

SENAI CIMATEC

Tecnologia, Inovação
e Educação para a Indústria

Sistema FIEB



PELO FUTURO DA INOVAÇÃO

CIMATEC 2
CIMATEC 1

SENAI
CIMATEC
FIEB
Federação das Indústrias do Estado de Alagoas
CIMATEC



QMS Certification Services

Sistema FIEB



**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

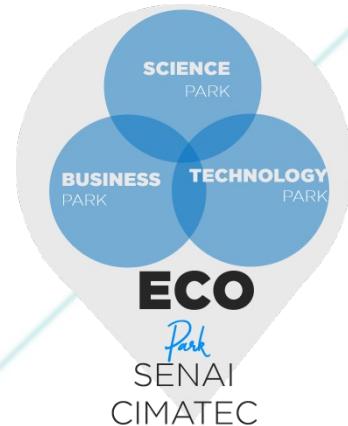
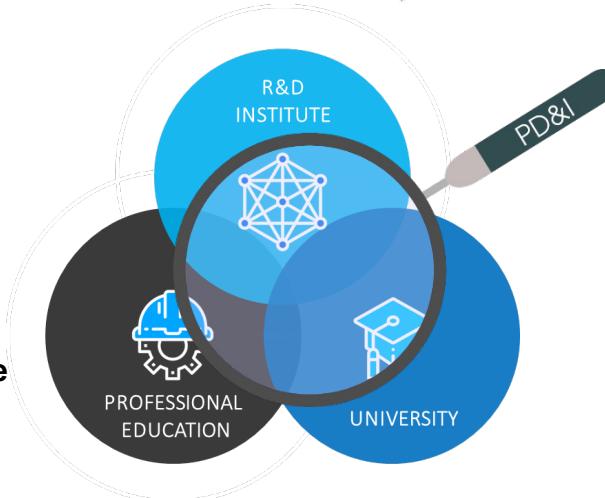


SENAI is present in all 27 states in Brazil
Represent all the sectors of the Brazilian
industry

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



Located at Bahia State



CIMATEC Park created in 2019



CIMATEC

Manufacturing and Technology Integrated Center
SENAI CIMATEC created in 2002

4 Buildings 35.000 m²

US\$200 mi investments

42 competence areas

1K employees



11 Buildings 65.000 m²

US\$ 50 mi Phase 1

10 Heavy Industry Projects

Total Area 4.000.000 m²

CIMATEC PARK

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

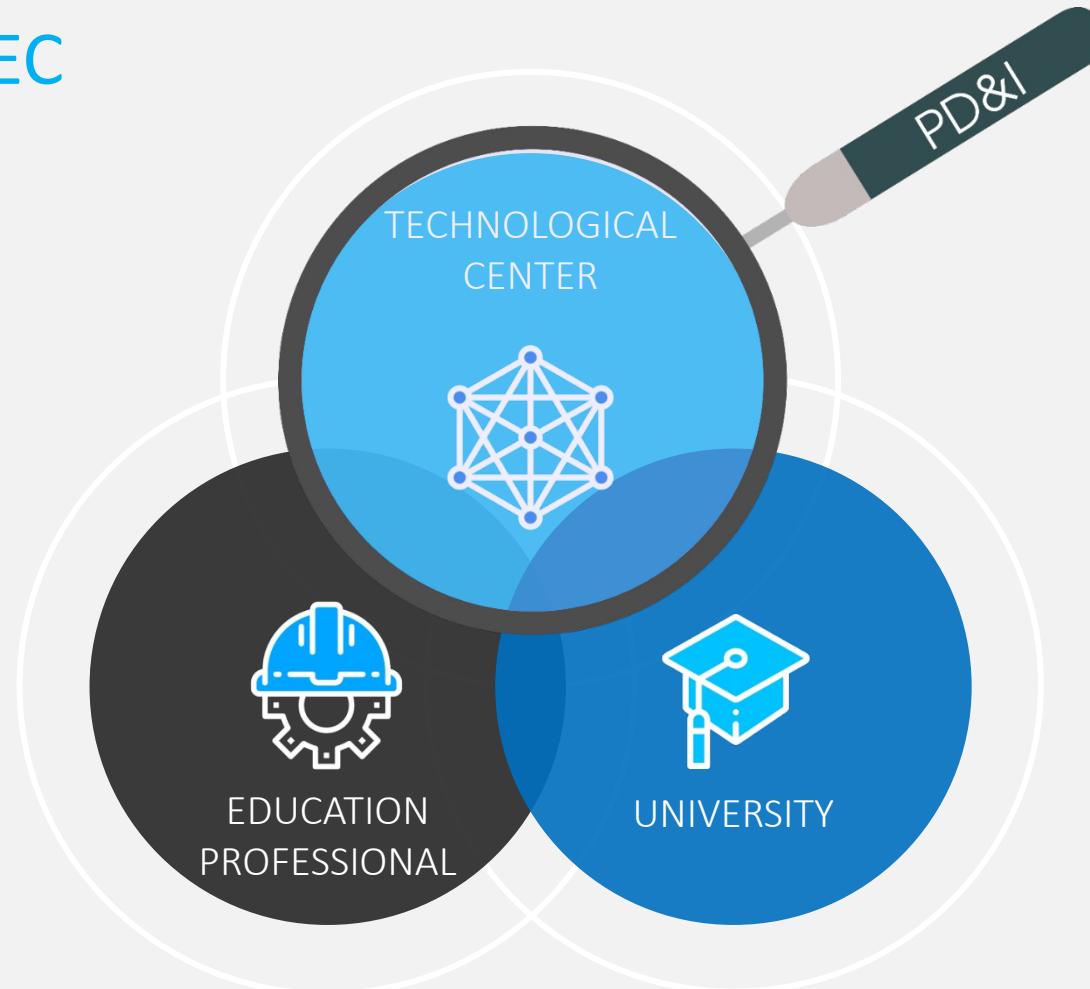
Engineers and Experts



31

Engineers in Training

New talents



Requests
in
Patents



**83 INPI
07 PCT/WIPO**



Record
in
Software



61



Record
in
Brand



37



Design
Industrial

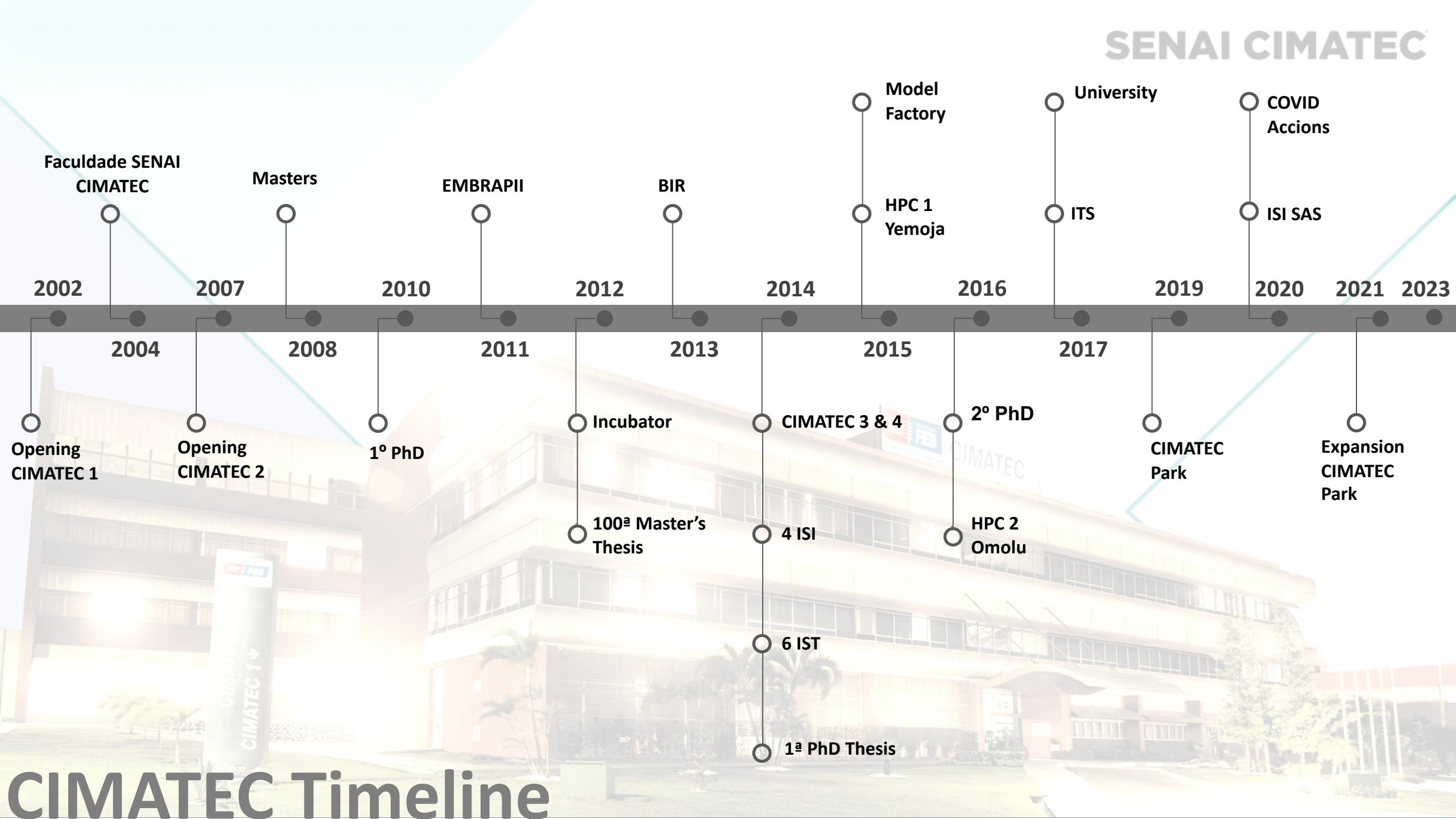


04

Total Assets
Property
Intellectual



192



Ecosystem CIMATEC

Entrepreneurship
and Innovation

ACELERA
CIMATEC

EMBRAPII



Partners
Industrial

McKinsey&Company

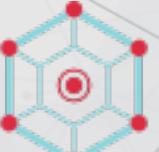


ISIs and ISTs

INSTITUTO SENAI
DE TECNOLOGIA

INSTITUTO SENAI
DE TECNOLOGIA

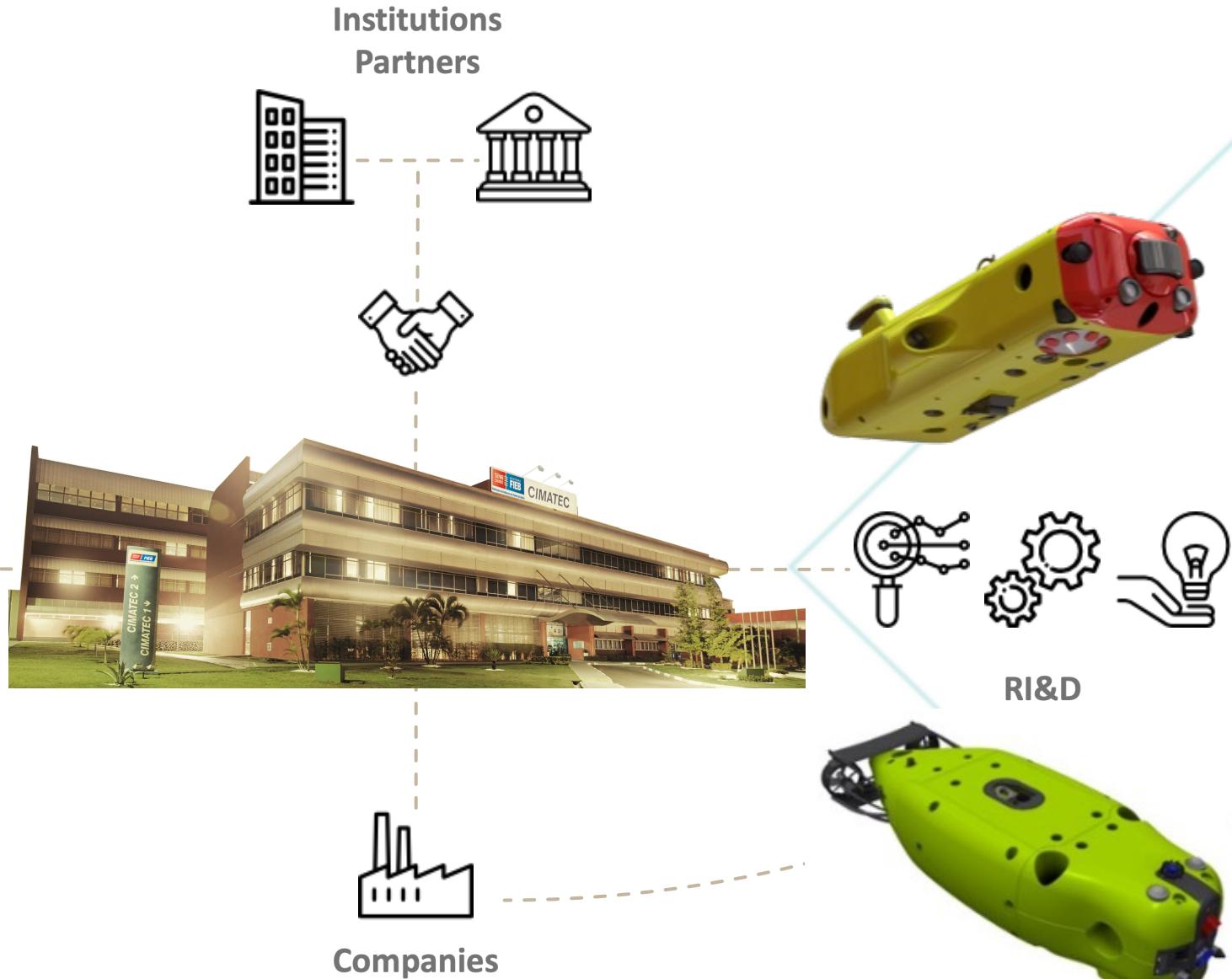
Technology
Centers



Areas of
Competence



RI&D - Operating Model



CIMATEC – Collaboration in the World

.TEC

.EDU

.ORG

.COM

International cooperation
for technology development

International academic
cooperation

Government cooperation
abroad

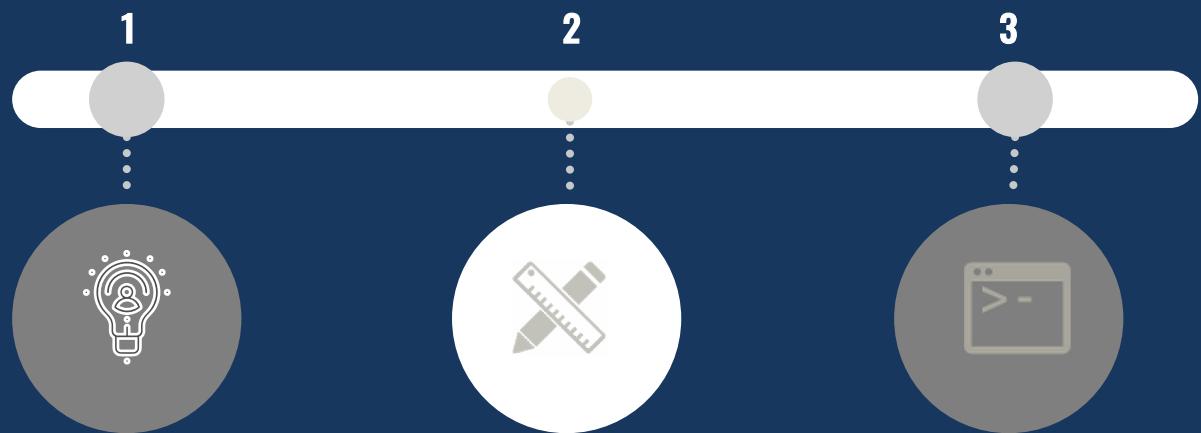
Support for Brazilian
industry abroad



HPC

Code Portability and Optimization

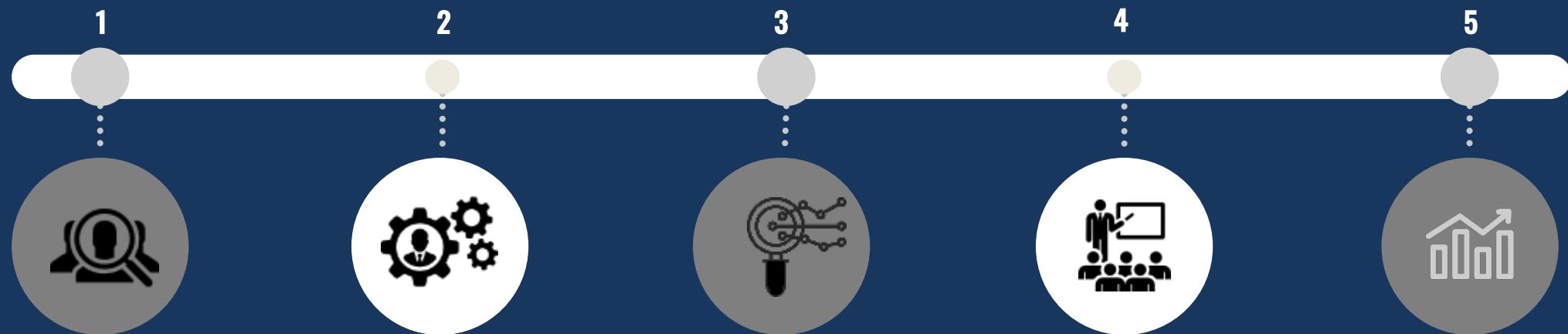
Methodology



**GEOPHYSICS
MODELING**

**MATHEMATICS
MODELING**

**COMPUTATIONAL
MODELING**



**APPLICATION
PERFORMANCE
ANALYSIS**

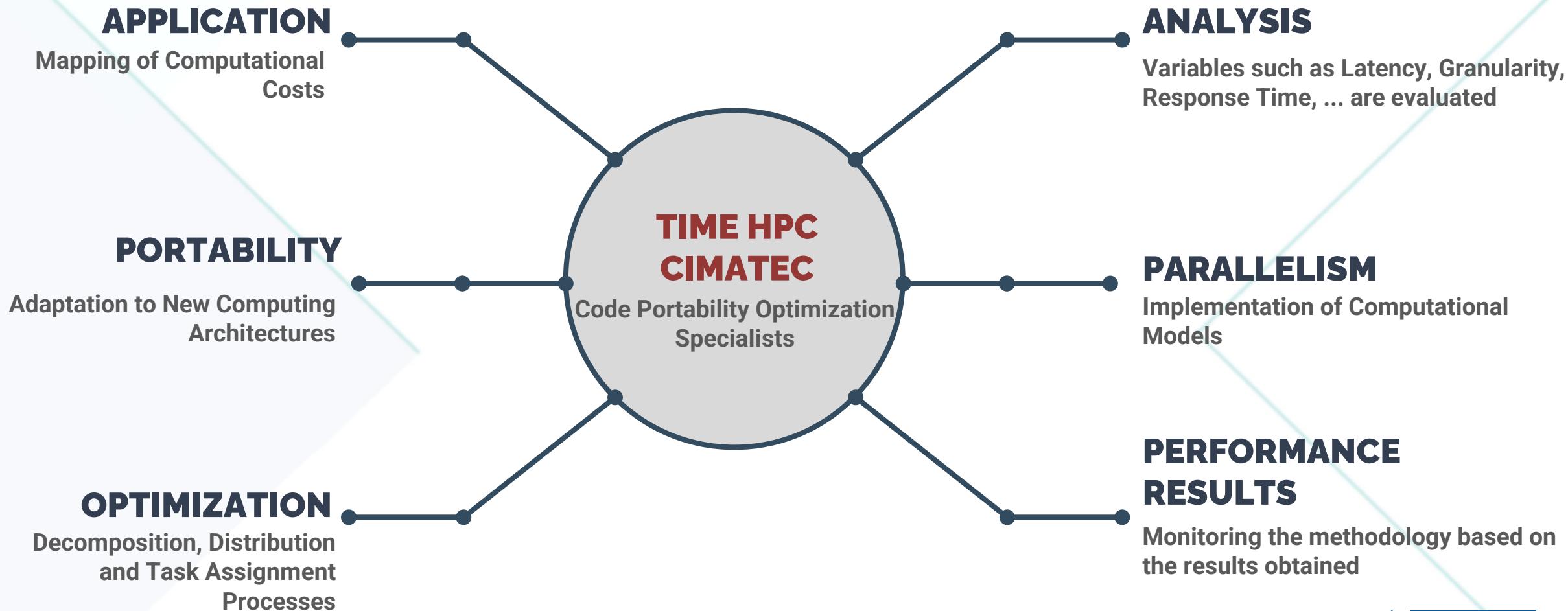
**DOMAIN SPLITTING
STRATEGIES**

**PARALLEL AND
DISTRIBUTED
SOLUTION DESIGN**

**PERFORMANCE
METRICS**

**RESULTS
ANALYSIS**

STRUCTURE



OPTIMIZATION TEAM



PETERSON NOGUEIRA
PhD in
Geophysics



MURILO BORATTO
Doutor em
Computação



LEONARDO FIALHO
Doutor em
Computação



MARCELO OLIVEIRA
Doutor em
Computação



OSCAR MOJICA
PhD in
Geophysics



PhDs



Masters



Experts



ÁTILA SARAIVA
Master in
Geophysics



LAIAN MOURA
Master in
Geophysics



VICTOR KOHENE
Master in
Geophysics



RODRIGO SANTANA
Master in
Geophysics



TIAGO CONCEIÇÃO
Master in
Computing Science



JOÃO SPEGLICH
Engineer
Computing



GUSTAVO COELHO
Engineer
Computing



GABRIEL PINHEIRO
Engineer
Computing

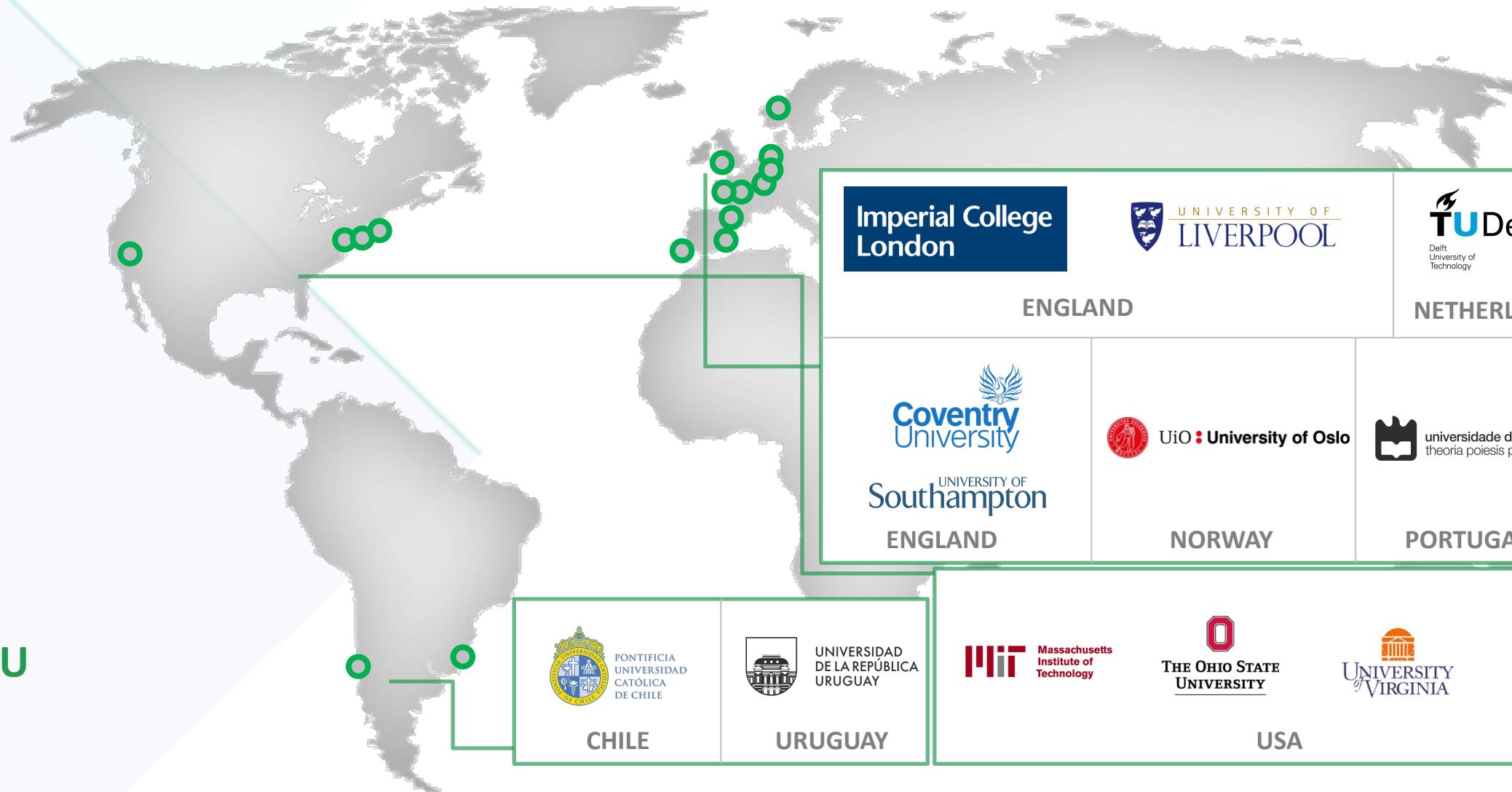


FILIPE MILANI
Engineer
Computing



MATHEU SANTOS
Engineer
Computing

CIMATEC – Collaboration in the World



CIMATEC – Collaboration in the World

**Fraunhofer****Helmholtz-Zentrum
Geesthacht**
Zentrum für Material- und Küstenforschung**DFK****RWTHAACHEN
UNIVERSITY**

GERMANY

**universidade de aveiro**
theoria poesis praxis**ineqi** driving innovation

PORTUGAL

TNO innovation
for life

NETHERLANDS

CiematCentro de Investigaciones
Energéticas, Medioambientales
y Tecnológicas

SPAIN

PONTIFICIA
UNIVERSIDAD
CATÓLICA DE CHILE

CHILE



URUGUAY

Massachusetts
Institute of
Technology**THE OHIO STATE
UNIVERSITY****UNIVERSITY
of VIRGINIA**

McKinsey&Company

**ELUCIDA**
RESEARCH
HARVARD MEDICAL SCHOOL

USA

SENAI CIMATEC Supercomputing Center



Sistema FIEB



PELO FUTURO DA INOVAÇÃO



QMS Certification Services



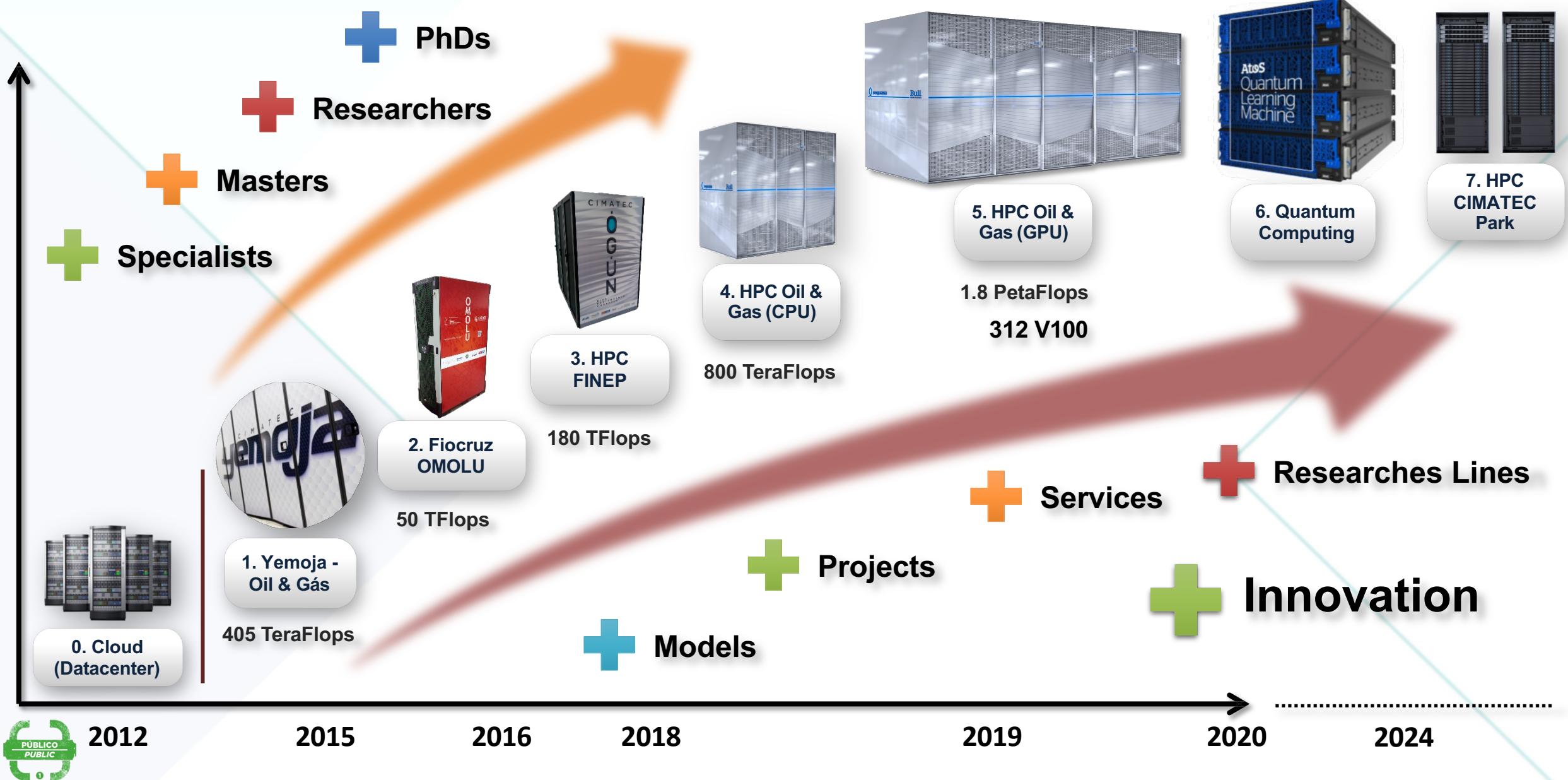


SENAI CIMATEC Supercomputing Center

SENAI CIMATEC



Supercomputing Center Timeline





COMPROMISSO COM INVESTIMENTO EM
PESQUISA & DESENVOLVIMENTO

HIGH PERFORMANCE COMPUTING

OGBON

SENAI CIMATEC - CENPES PETROBRAS



Sistema FIEB



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OGBON

BR PETROBRAS

Sistema FIEB



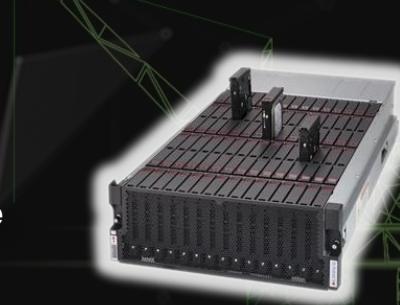
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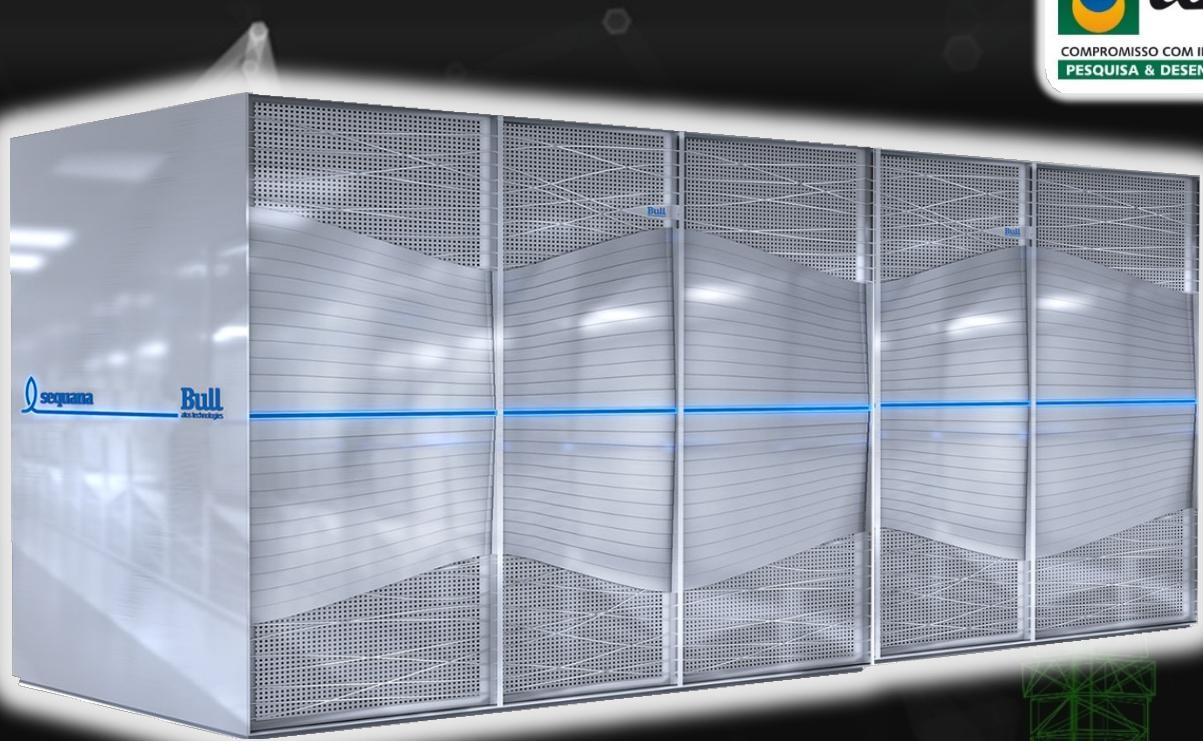
312 GPUs
78 Nodes
4 x NVIDIA V100 32 GB
1605 Peta Flops (RMAX)
384 GB RAM per node



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



100% Cool Water Technology
Direct Cooling at 5 Racks
1 PB Parallel Lustre
26 GB/s IOR
500 TB Storage
100 Gbps Infiniband
8 Login Nodes



Code Optimization Projects

CIMATEC

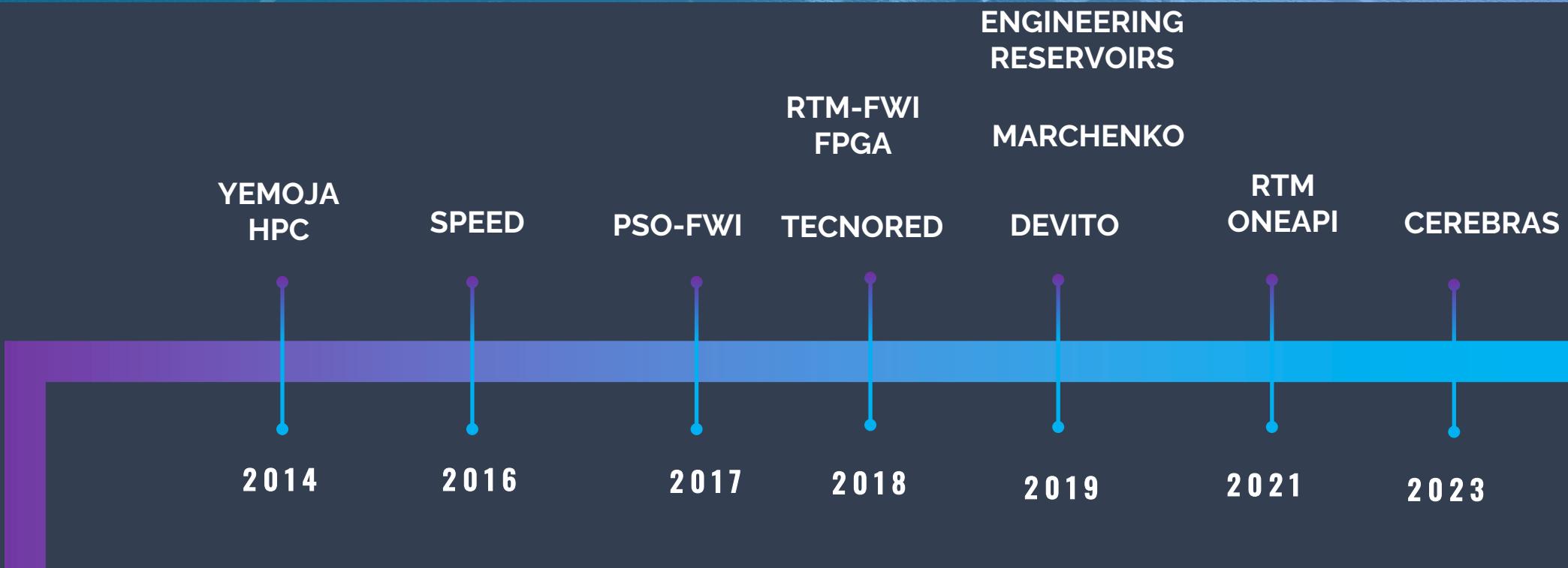
SENAI CIMATEC carries out research and development of complex projects, integrating them into customers' production systems.



Timeline HPC

Sistema FIEB

**SENAI
CIMATEC**
PELO FUTURO DA INOVAÇÃO



PROJECT

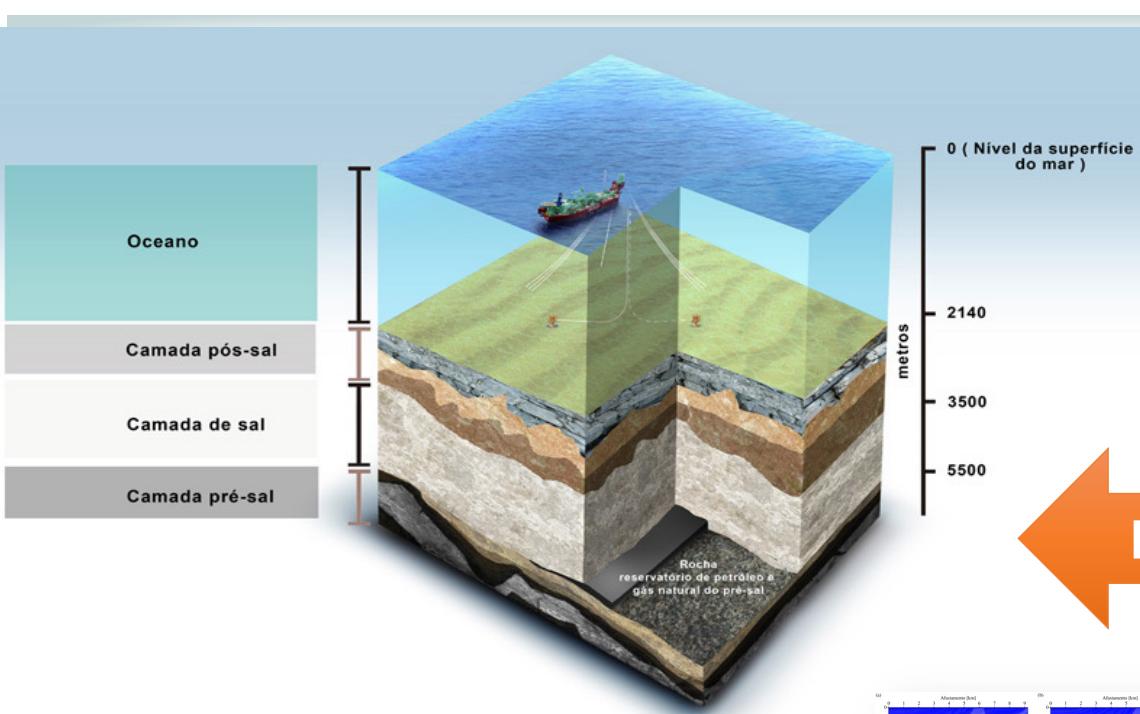
YEMOJA

HPC

GOAL

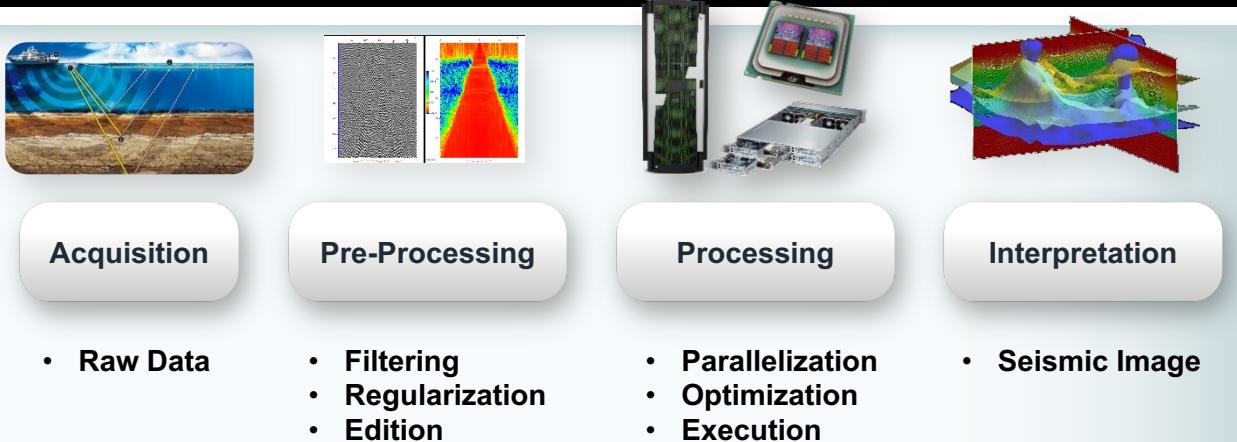
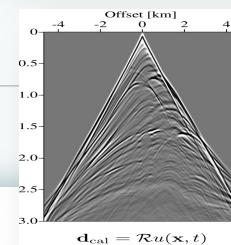
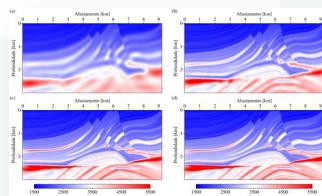
The first project of the SENAI CIMATEC supercomputing center aimed to process images of the Brazilian pre-salt oil reserve layer. And only through the processing of seismic imaging of this layer was it possible to measure the values of barrels of oil produced.

PROJECT YEMOJA HPC



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

Sistema FIEB

SENAI
CIMATEC

PELO FUTURO DA INOVAÇÃO

PROJECT

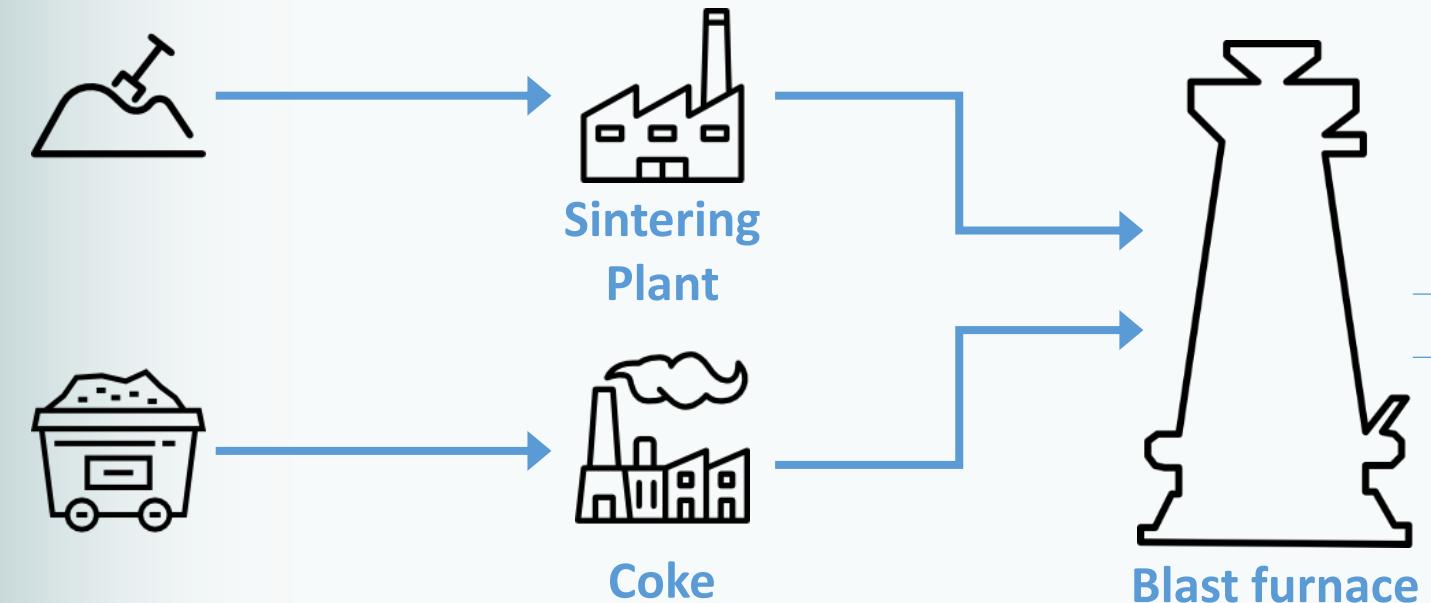
TecnoRed-CFD

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

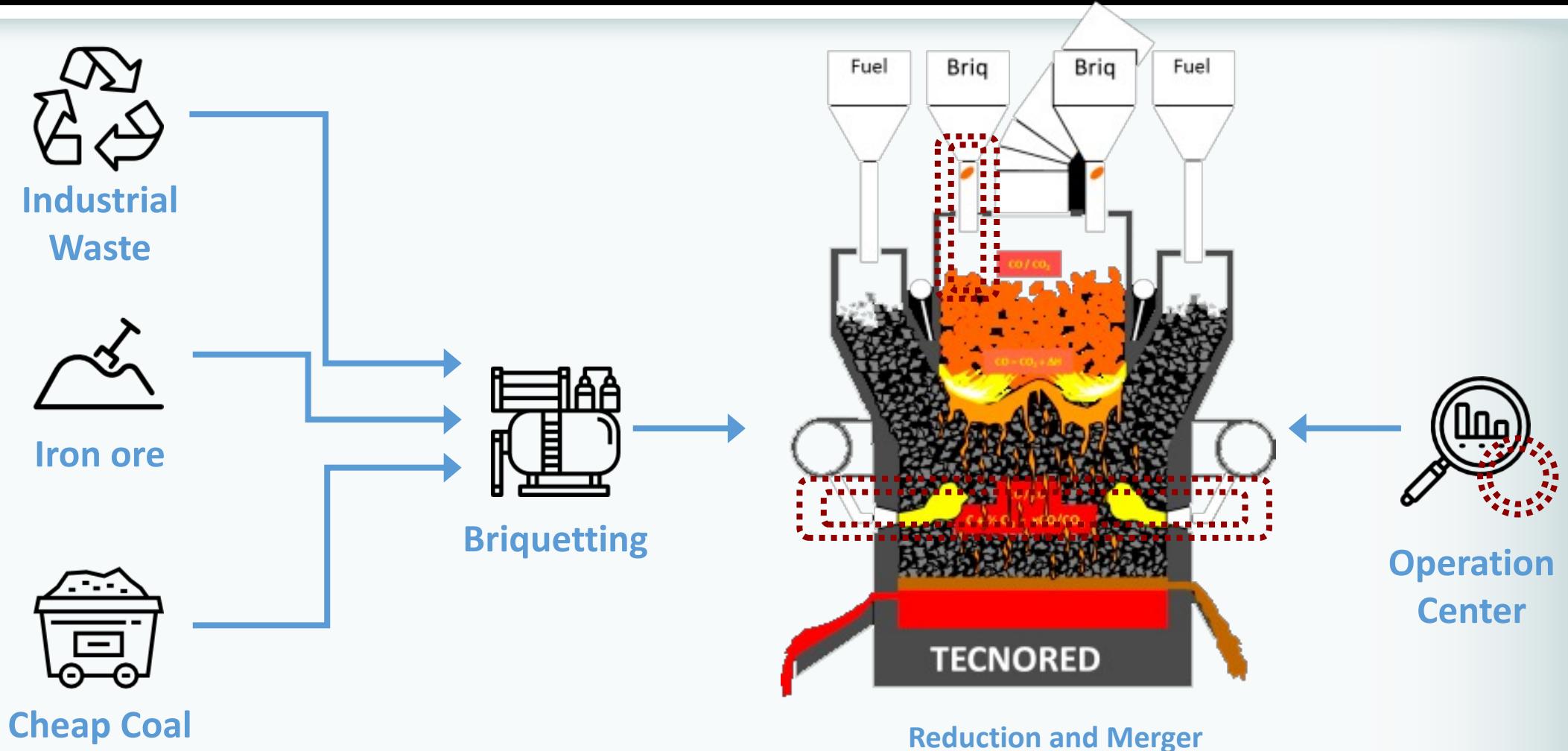
CONVENTIONAL REDUCTION PROCESS



CO₂ Emission		2 ton / ton steel
Implementation and operation cost		
Iron specifications		
Process duration		8h
Inputs		Expensive and complex
Performance		

Sistema FIEB

PROJECT TecnoRed-CFD



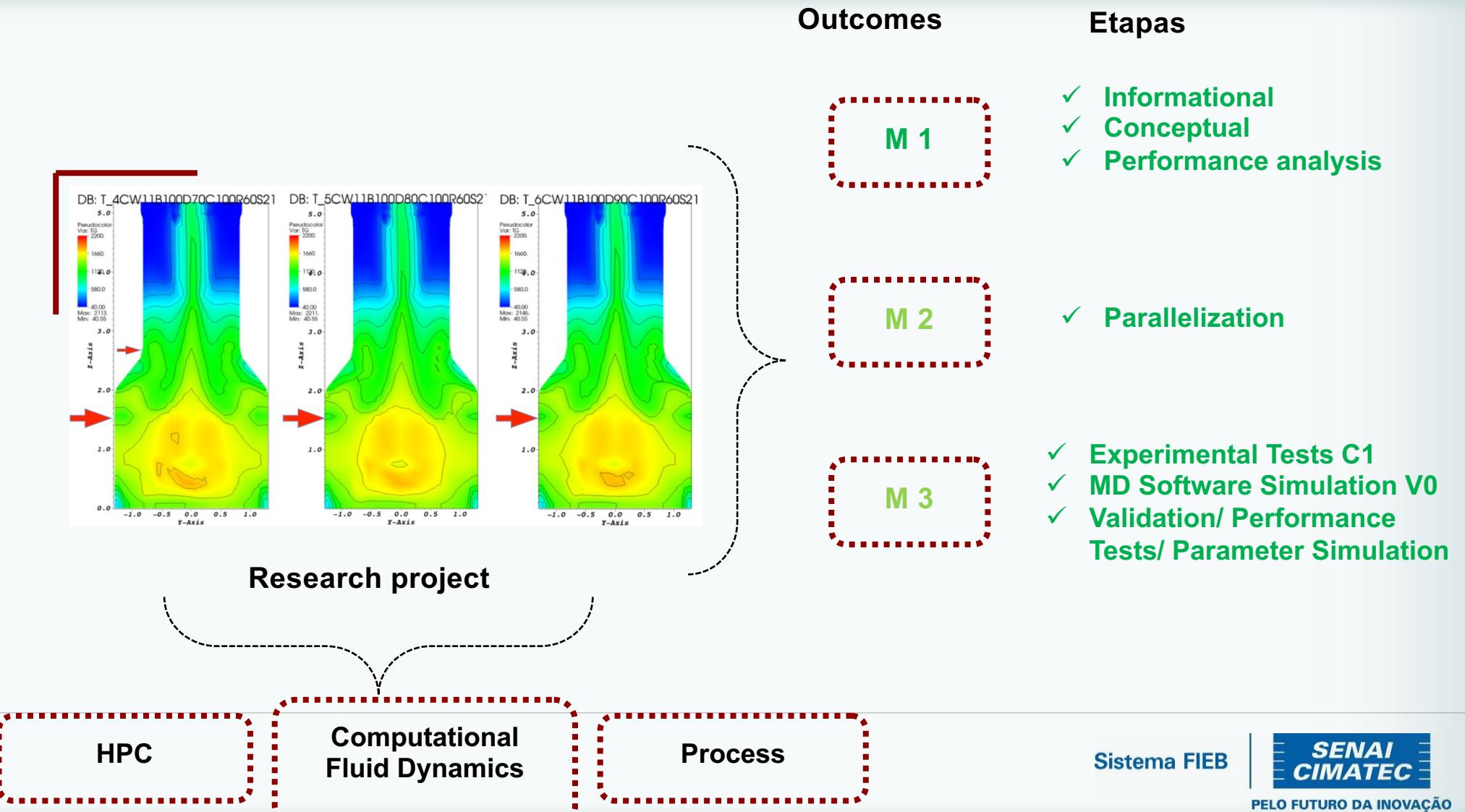
Processing of Fuel and Self-Reducing Briquettes

Sistema FIEB

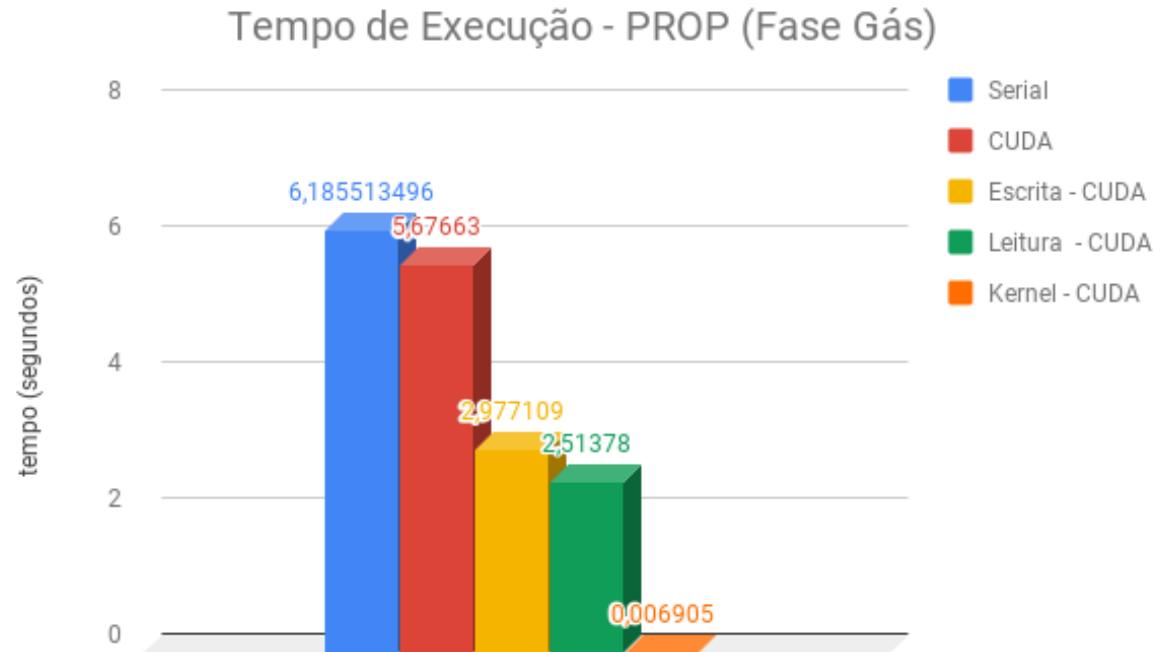
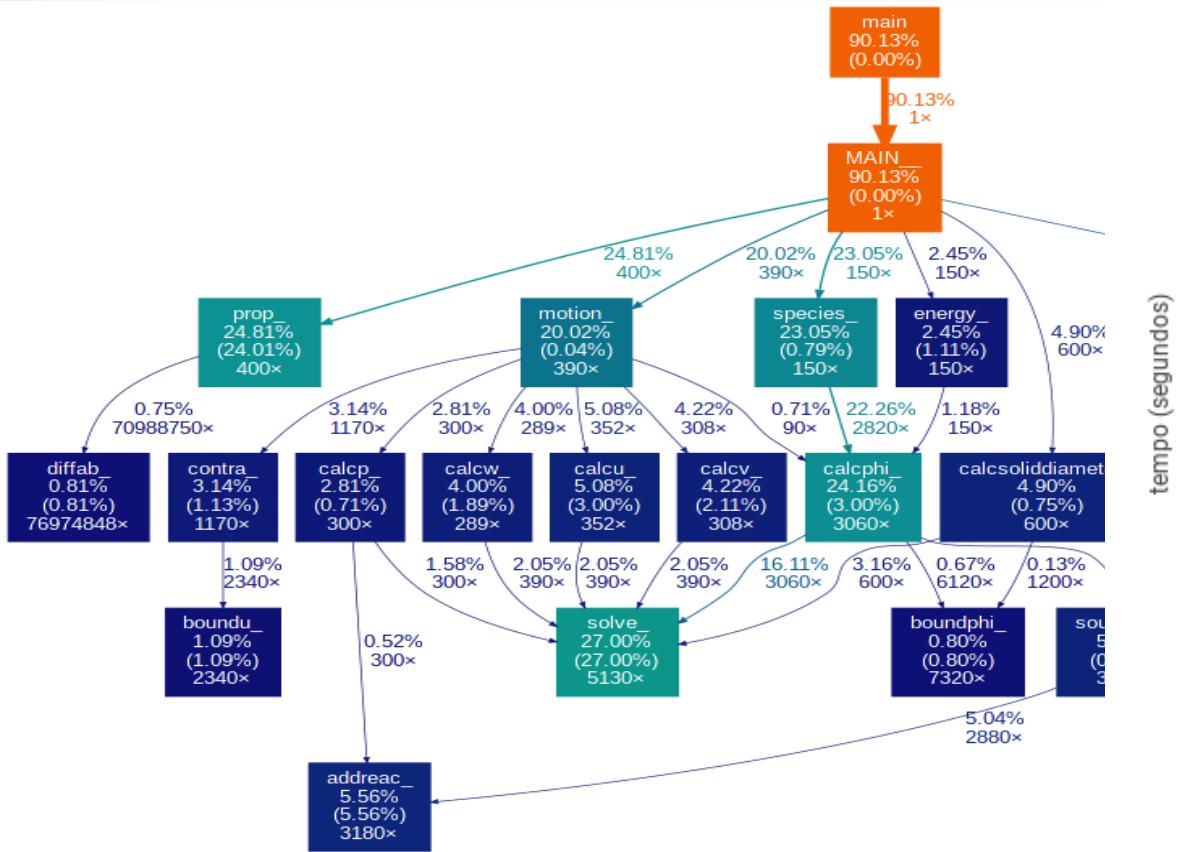
SENAI
CIMATEC

PELO FUTURO DA INOVAÇÃO

PROJECT TecnoRed-CFD



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

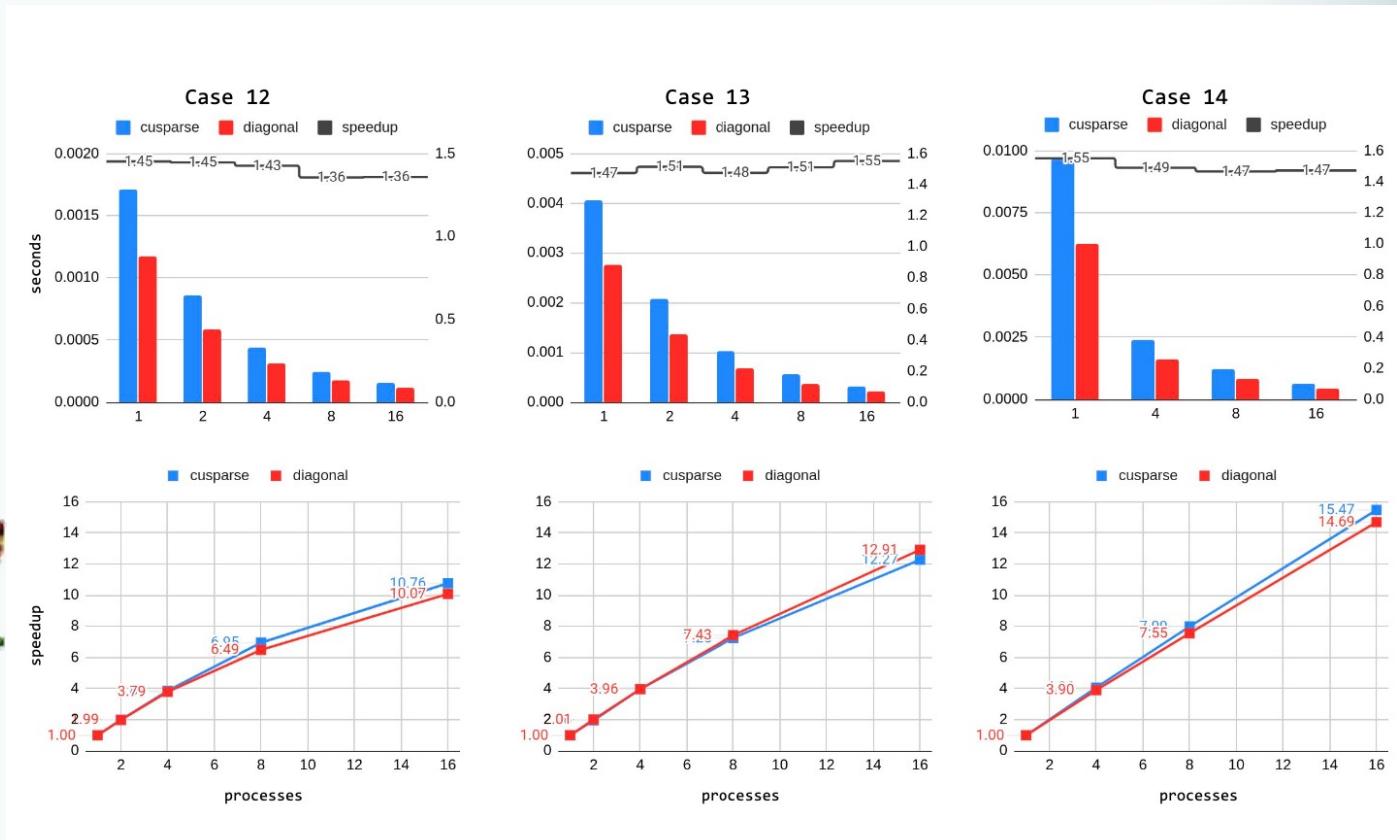
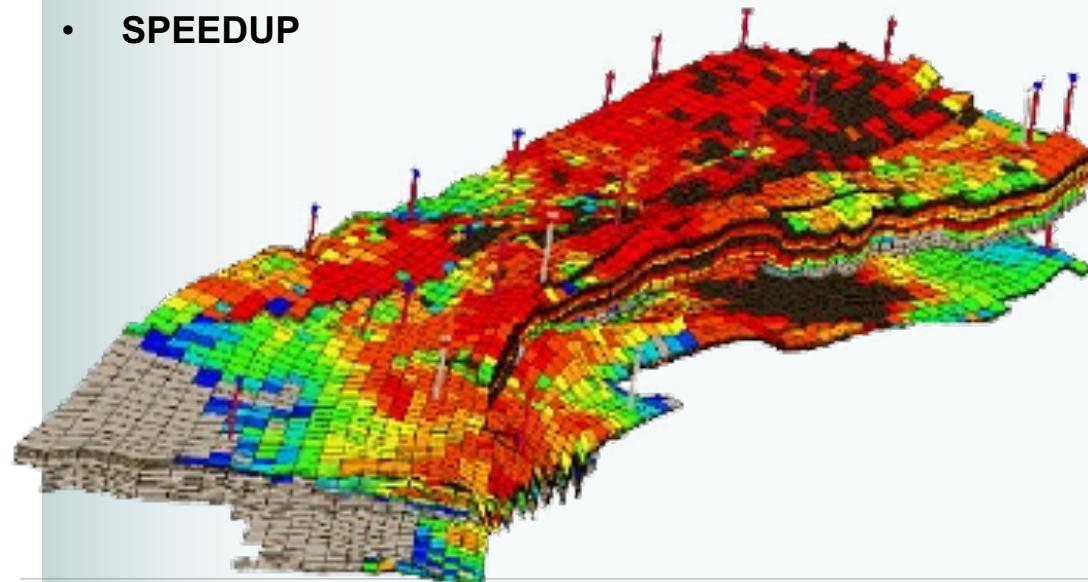
- SOLVERBR

Performance Analysis

- PETSc

Performance Metrics

- SPEEDUP



PROJECT

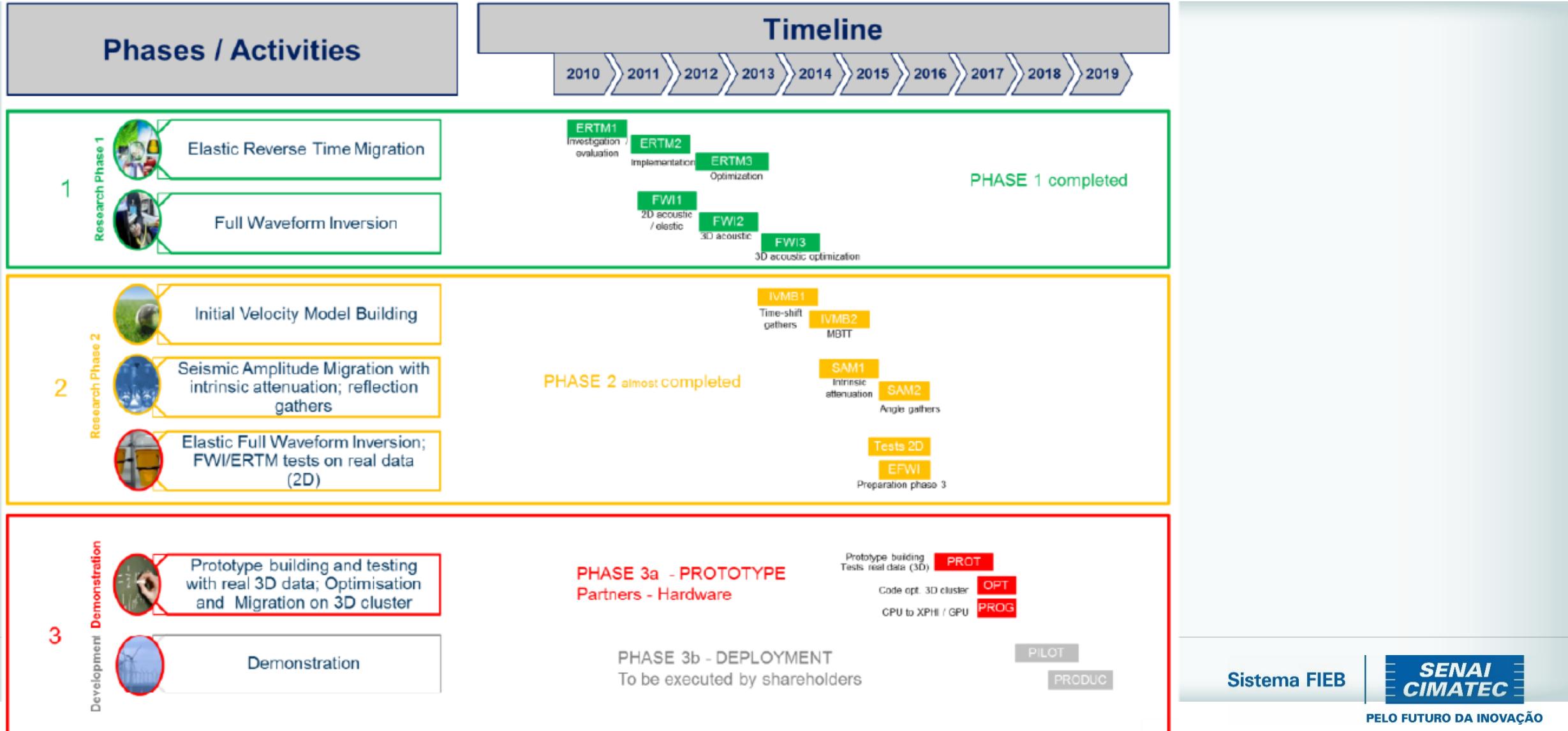
SPEED

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



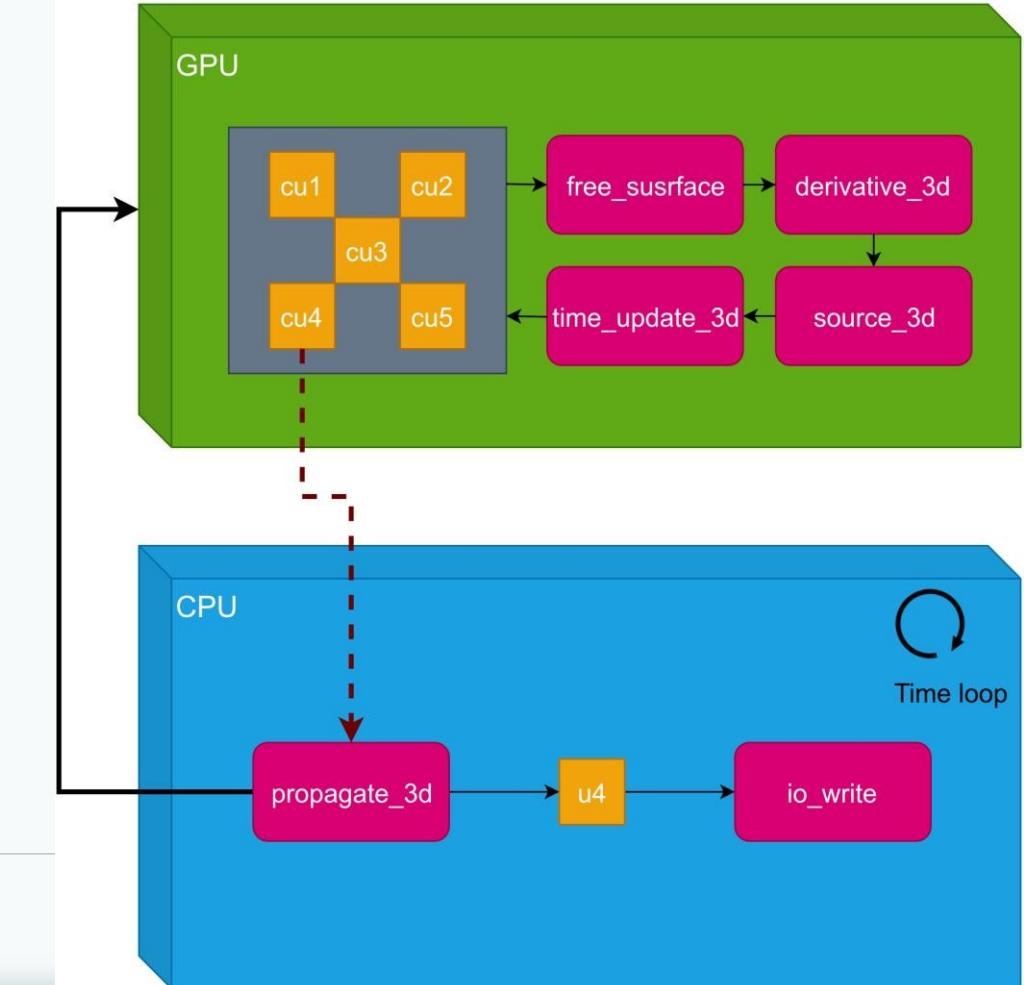
PROJECT

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

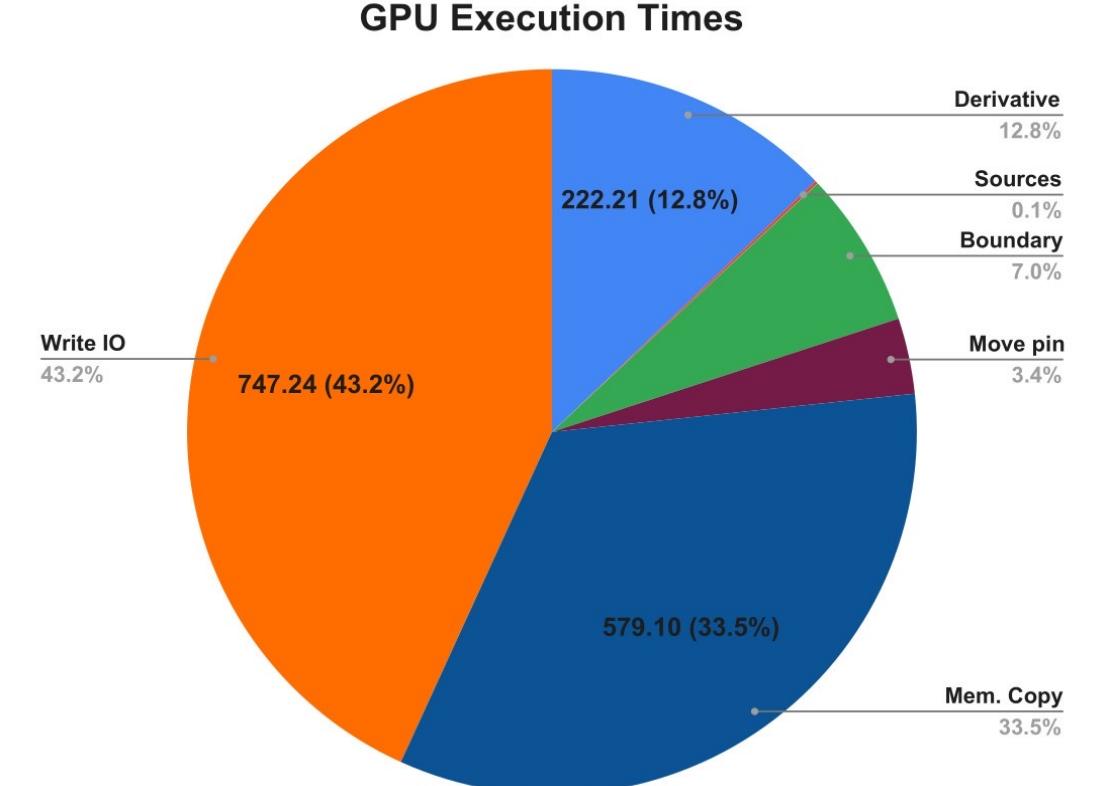
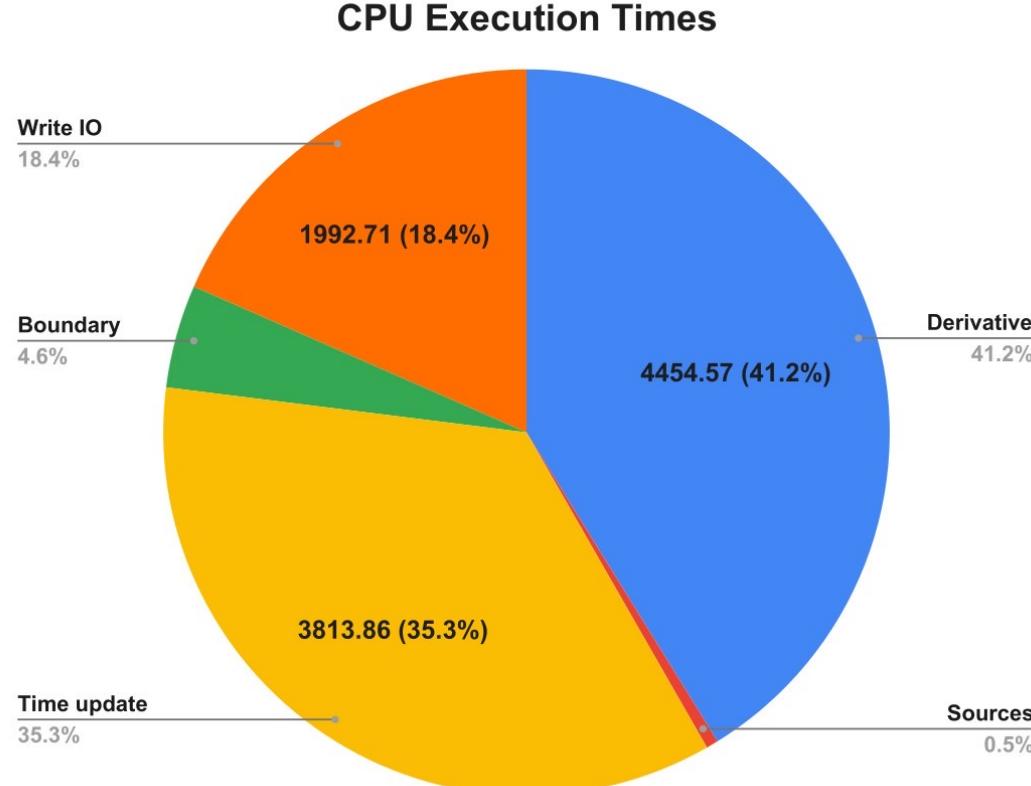
- The implementation of other kernels made it possible for the temporal loop to be done within the GPU;
- Development of methods to improve the relationship between host-device communication for data transfer and model computation time;
- The **u[1-5]** structures are now inside the GPU.



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

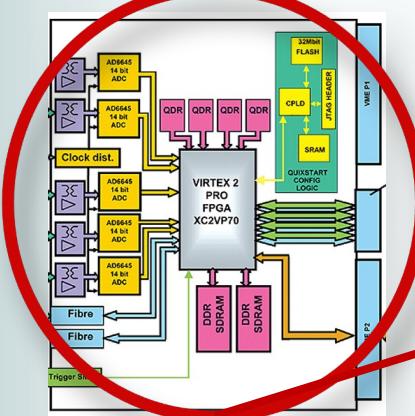
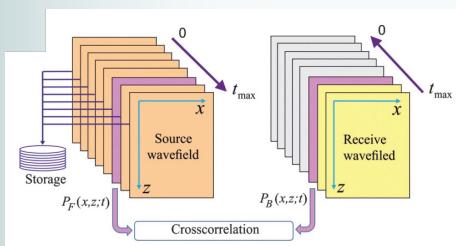
RTM-FWI FPGA

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

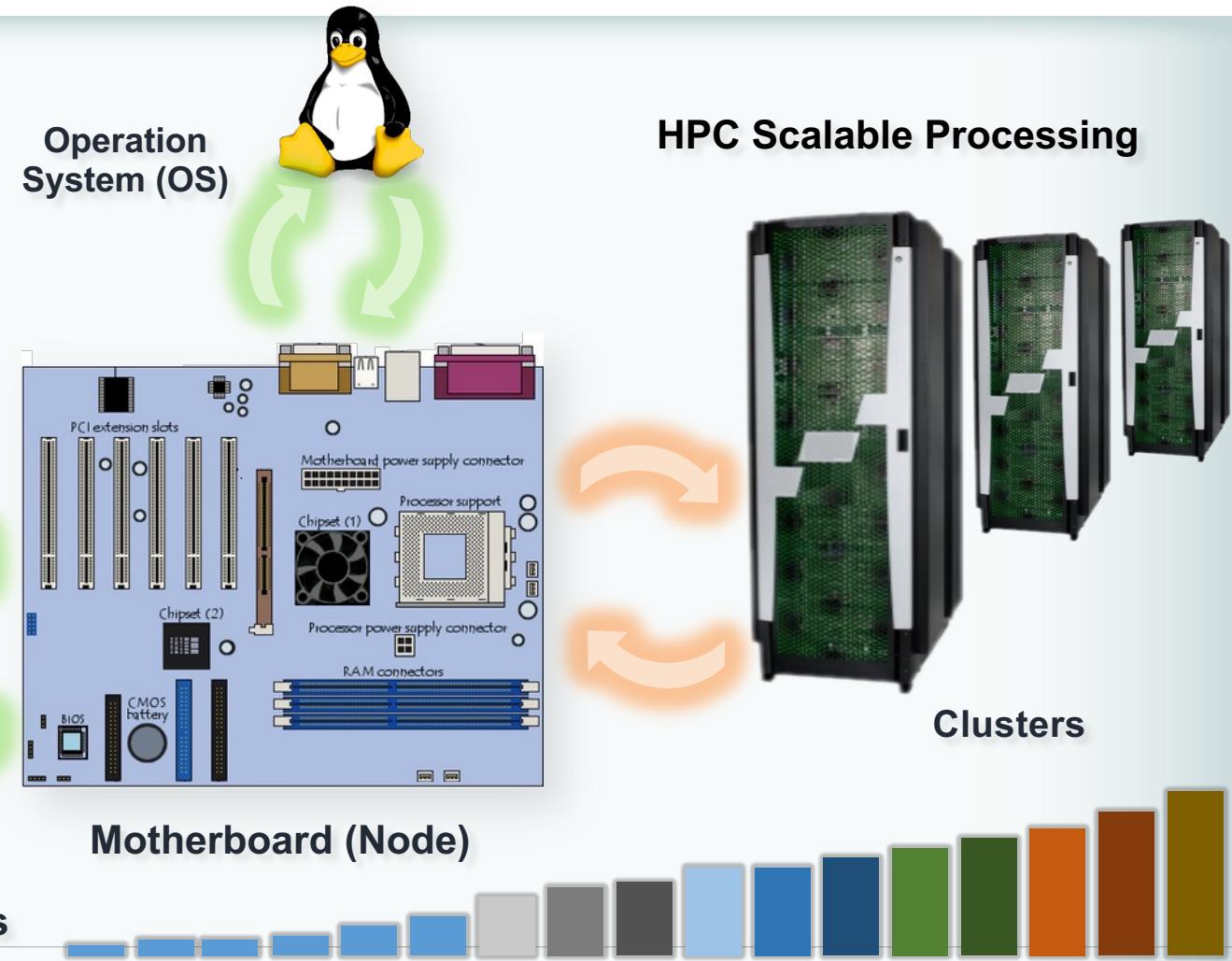


Seismic Co-Processor



FPGA

PCI-Express



Sistema FIEB

SENAI
CIMATEC

PELO FUTURO DA INOVAÇÃO

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.

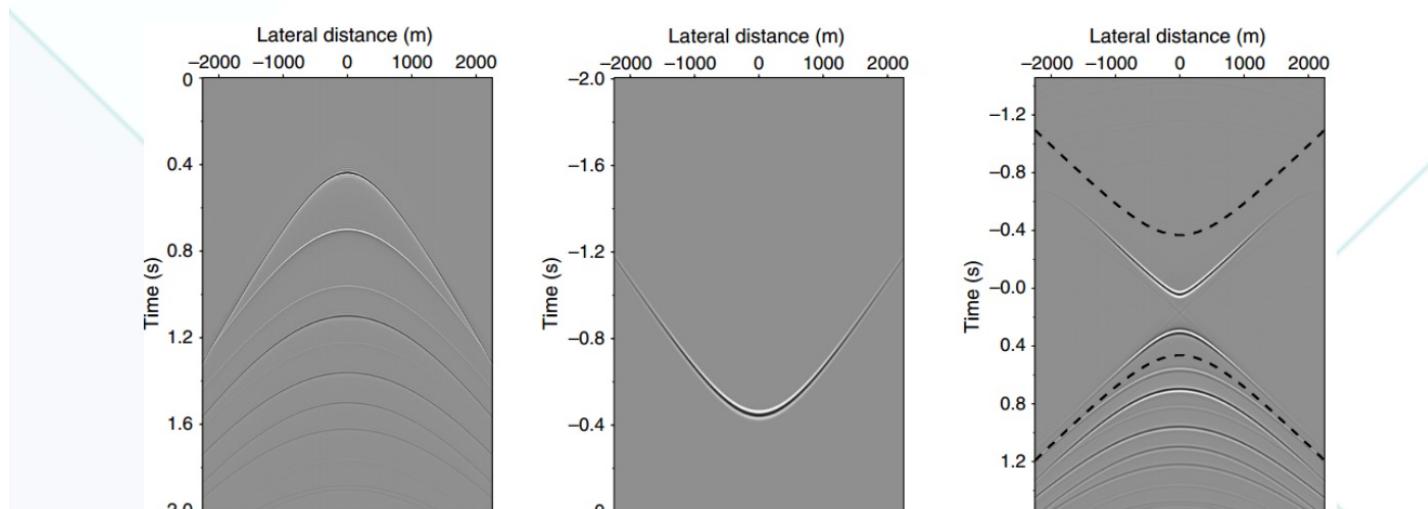
PROJECT

Marchenko Imaging

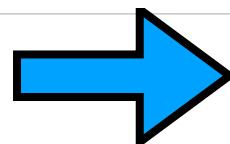
What is the Marchenko Method?

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):



$$\theta_t \int_{\partial D_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') N_{i-1}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x} = N_i(\mathbf{x}_R, \mathbf{x}_F, -t)$$



1. Marchenko imaging on real 2D/3D data
2. 2D/3D multiple attenuation and removal

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

$$N_i(\mathbf{x}_R, \mathbf{x}_F, -t) = \theta_t \int_{\partial D_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') N_{i-1}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

Paso 1

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

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

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

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

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

Paso 2

$$G(\mathbf{x}_R, \mathbf{x}_F, t) = f_2(\mathbf{x}, \mathbf{x}_F, -t) + \theta_t \int_{\partial D_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') f_2(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

$$G_{min}(\mathbf{x}_R, \mathbf{x}_F, t) = -f_{1min}(\mathbf{x}, \mathbf{x}_F, t) + \theta_t \int_{\partial D_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') f_{1plus}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

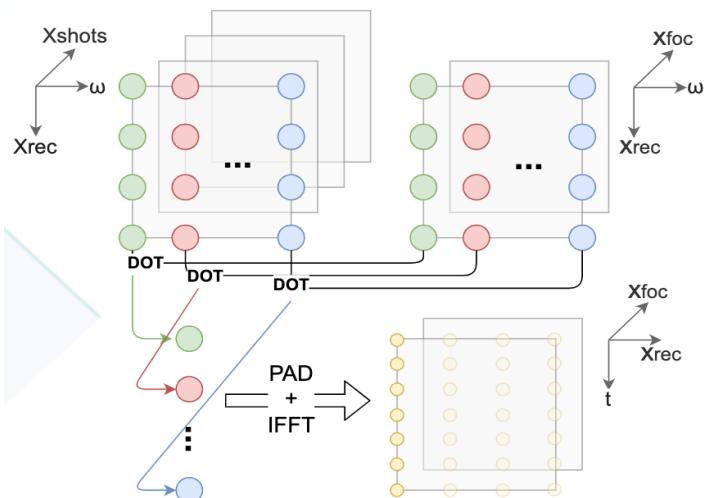
$$G_{plus}(\mathbf{x}_R, \mathbf{x}_F, t) = f_{1plus}(\mathbf{x}, \mathbf{x}_F, -t) - \theta_t \int_{\partial D_0} \int_{t'} R(\mathbf{x}_R, \mathbf{x}, t - t') f_{1min}(\mathbf{x}, \mathbf{x}_F, t') dt' d\mathbf{x}$$

Imageamento

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

or

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

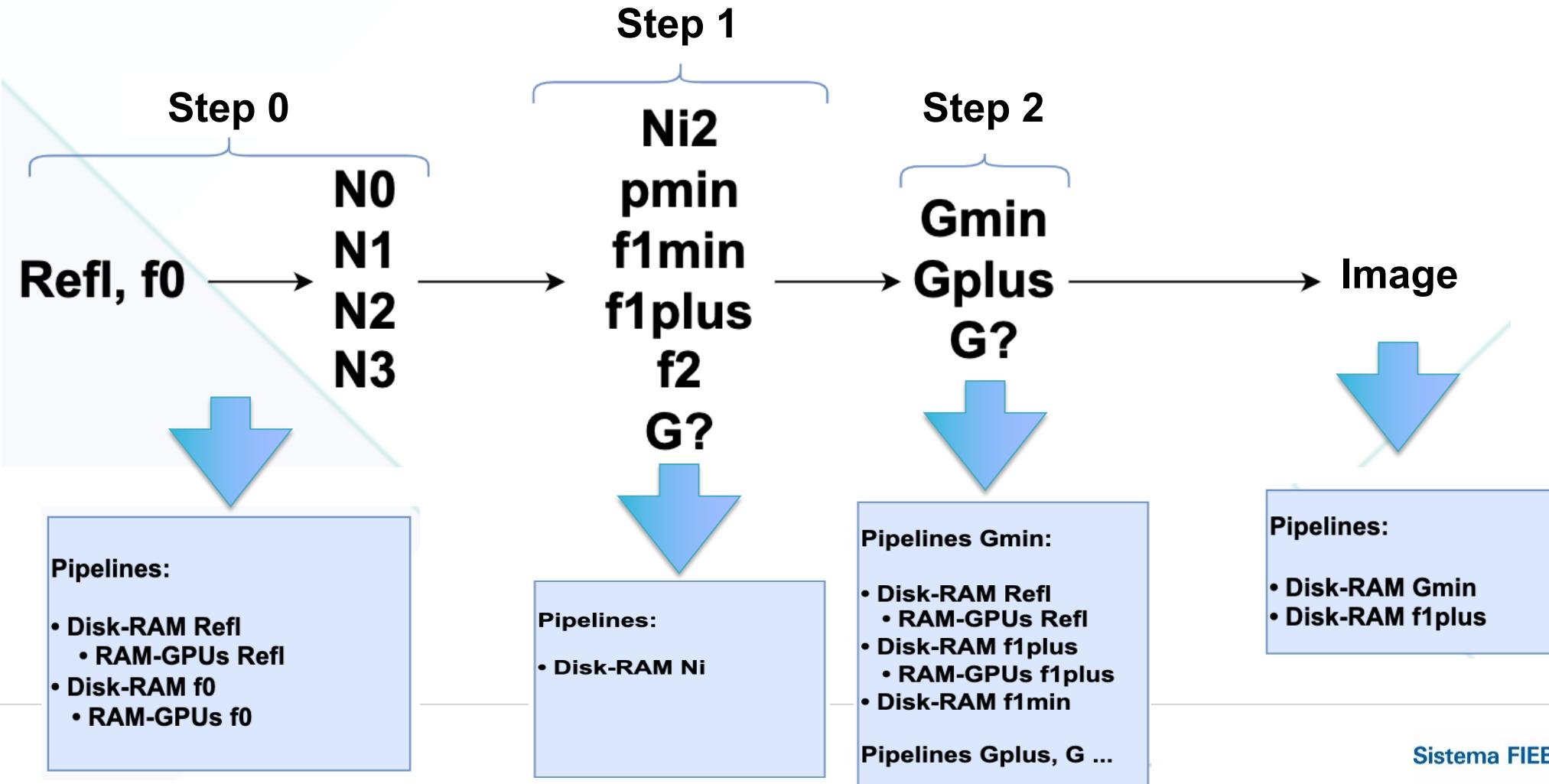


Kernel
cross-correlação

Sistema FIEB

PROJECT Marchenko Imaging

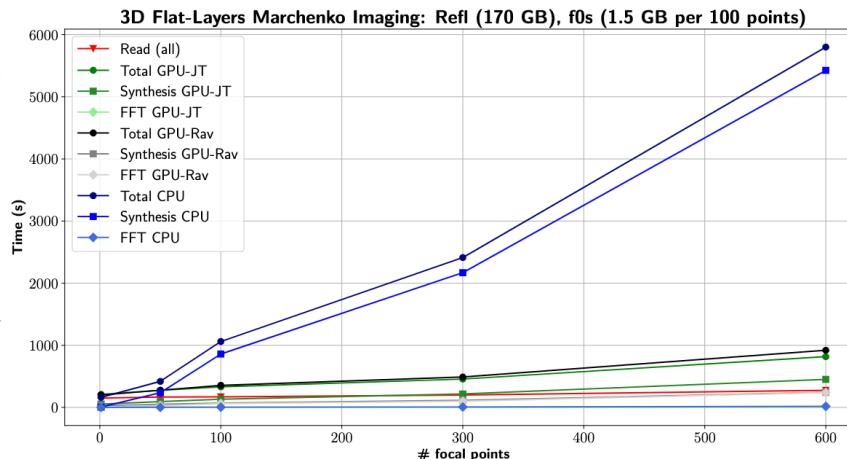
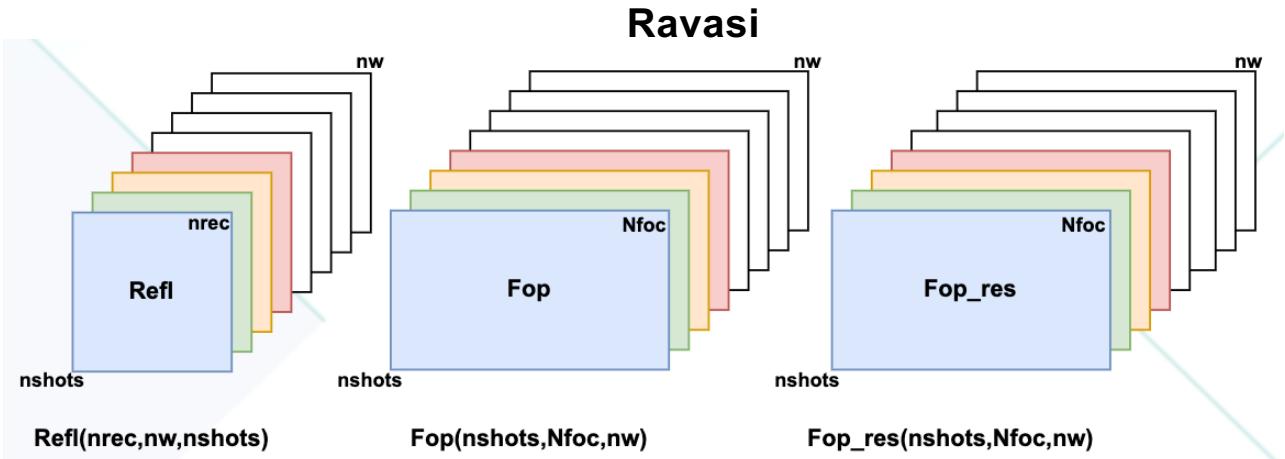
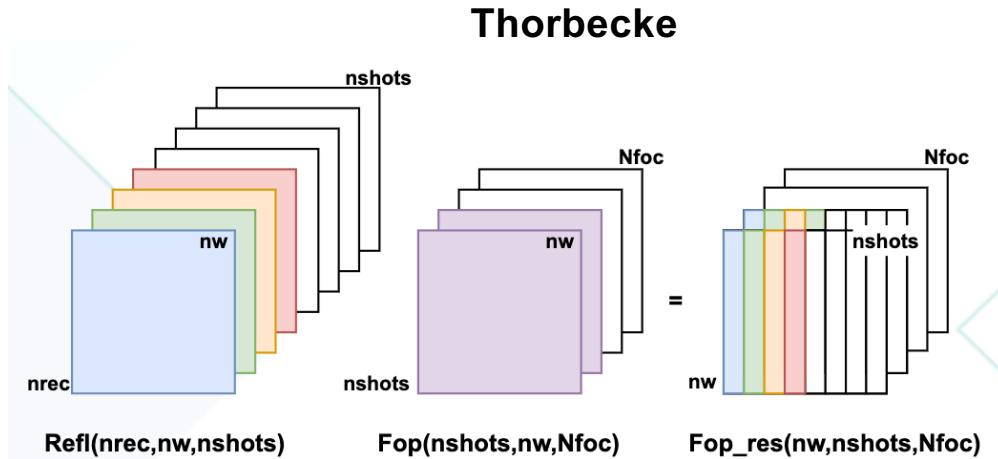
Pipelines on GPU



PROJECT

Marchenko Imaging

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



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): $201 \times 61 = 1261$ shots/receptors, 286 frequencies, total 170GB;

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

Sistema FIEB

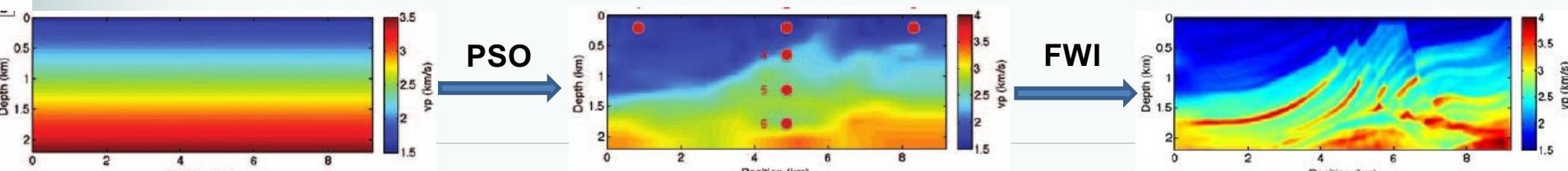
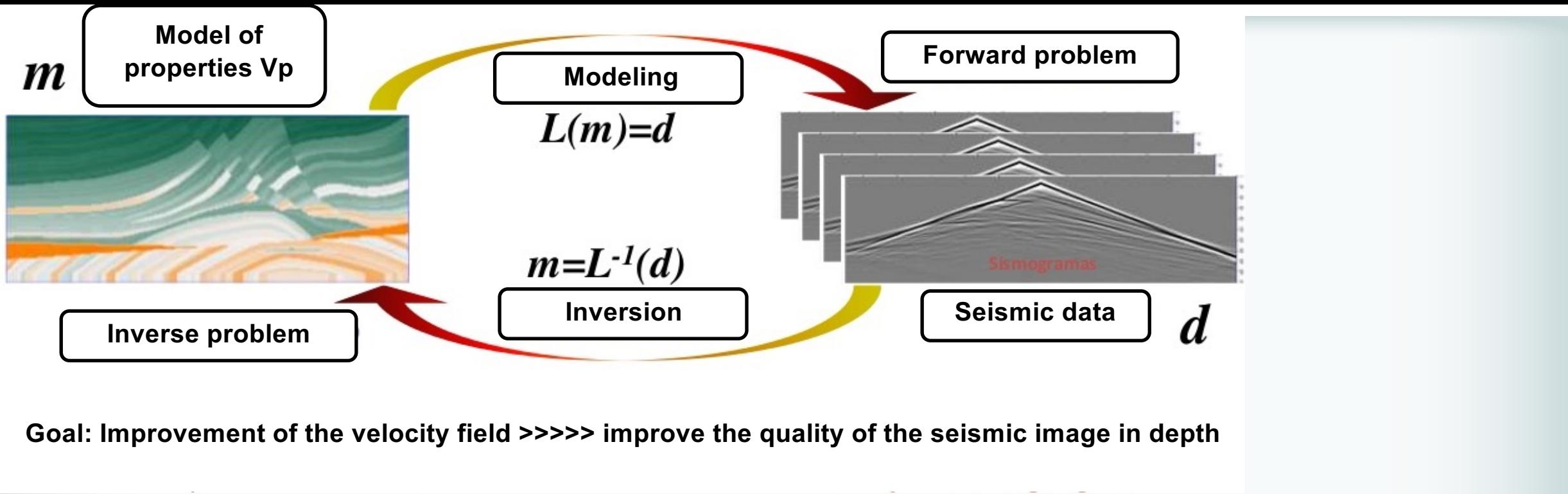
PROJECT

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



Higher resolution

Sistema FIEB

SENAI
CIMATEC

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PROJECT

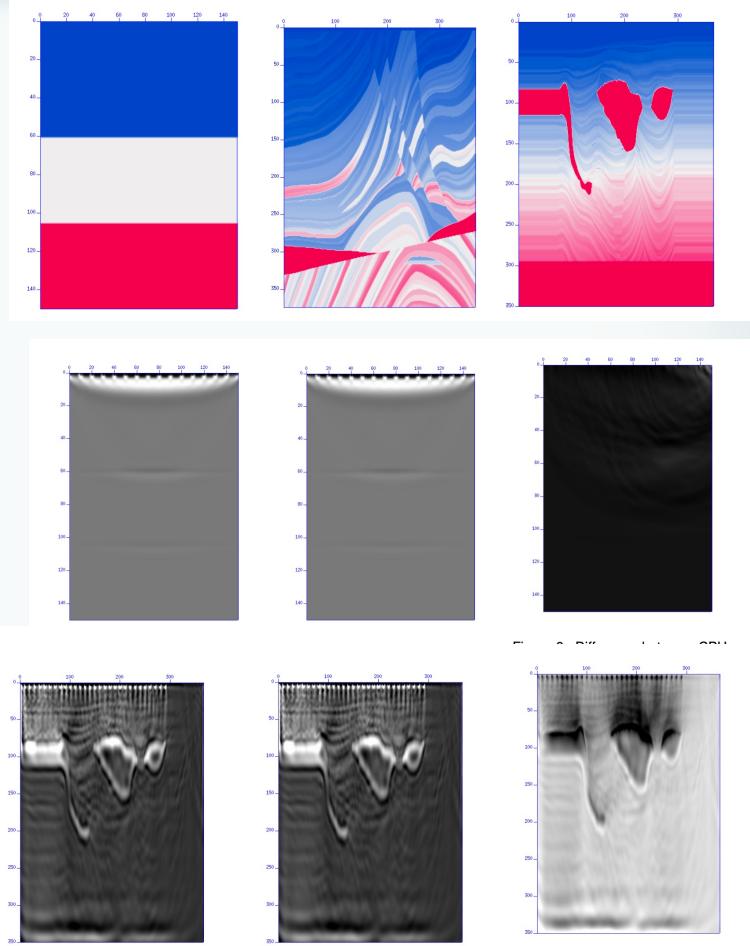
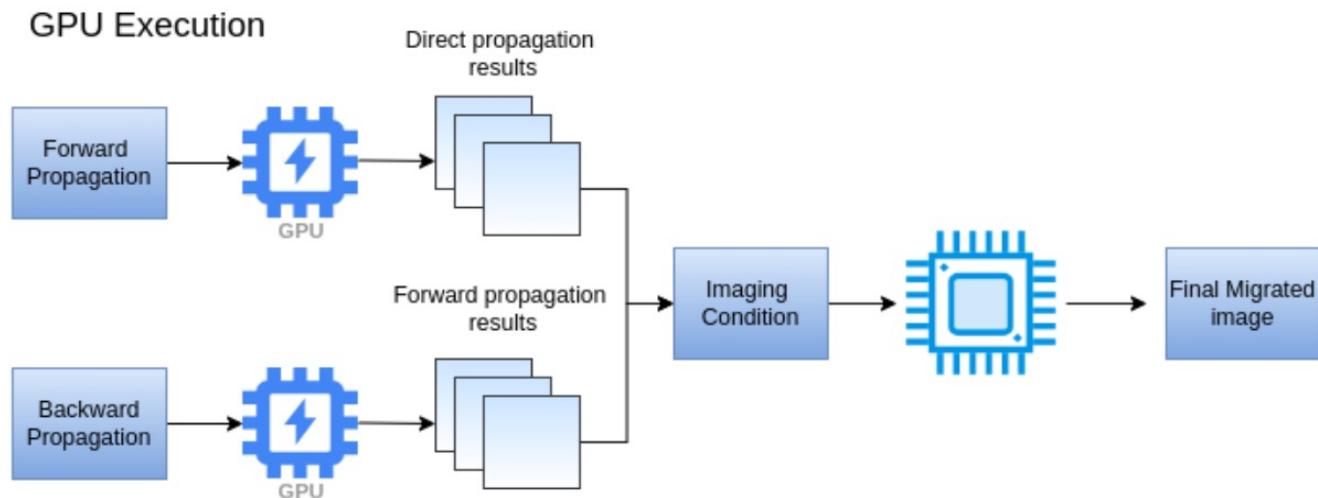
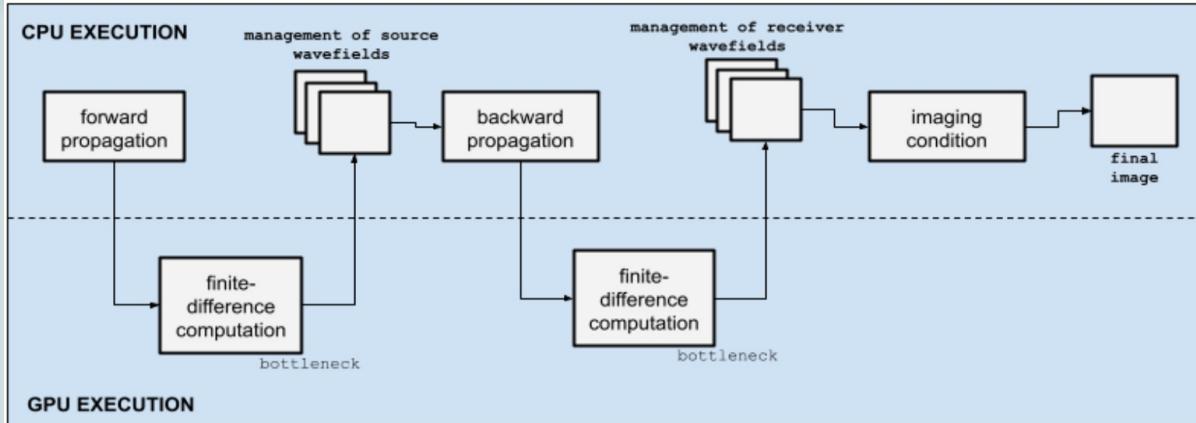
RTM OneAPI

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.

Sistema FIEB

SENAI
CIMATEC

PELO FUTURO DA INOVAÇÃO

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

Sistema FIEB



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