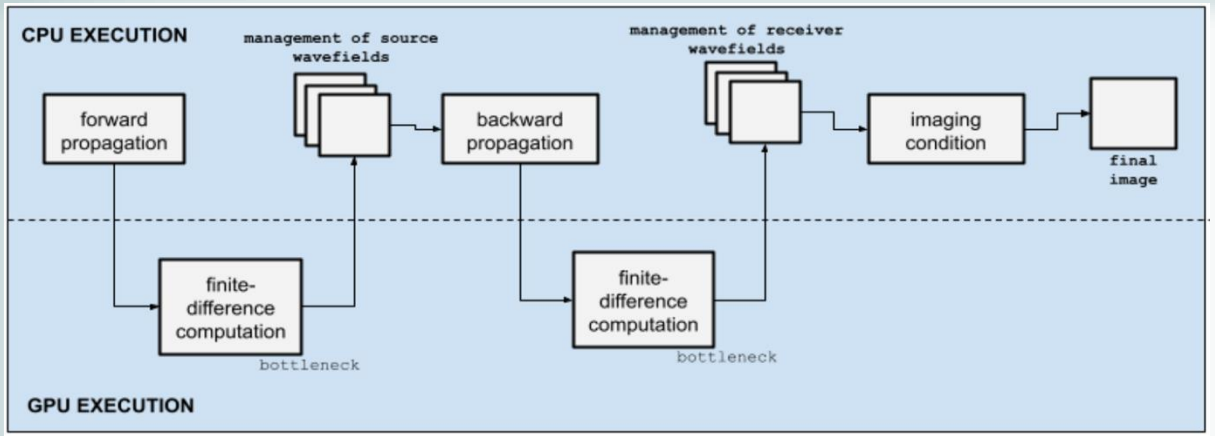
RTM OneAPI

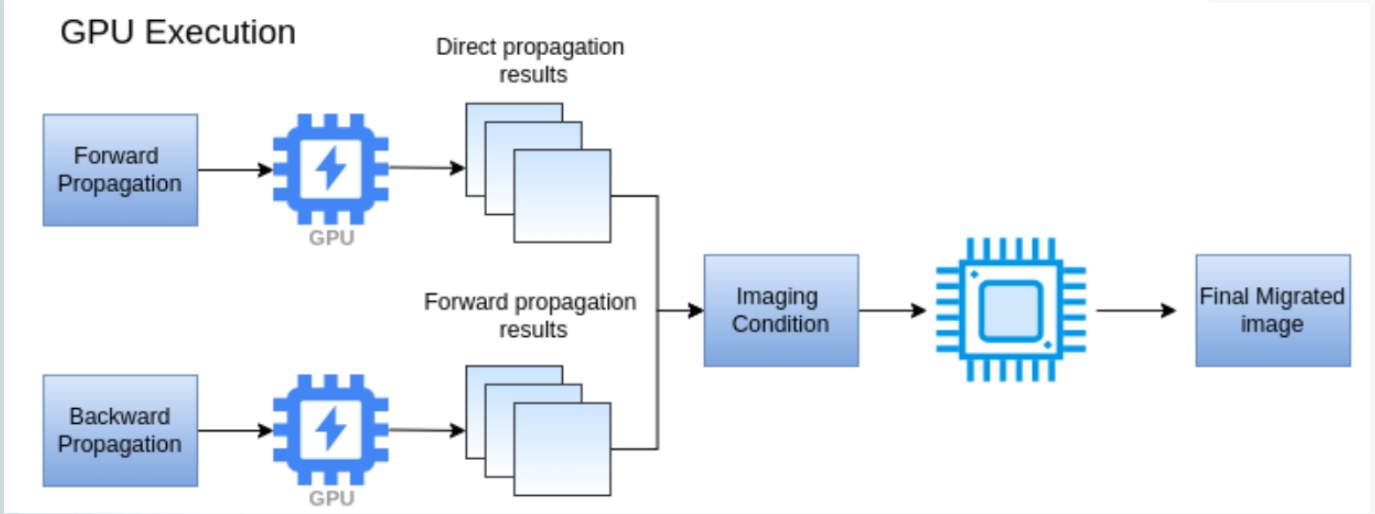
GOAL

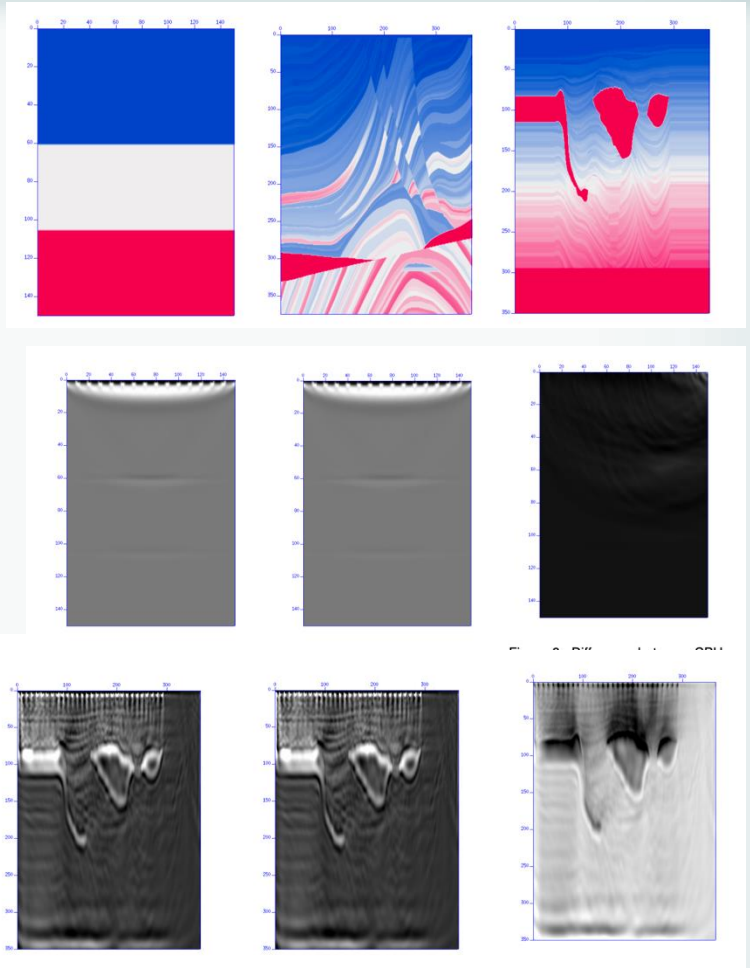
Explore the functionalities of the Intel OneAPI API and the capabilities of the DPC++ compiler to deal with heterogeneous computing in a multi-GPU system using as a proof of concept a seismic imaging application for a two-dimensional acoustic case of the Reverse Time Migration (RTM) algorithm.

PROJECT

RTM Domain Division on Multi-GPU using OneAPI







[Multi-GPU 2D-RTM] Migration and propagation structure of an acoustic model using multiple GPUs.

PROJECT

RTM Domain Division on Multi-GPU using OneAPI

```
void fd_forward(int order, float **p, float **pp, float **v2, int nz, int nx, int nt, int is, int sz,  int *sx, float *srce, int propag)
{
   //Grid and block definition
   {
      sycl::buffer<float, 1> *b_p = new
      sycl::buffer<float, 1> *b_pp = ne
      sycl::buffer<float, 1> b_v2(v2[0],
      sycl::buffer<float, 1> b_coefs_x(c
      sycl::buffer<float, 1> b_coefs_z(c
      sycl::buffer<float, 1> b_taperx(ta
      sycl::buffer<float, 1> b_taperz(ta
      sycl::buffer<float, 1> *b_swap;
      for (int it = 0; it < nt; it++){
            b_swap = b_pp;
            b_pp = b_p;
            b_p = b_swap;
            kernel_tapper()
            kernel_lap()
            kernel_time()
            kernel_scr()
      }
   }
}
```

```
q_ct1.submit([&](sycl::handler &cgh) {
      auto acc_p = b_p->get_access<sycl::access::mode::read_write>(cgh);
      auto d_laplace_ct4 = d_laplace;
      auto acc_coefs_x = b_coefs_x.get_access<sycl::access::mode::read_write>(cgh);
      auto acc_coefs_z = b_coefs_z.get_access<sycl::access::mode::read_write>(cgh);


      cgh.parallel_for(
      sycl::nd_range<3>(dimGrid * dimBlock, dimBlock),
      [=](sycl::nd_item<3> item_ct1) {
      kernel_lap(order, nx, nz, acc_p,
      d_laplace_ct4, acc_coefs_x,
      acc_coefs_z, item_ct1);
            });
      });
```

Velocity Model	Serial time (s)	Parallel time (s)
3 layer	4,76	1,08
Marmousi	42,93	3,6
SPluto	54,91	5,5

Comparison of results in C and SYCL/DPC++ after reengineering

SENAI CIMATEC

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