Towards an Efficient and Reliable HPC Software Platform for 3D Geophysical Inversion*

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Search and Discovery Article #70238 (2017)**
Posted March 27, 2017

*Adapted from oral presentation given at AAPG/SEG International Conference and Exhibition, Barcelona, Spain, April 3-6, 2016

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Abstract

The inversion process is one of the most important and complex processes in subsurface exploration. Even if usually the theoretical methods are well known and prototyping is not a painful issue, the reality is that the oil and gas industry requires a huge amount of computational resources to solve those problems. Therefore, software able to manage and provide enough capabilities to deal with 3D inversion in a High Performance Computing (HPC) environment is of outmost importance. Furthermore, defining specific software for each process such as Full Waveform Inversion (FWI) or Electromagnetic Inversion (EMI) independently is too costly and the maintenance and porting of such codes unaffordable. Furthermore, the upcoming joint inversion algorithms will need similarly capable seismic and EM inversion tools.

In this work we propose using two software frameworks that provide HPC developers with tools oriented towards efficiency and resiliency, respectively. The efficiency-oriented framework automatically provides the developer with parallel strategies, such as domain decomposition or asynchronous disk I/O so that the developer can concentrate on writing the algorithm specific to the problem at hand. At the same time, the framework structure simplifies the portability of the code to different HPC architectures. On the other hand, the resiliency-oriented framework provides the developer with the means to launch parallel applications in a distributed environment with full support to fault tolerance.

As an example, we show a whole geophysical imaging system called BSIT, which is built upon the usage of such frameworks and some additional supporting modules. In particular, BSIT's wave propagation libraries have been developed using the efficiency-oriented framework and ported to many HPC platforms and its master-worker parallelism and distributed workflows have been built using the resiliency-oriented framework and are able to sustain large workflow tasks in a robust and scalable way.

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BSIT

An HPC platform for 3d geophysical inversion

Juan Esteban Rodríguez

REPSOL

HPC

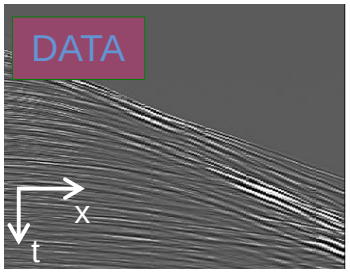
Barcelona, April 6, 2016

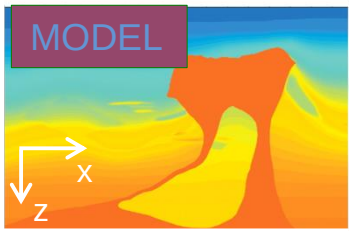
Motivation

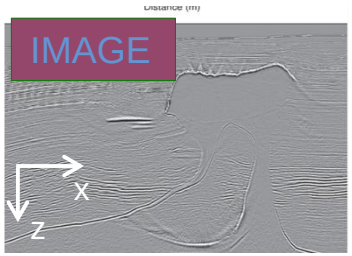
Large **seismic simulations** on HPC environments require dealing with a large amount of computational resources

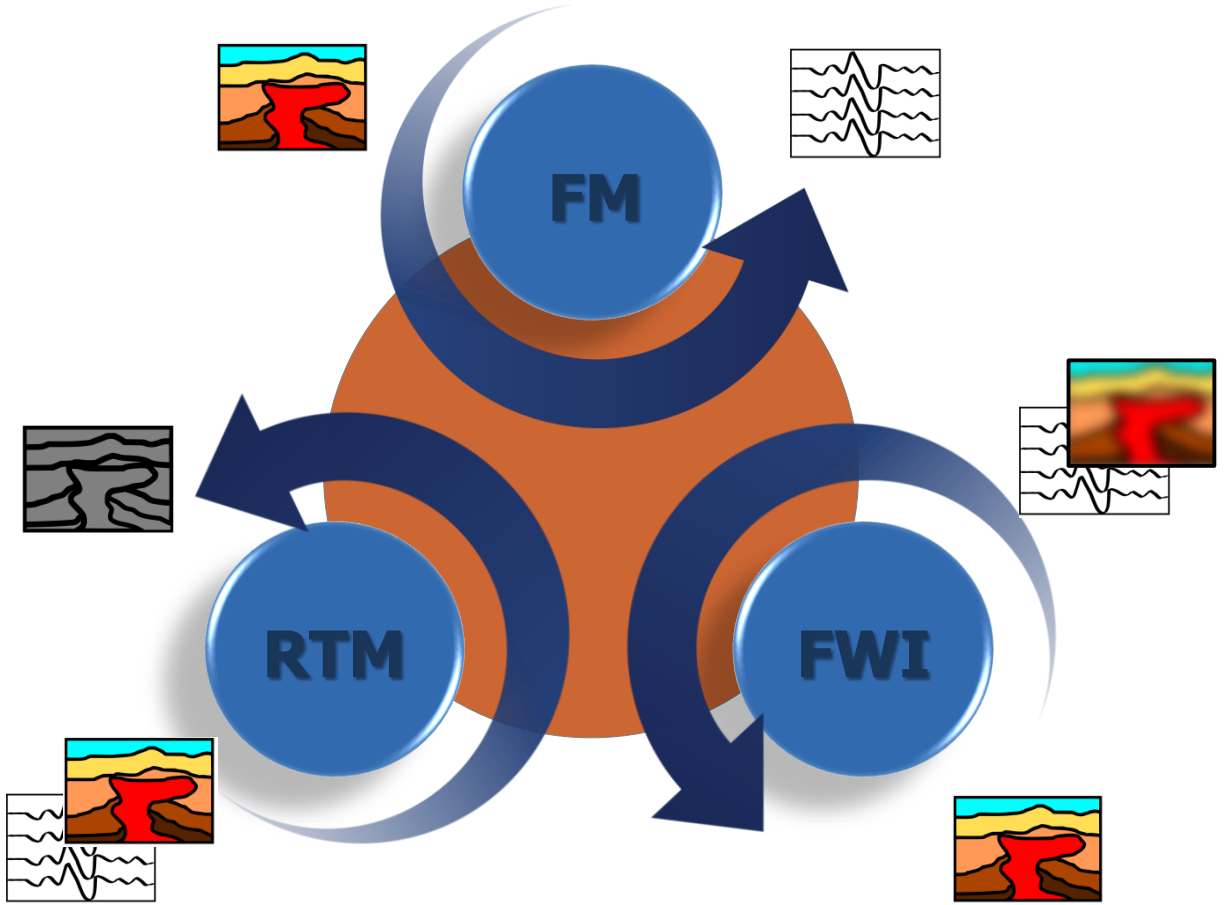
- The **challenges** are every time **harder**.
- **Hardware** and **software** libraries become **complex**
- Most important is to **solve the numerical problem** but it is not enough due to we must:
  - **Maximize** the **performance**.
  - Add **resiliency capabilities.**

Target









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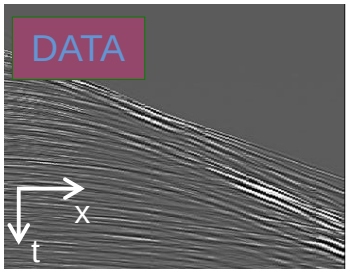
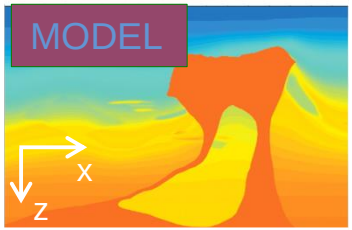
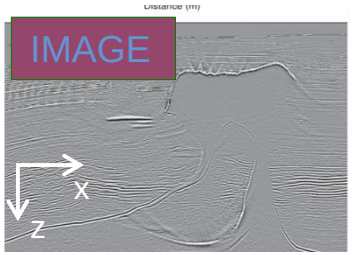
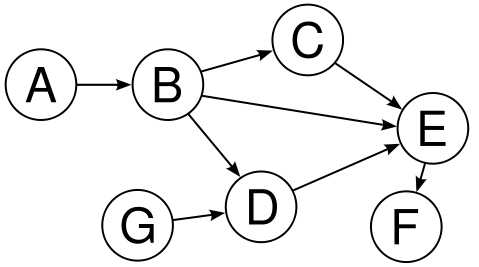


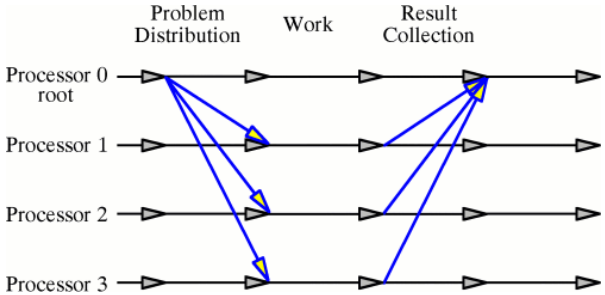


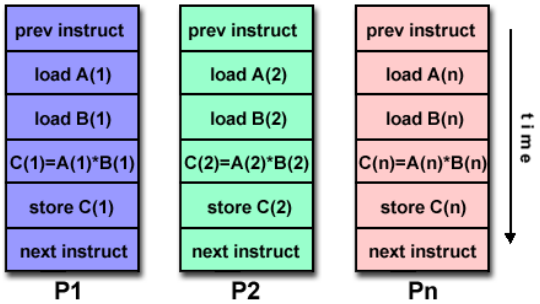


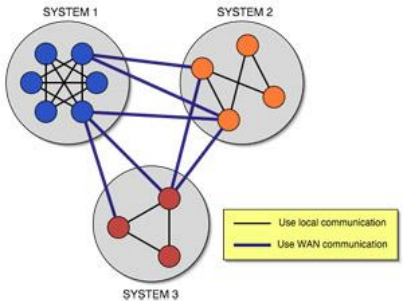
Many levels of parallelism

- **Workflow**: embarrassingly parallel
- **MPI**: message passing between tasks
- **OpenMP**: shared memory between threads
- **SIMD/SIMT:** vectorial code

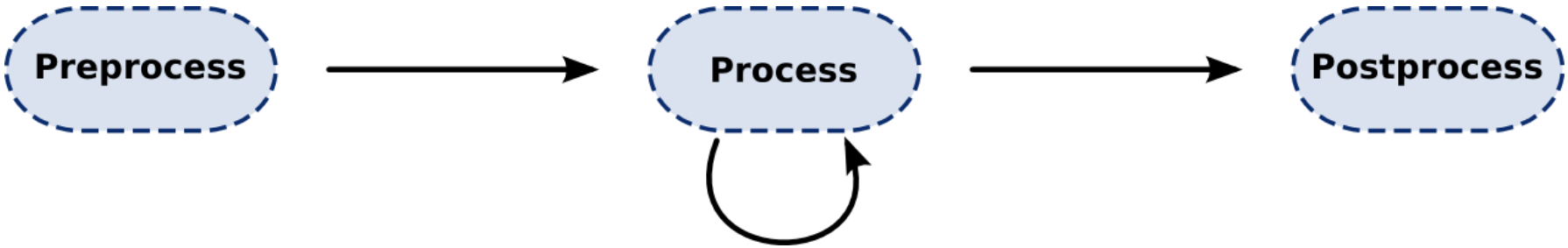




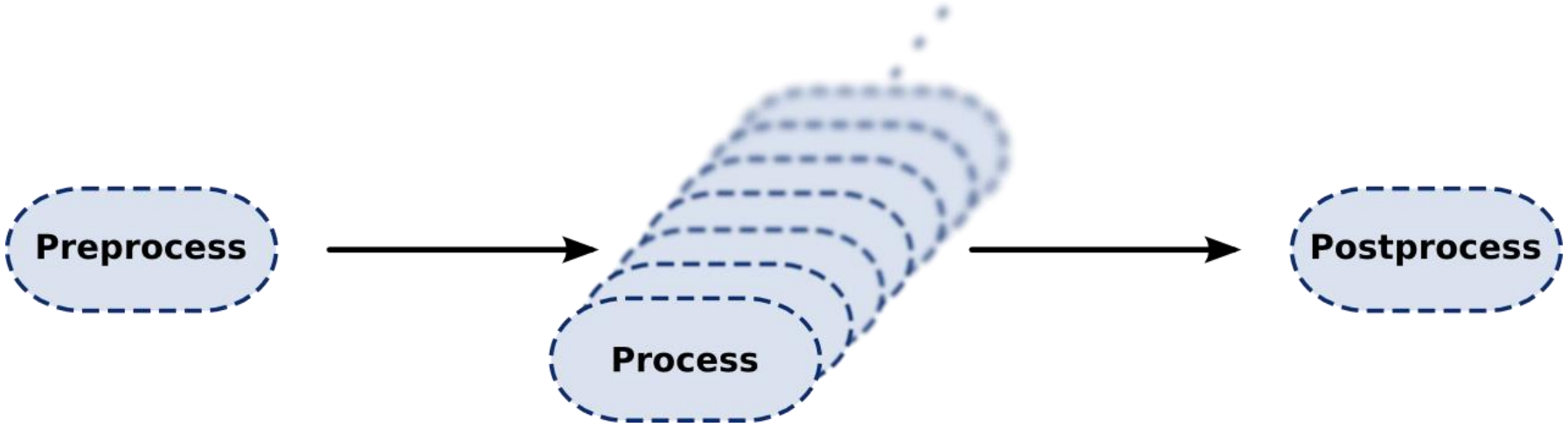




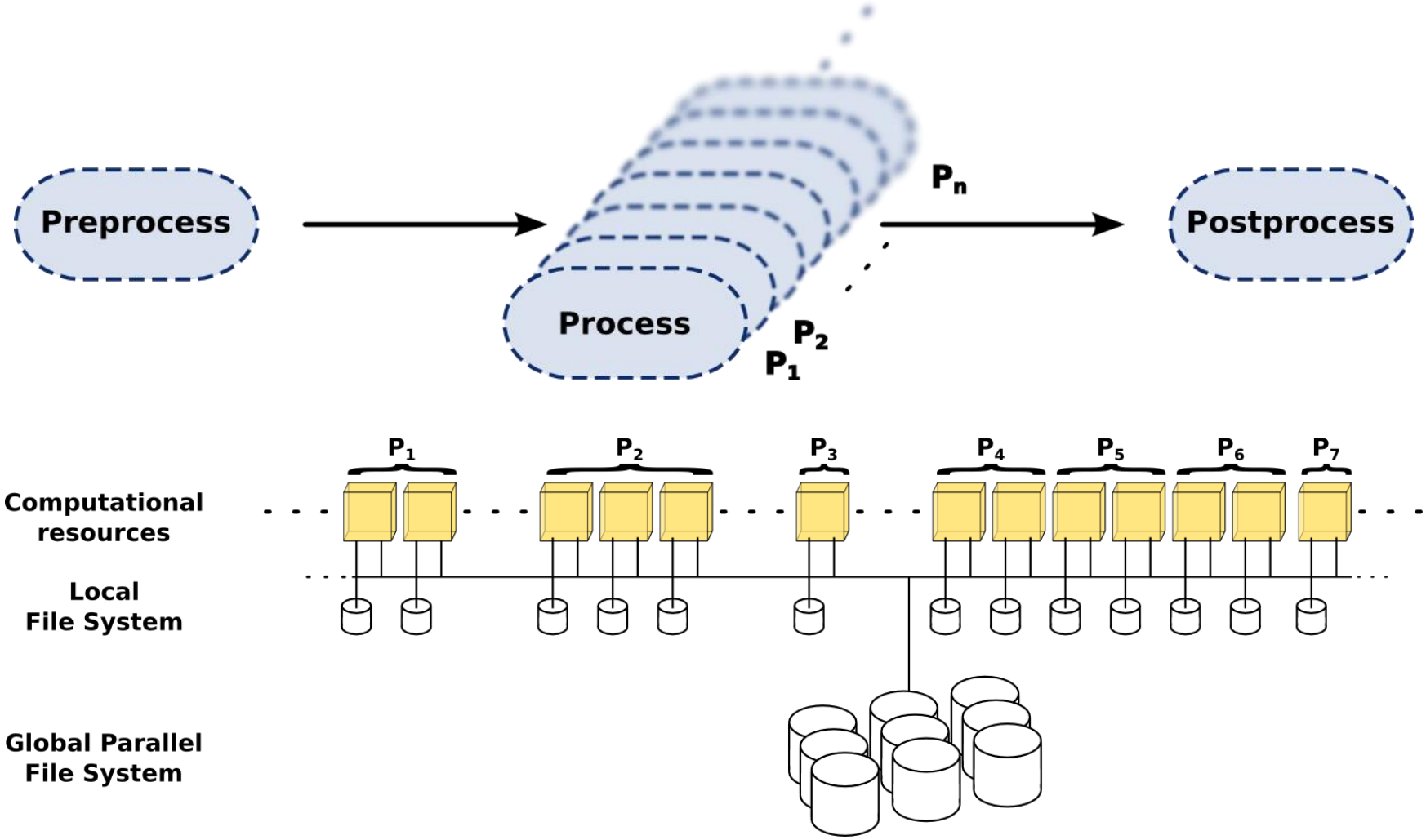
Starting point



Exploiting the massive paralellism

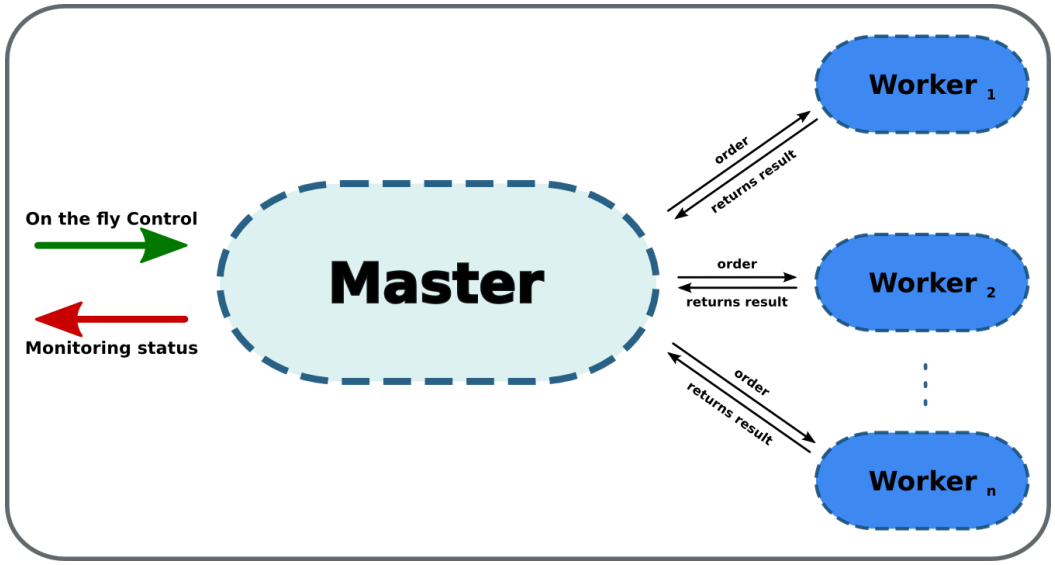


Seismic process on a distributed system



ENVIRONMENT FOR ASSESING CONFIDENCE (EAC)

EAC



- Master manages:
  - Resiliency
  - Jobs workflows
  - On the fly reconfiguration
  - Monitoring
  - Pre and Post process tasks
  - Restart process
- Workers simulate shots:
  - Process
  - Postprocess
  - Checkpointing

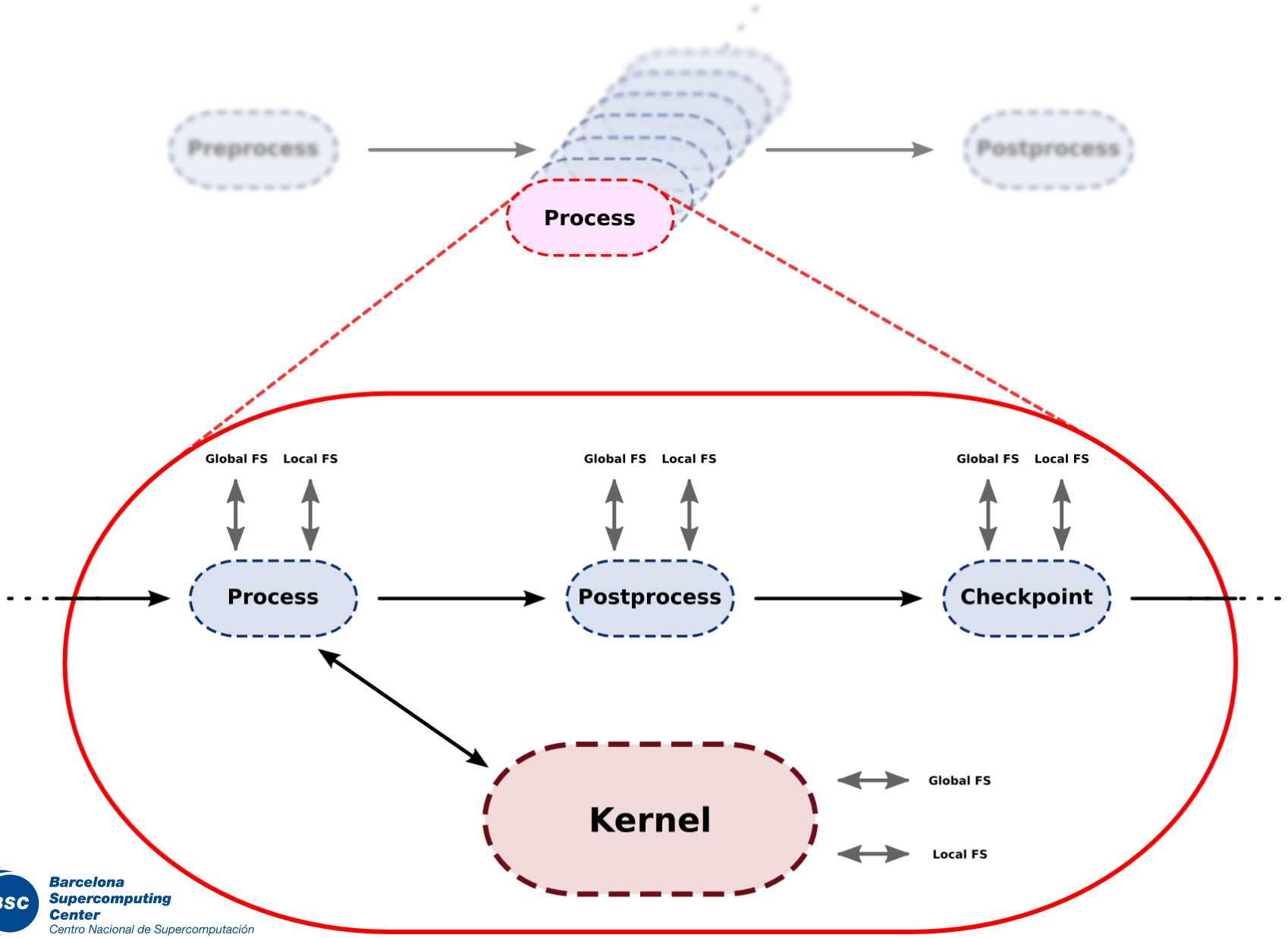
EAC Main Contributions

- Focus on your problem and not in the Fault Tolerance
  - You already have data corruption and worker failure management included.

- Maleability and monitoring
  - Remove/add computational resources, modify parameters on the fly or simply create a remote aplication for monitoring.

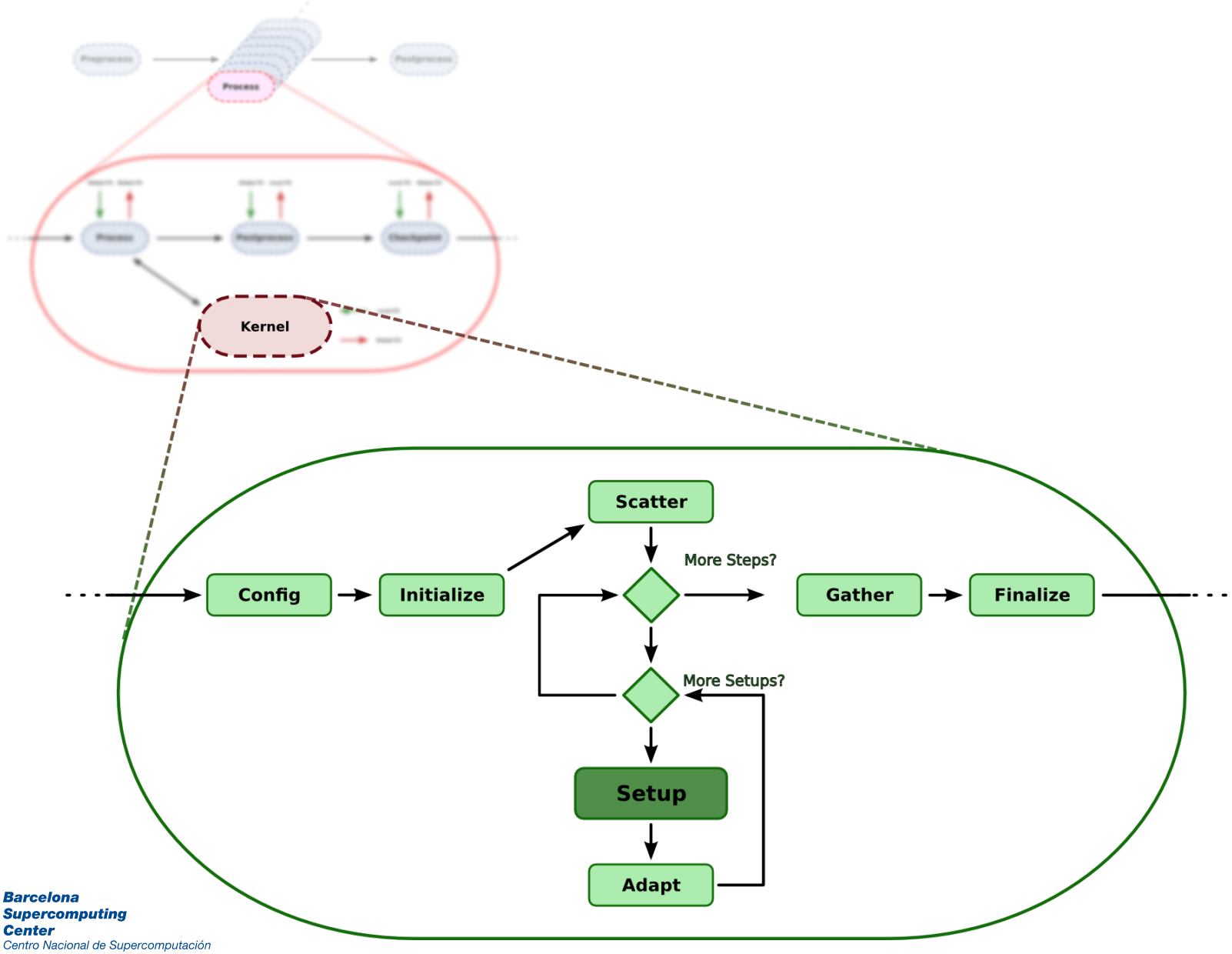
- Large support API for Geophysical data
  - Management for volumetric data, signal traces, wavelets, databases, etc, already in place and can be easily extended with new functionality as needed

EAC Workflow

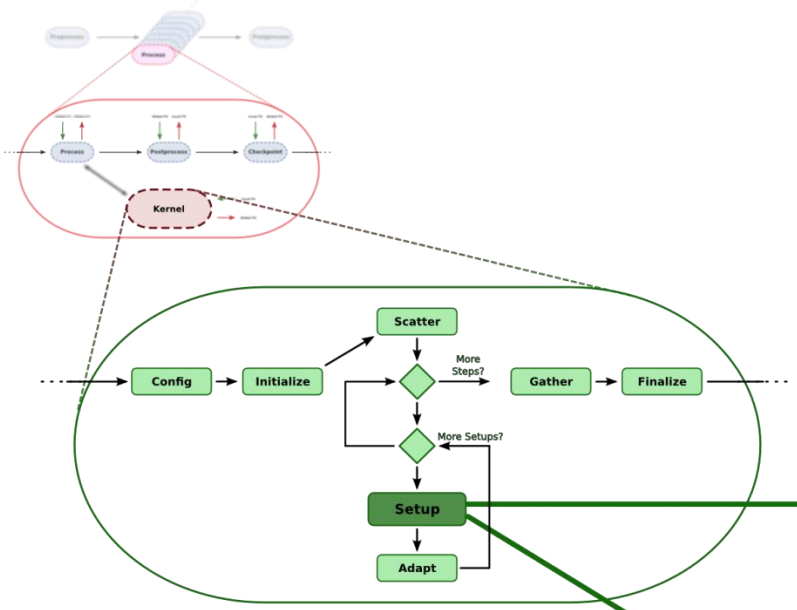


ENVIRONMENT FOR ASSESING PERFORMANCE (EAP)

EAP


Process
Kernel
Scatter
Config
Initialize
More Steps?
Gather
Finalize
More Setups?
Setup
Adapt

EAP Setups



Sequential

OpenMP / SIMT / SIMD

MPI

Implicit setup

Preprocessing

Solver function

Postprocessing

Explicit setup

Preprocessing

Comunication Start

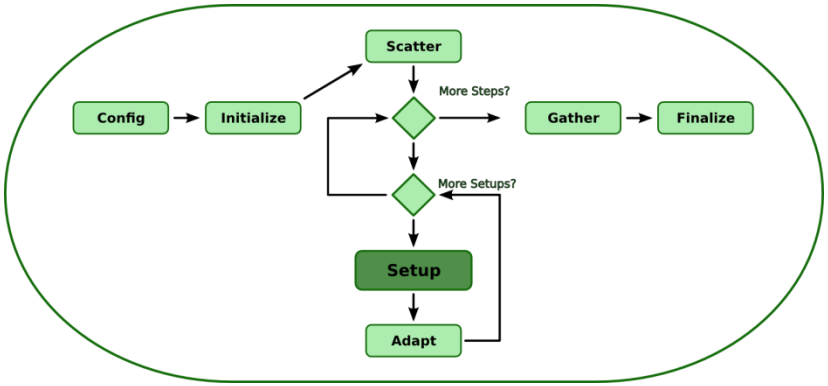
Main Processing

Comunication End

Postprocessing

EAP Main Contributions

- Focus on your problem and not in the HPC
  - You already have domain decomposition and parallel I/O.

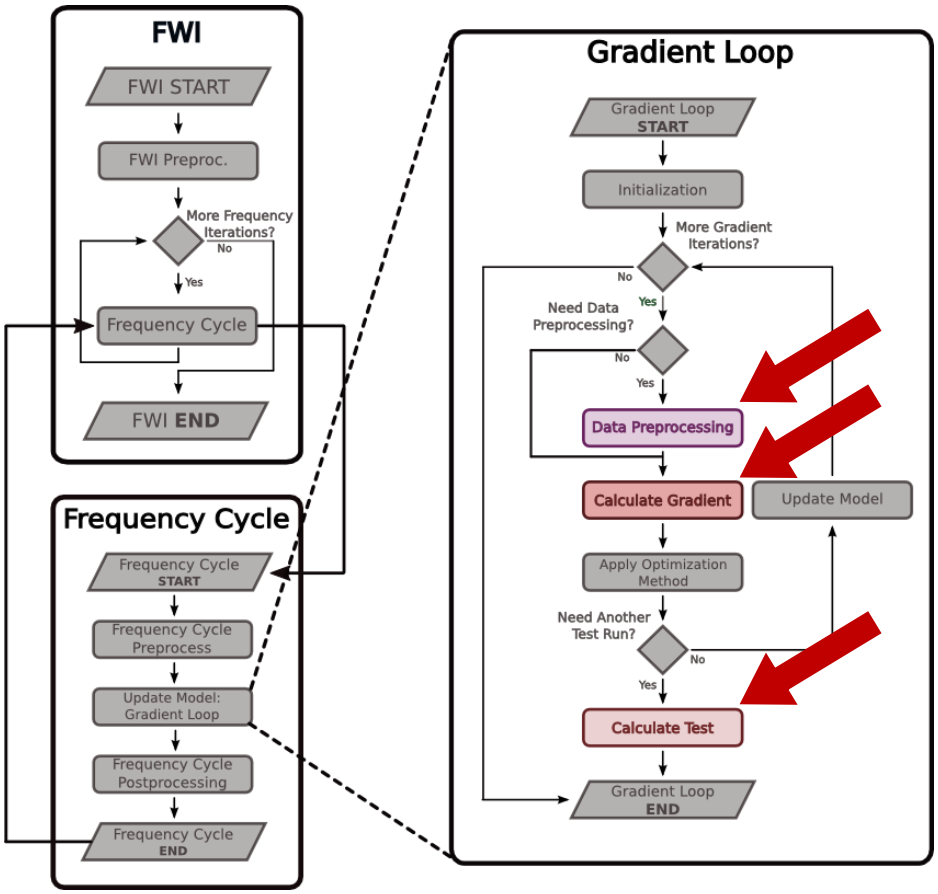


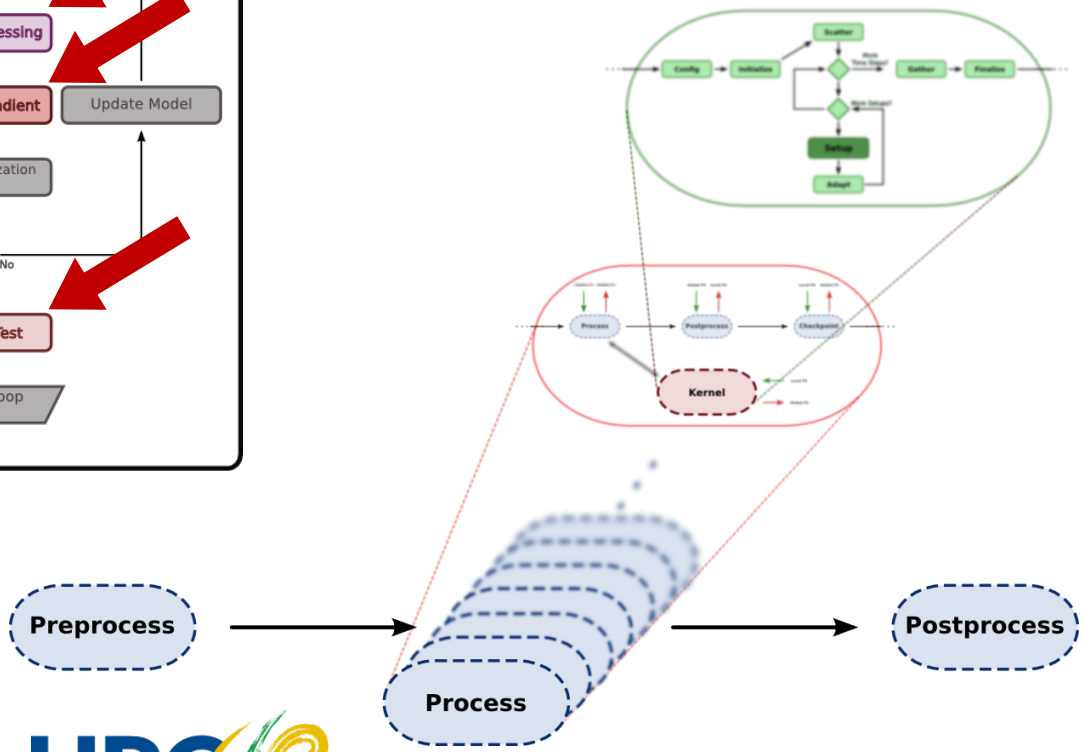
- Easier to port to novel architectures
  - Only some specific pieces must be ported, and they are well defined and encapsulated.

- Can produce different systems with minimal effort
  - Code reusing is easier due to framework modularity.

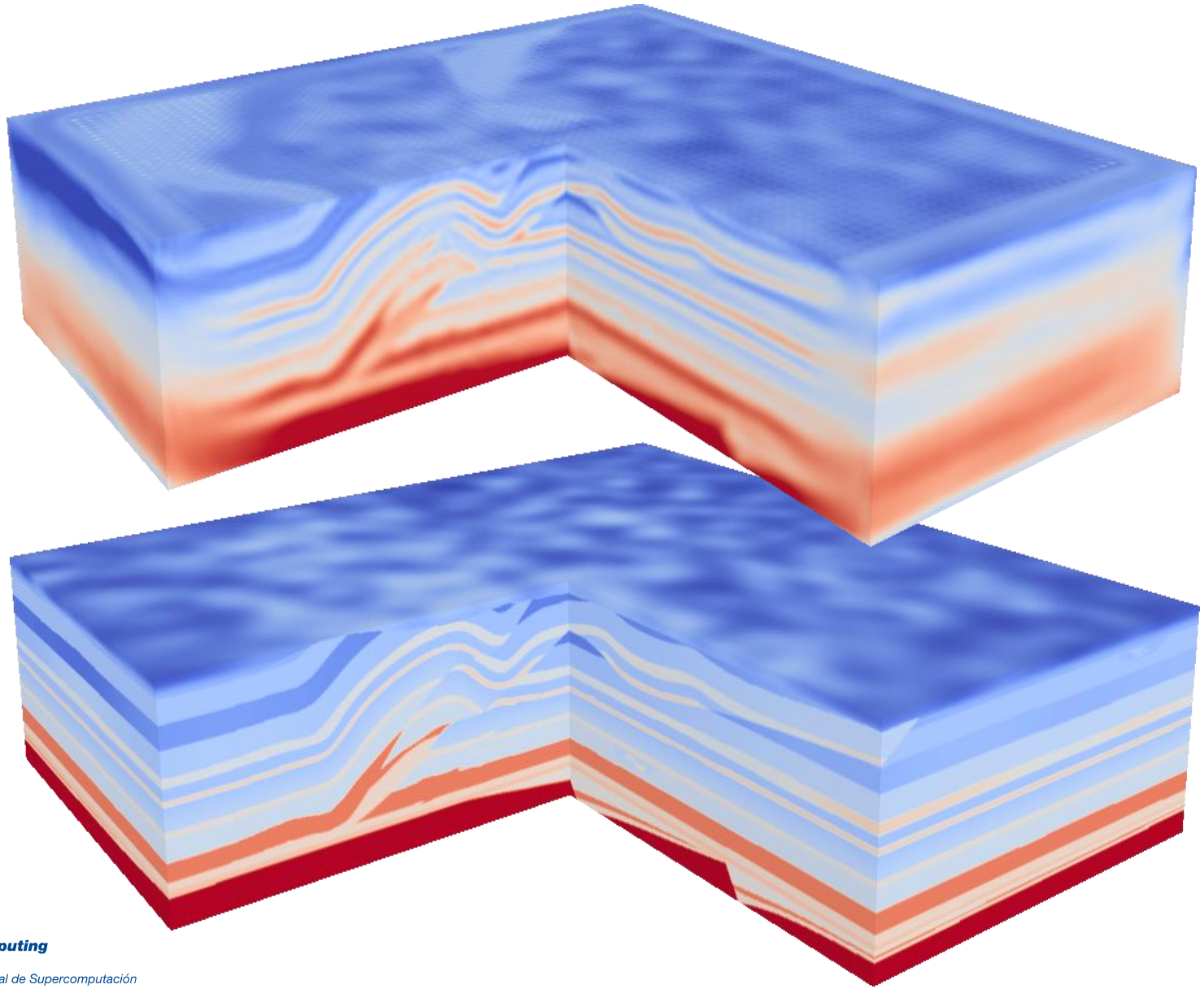
INVERSION PROBLEMS SOLVED WITH EAC/EAP FRAMEWORKS

Full Waveform Inversion (FWI)

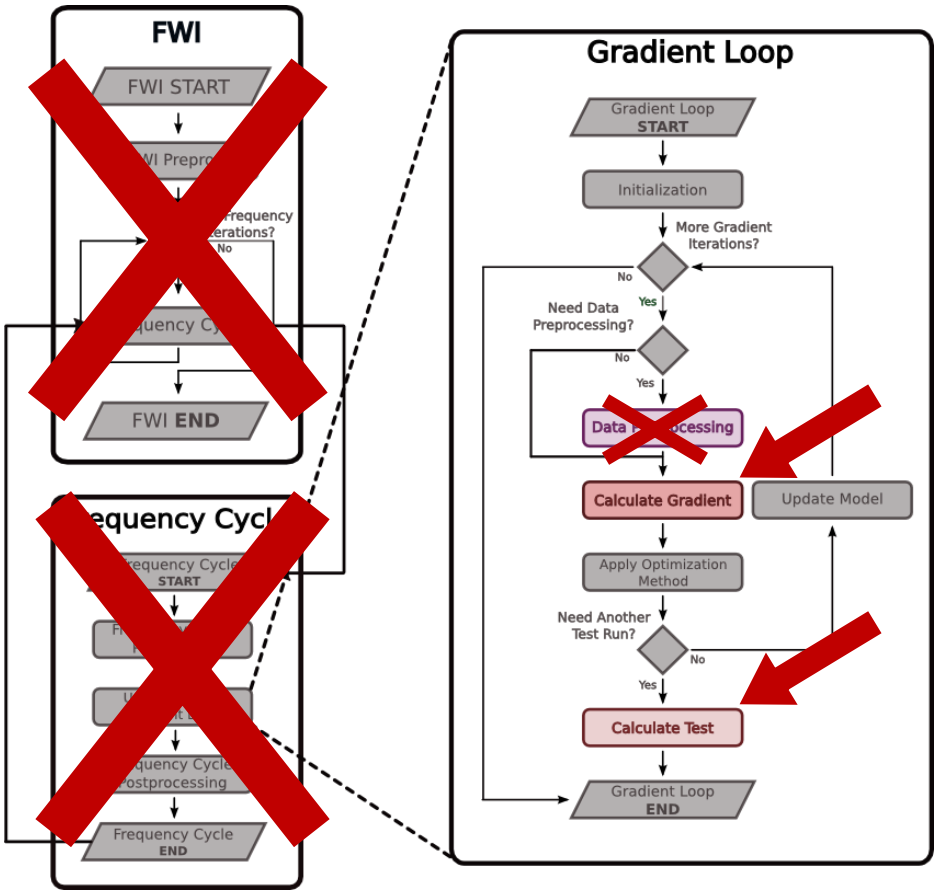


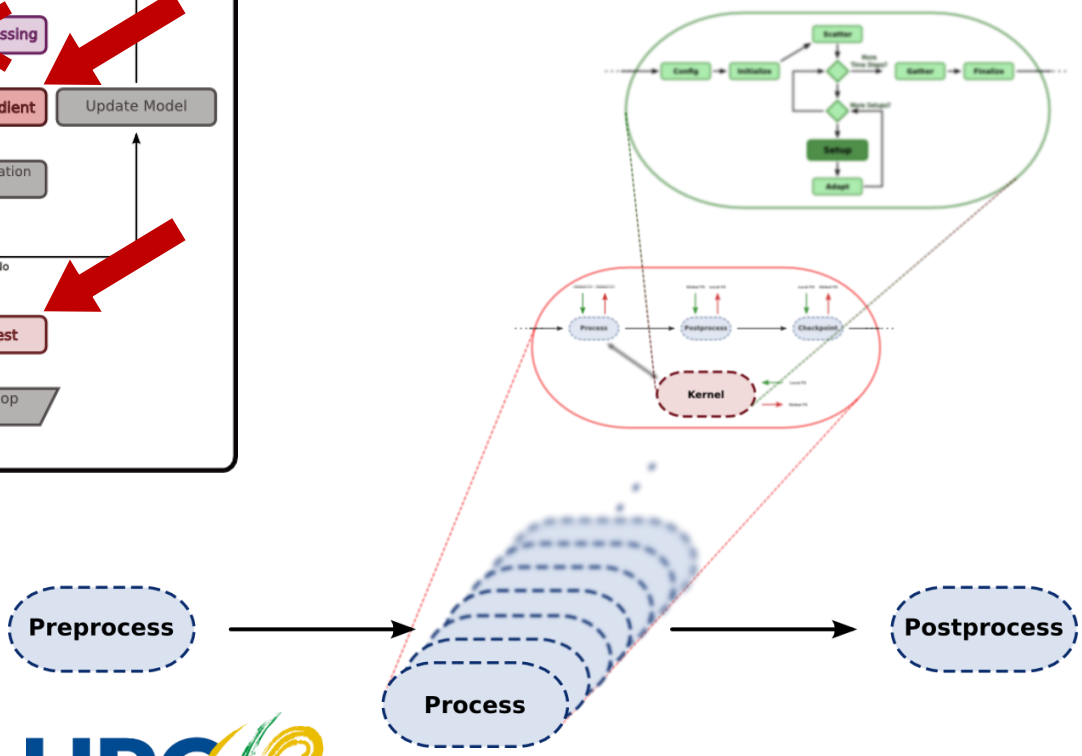


Results: FWI on BSIT

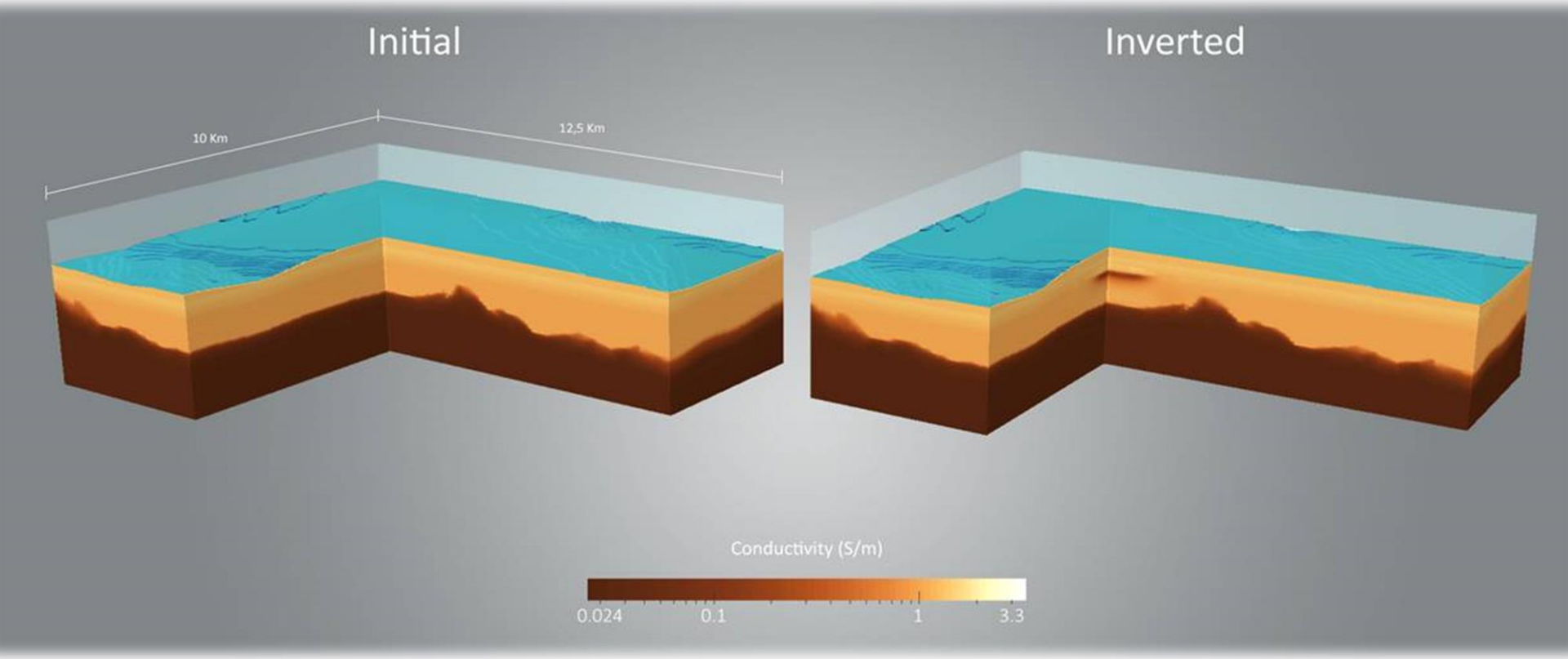


CSEM Inversion





Results: CSEM Inversion on BSIT



Conclusions and future work

- **Disengage** the **numerical problem** of the **resiliency** and **efficiency** as help to build new systems.
- **EAP** provides **asynchronous communications and I/O** for tightly coupled problems.
- **EAC** provides **embarrassingly parallelism** with task-level **resiliency** to software and hardware failures.
- Presented frameworks define the base for designing next generation challenges as the Joint Inversion.

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Thank you!

For further information please contact

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