



Co-design across four European Centres of Excellence using Domain Specific Benchmarks for EU sovereign technologies

Readiness of HPC Extreme-scaling Applications (3rd Edition)
ISC HPC 2026 Workshop

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CEPP, HPC, AI & QC Global Business Line

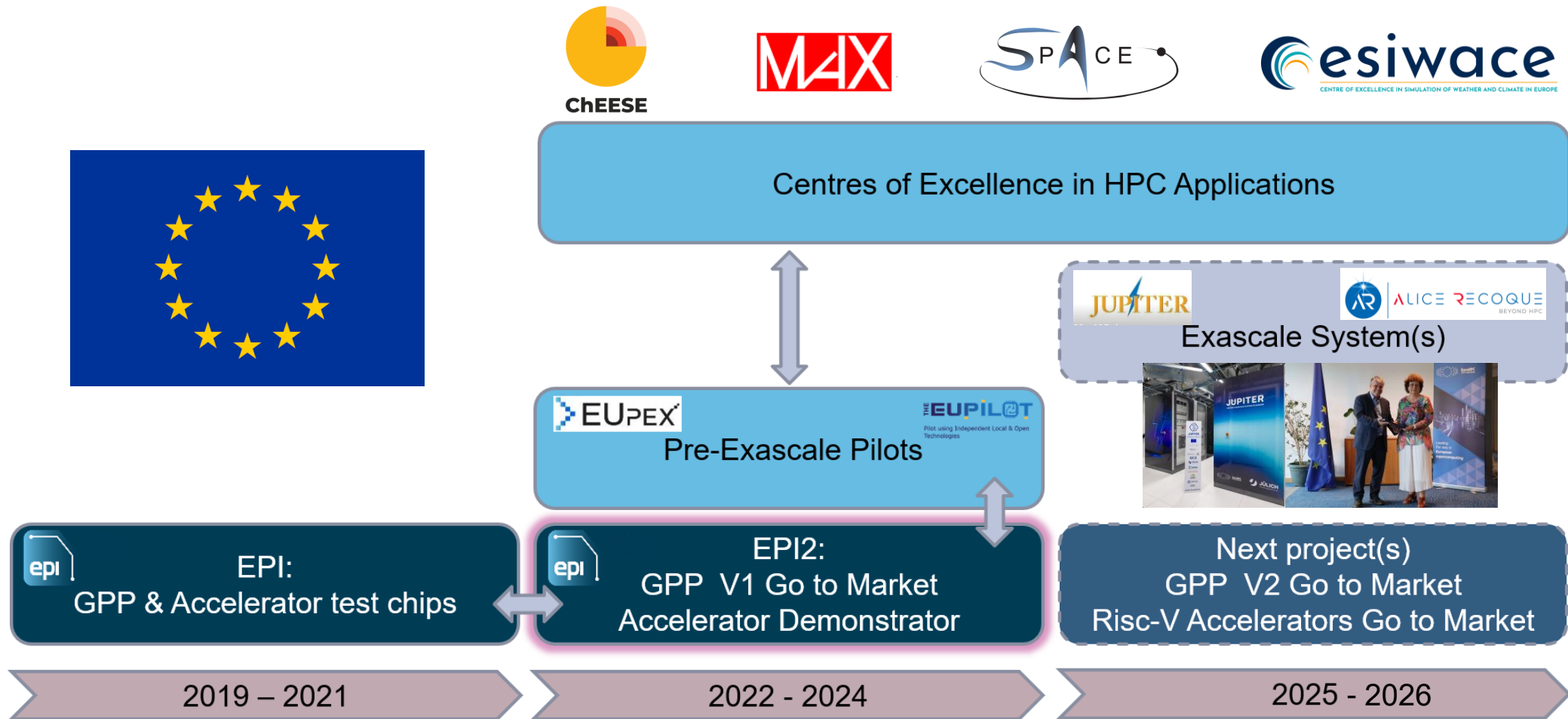
Hamburg, 2026-06-26



1 EU sovereign technology with EPI and EUPEX projects

EPI and EUPEX

From EU sovereign technology development to real applications

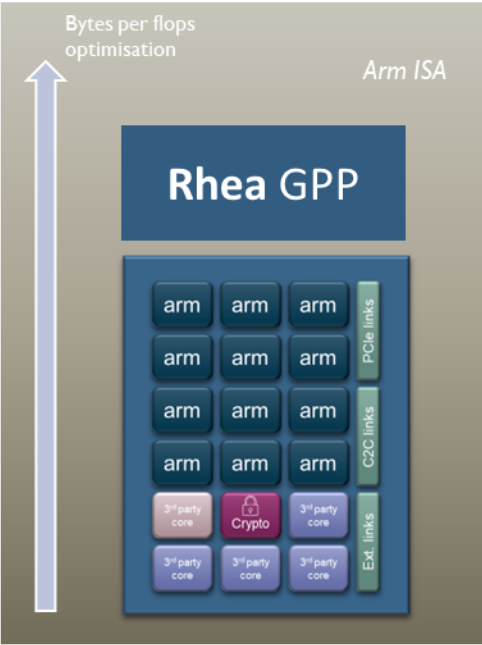


EPI : Main objectives

EU chips fit for HPC usage - at Exascale level

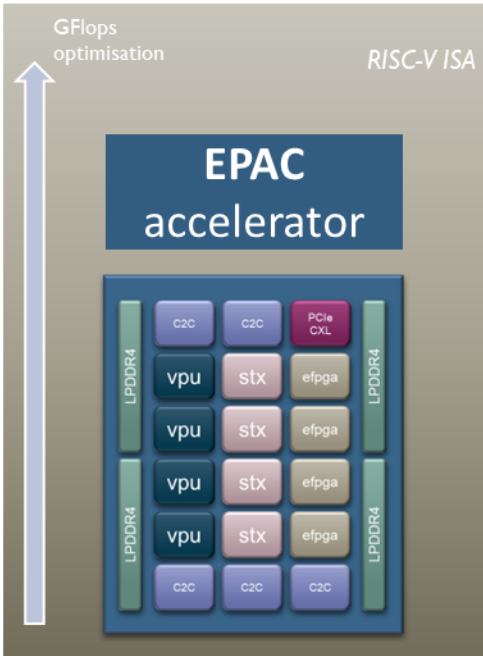
arm

General Purpose Processors:
Legacy & programmability

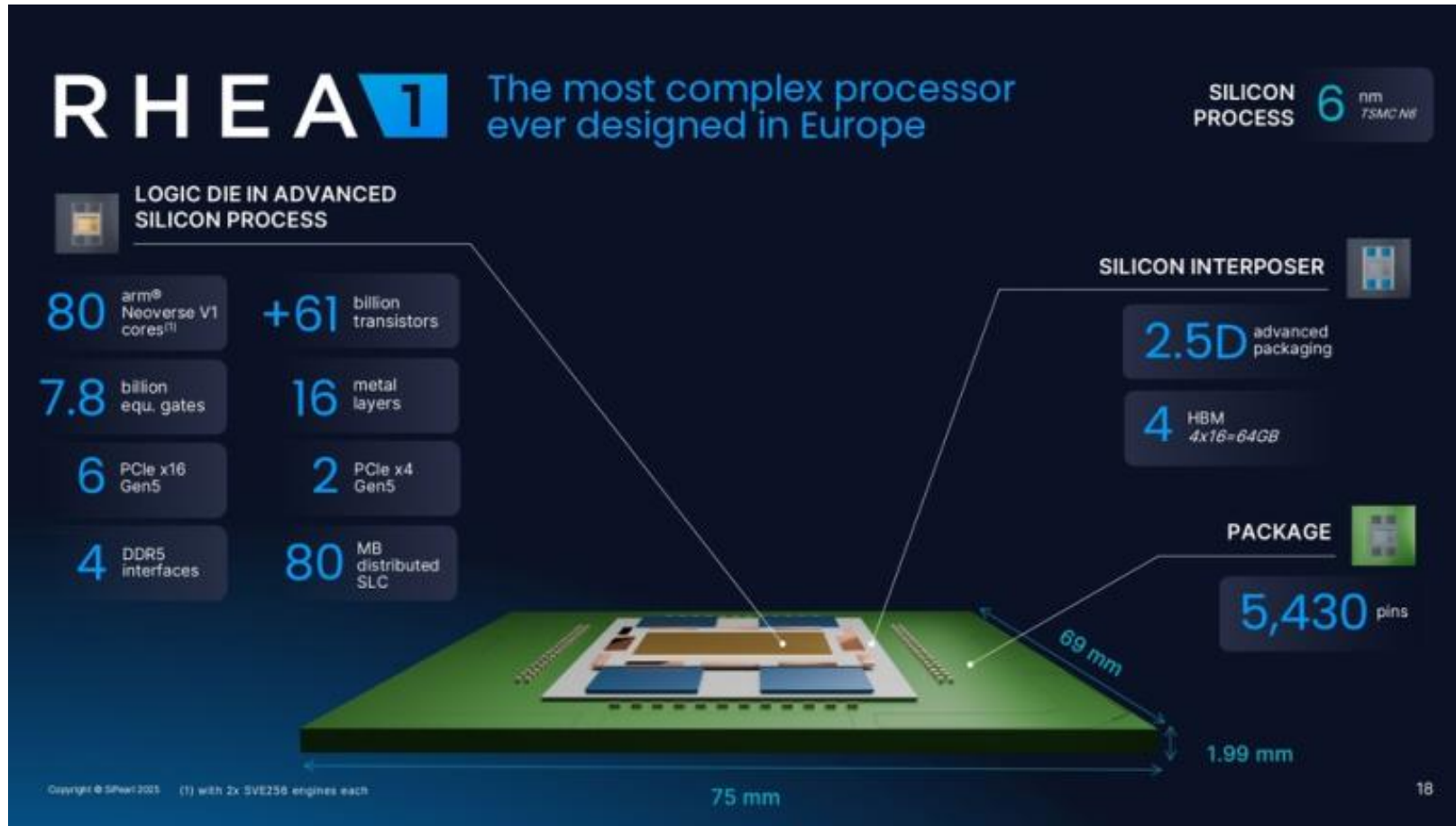


Accelerators:
Computing force

RISC-V







SiPearl Rhea1 processor



EUPEX

European Pilot for EXascale

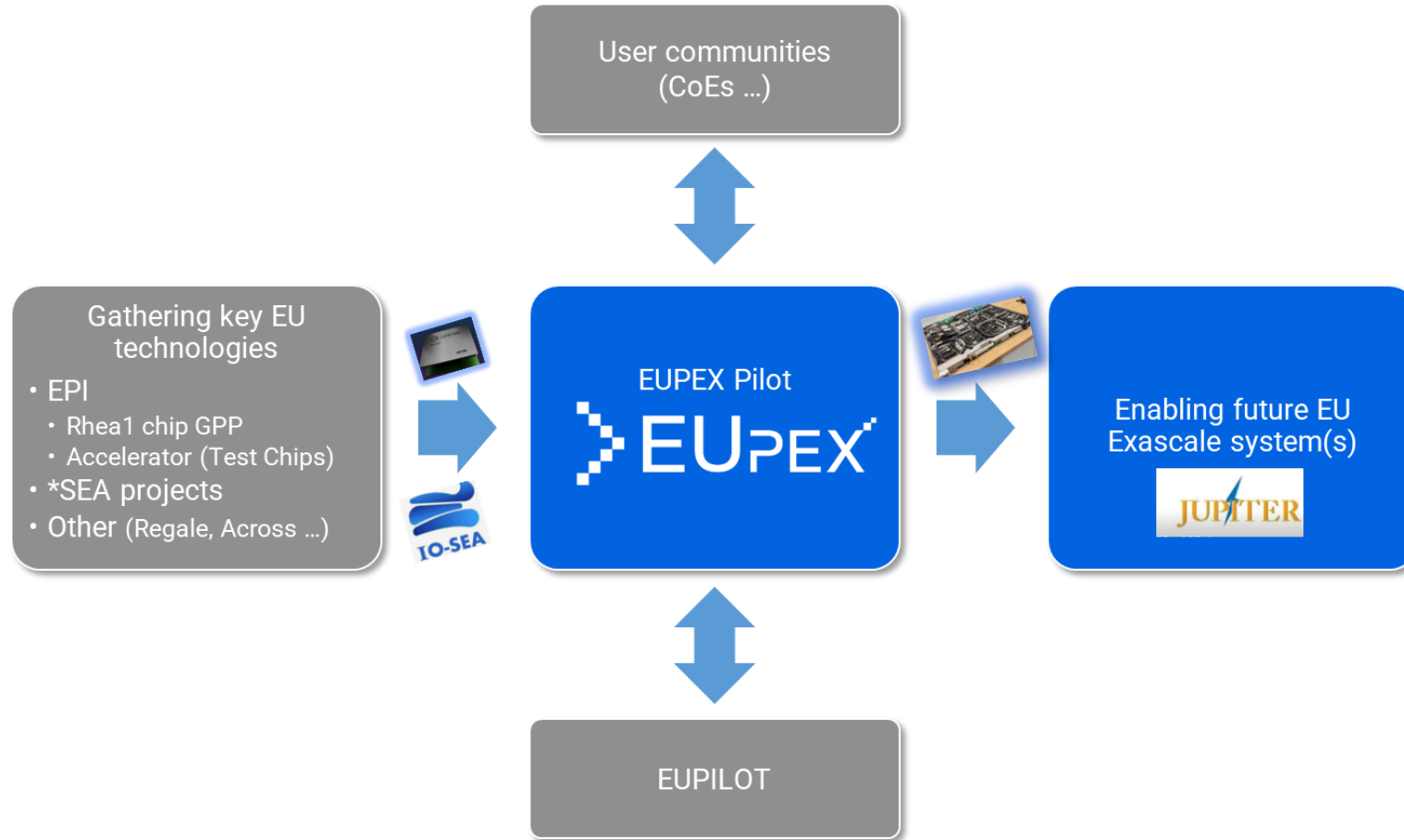
- What is EUPEX?
- 5-year project (Jan. 2022 to Dec. 2026)
- Goal: Covering the full spectrum of required supercomputing technologies with EU solutions

 Co-design	Co-design a modular Exascale-pilot system
 Deploy	Build and deploy a pilot hardware and software platform integrating European technology
 Demonstrate	Demonstrate the readiness and the scalability of the pilot technology in general and the MSA in particular, towards Exascale
 Applications	Prepare applications and European users to efficiently exploit the future Exascale machines



EUPEX

A key project in the EU network of know-how



EUPEX

Software Stack



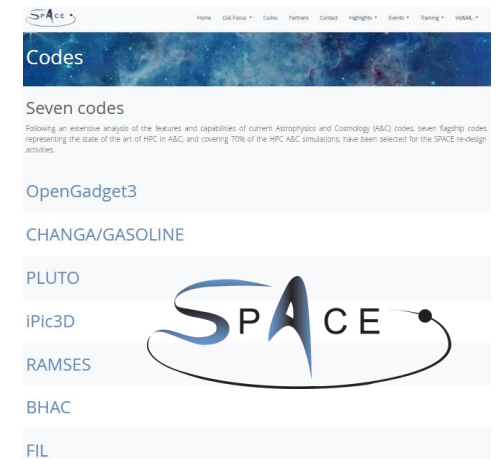
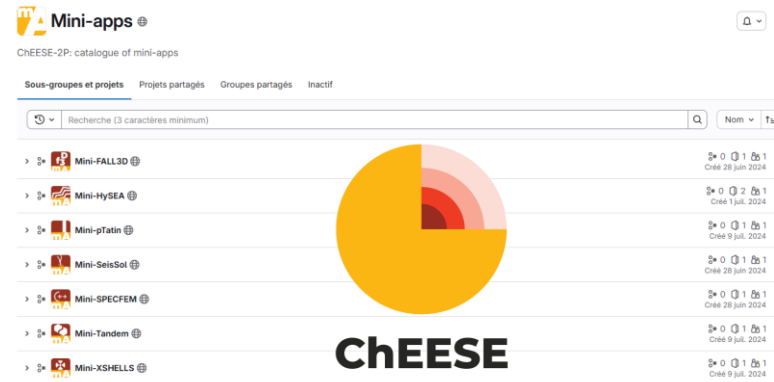
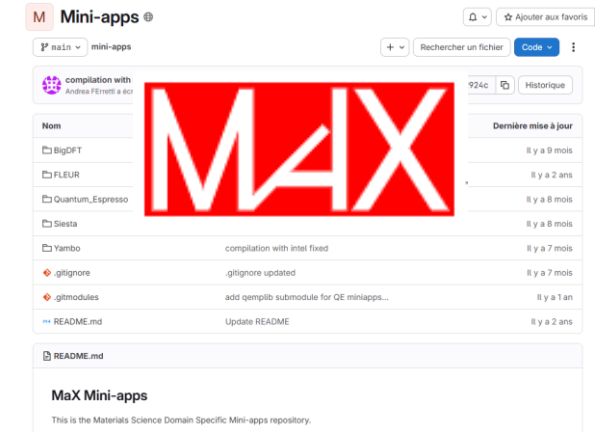


2 Domain Specific Benchmarks

Domain Specific Benchmarks (DSB)

Application vehicles for co-design

- **Technology assessment and performance portability**
 - Complementary to synthetic benchmarks
 - Made of full applications and/or mini-applications
 - Associated relevant test cases
 - Numerical verification procedure
 - Reproducibility and easy deployment



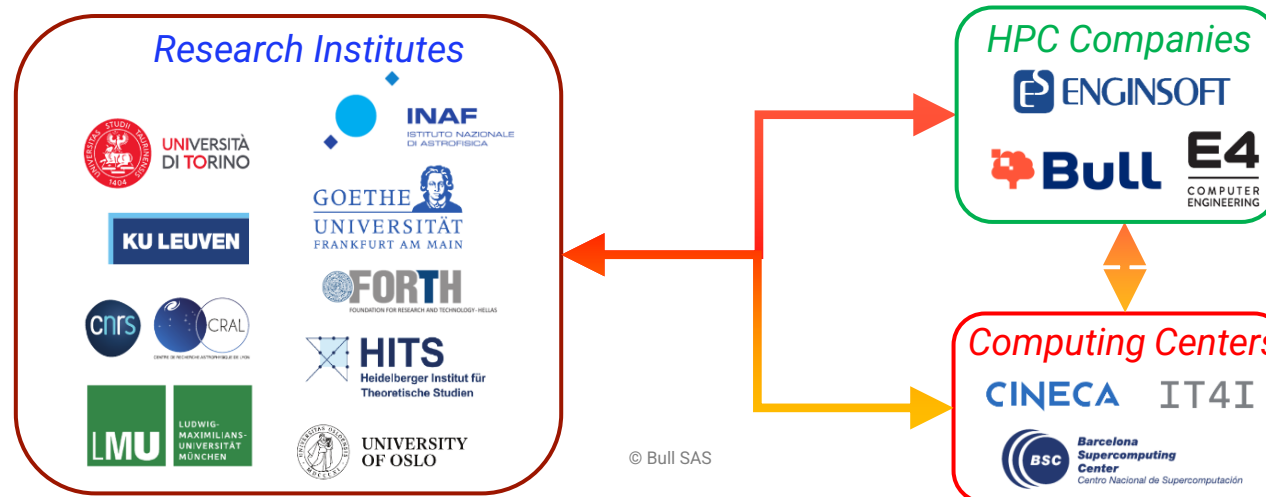
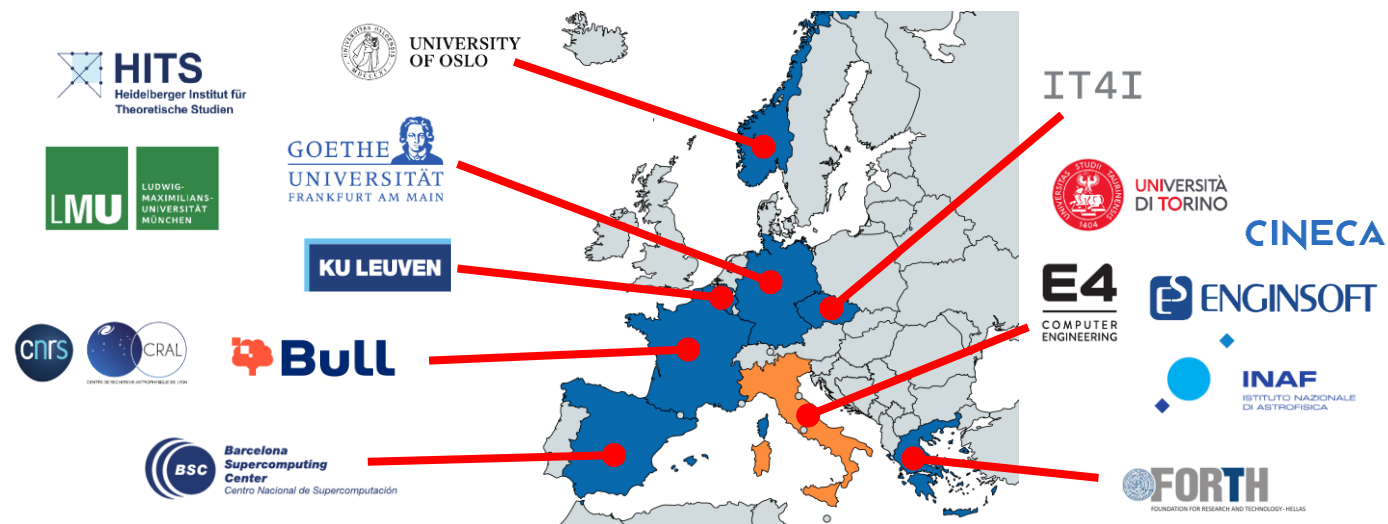
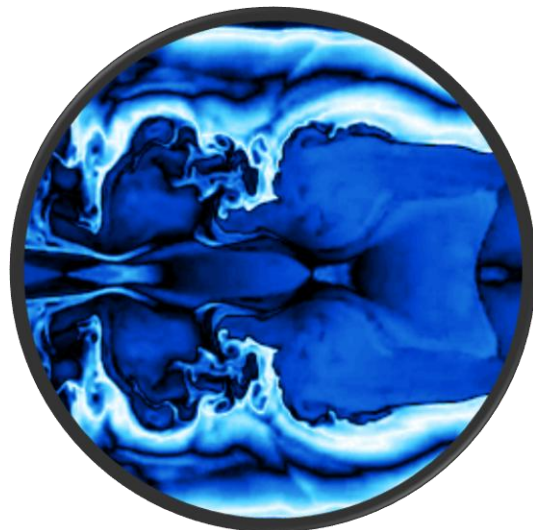


3 SPACE CoE

SPACE CoE - Scalable Parallel Astrophysical Codes for Exascale

Overview

- Codes:
 - Pluto
 - OpenGADGET
 - iPIC3D
 - RAMSES
 - BHAC
 - FIL / GRACE
 - ChaNGa



SPACE CoE - Scalable Parallel Astrophysical Codes for Exascale

Notable Results and Experiences from SPACE

Code	DDR (s)	HBM (s)	Gain(+) / Loss(-)
gPLUTO	313	235	+25%
OpenGadget3	285	279	+2%
iPIC3D	219	186	+15%
RAMSES	324	317	+2%
BHAC	163	133	+18%
FIL	244	239	+2%
ChaNGa	321	312	+3%

Summary of HBM relevancy for SPACE applications.

Code	GCC	LLVM
gPLUTO	OK	OK
OpenGadget3	OK	OK
iPIC3D	OK	OK
RAMSES	OK	OK
BHAC	OK	KO
FIL	partial	KO
ChaNGa	OK	OK

Summary of ARM readiness assessment.

OK: the code compiles, runs with full compiler support.

partial: the code compiles and runs but with partial compiler support.

KO: the code does not compile.

Global Metrics ?				
Metric	GNU NEON	GNU SVE	LLVM NEON	LLVM SVE
Total Time (s)	121.17	131.20	143.98	144.12
Max (Thread Active Time) (s)	117.03	128.94	140.20	142.00
Average Active Time (s)	103.00	114.51	135.92	137.66
Activity Ratio (%)	87.6	88.6	96.7	96.7
Average number of active threads	244.807	251.370	271.881	275.096
Affinity Stability (%)	98.7	99.1	99.7	99.9
Time in analyzed loops (%)	89.3	90.6	86.0	86.0
Time in analyzed innermost loops (%)	75.9	70.2	73.1	70.9
Time in user code (%)	95.5	96.1	88.2	88.2
Compilation Options Score (%)	75.0	75.0	16.7	16.7
Array Access Efficiency (%)	89.4	71.6	45.9	45.4

MAQAO global metrics comparison between RAMSES binaries compiled with GCC 14.2.0 and with LLVM 20.1.1, with SIMD passes, and executed with NEON and SVE ISA

SPACE CoE - Scalable Parallel Astrophysical Codes for Exascale

Notable Results and Experiences from SPACE

Code energy efficiency	NVidia GRACE CPU [MFLOPS/W]	Intel Sapphire Rapids with DDR [MFLOPS/W]	Intel Sapphire Rapids with HBM [MFLOPS/W]
Pluto	805.4	264.0	309.0
OpenGADGET	716.2	138.2	149.2
iPIC3D	791.3	238.2	321.4
RAMSES	854.9	399.7	417.8
BHAC	292.9	121.9	125.5
FIL	522.2	223.9	248.9
ChaNGa	1478.9	779.6	1018.3

Energy efficiency of SPACE codesign platforms.

Potential savings if platform is tuned for specific application (codesign platforms.)

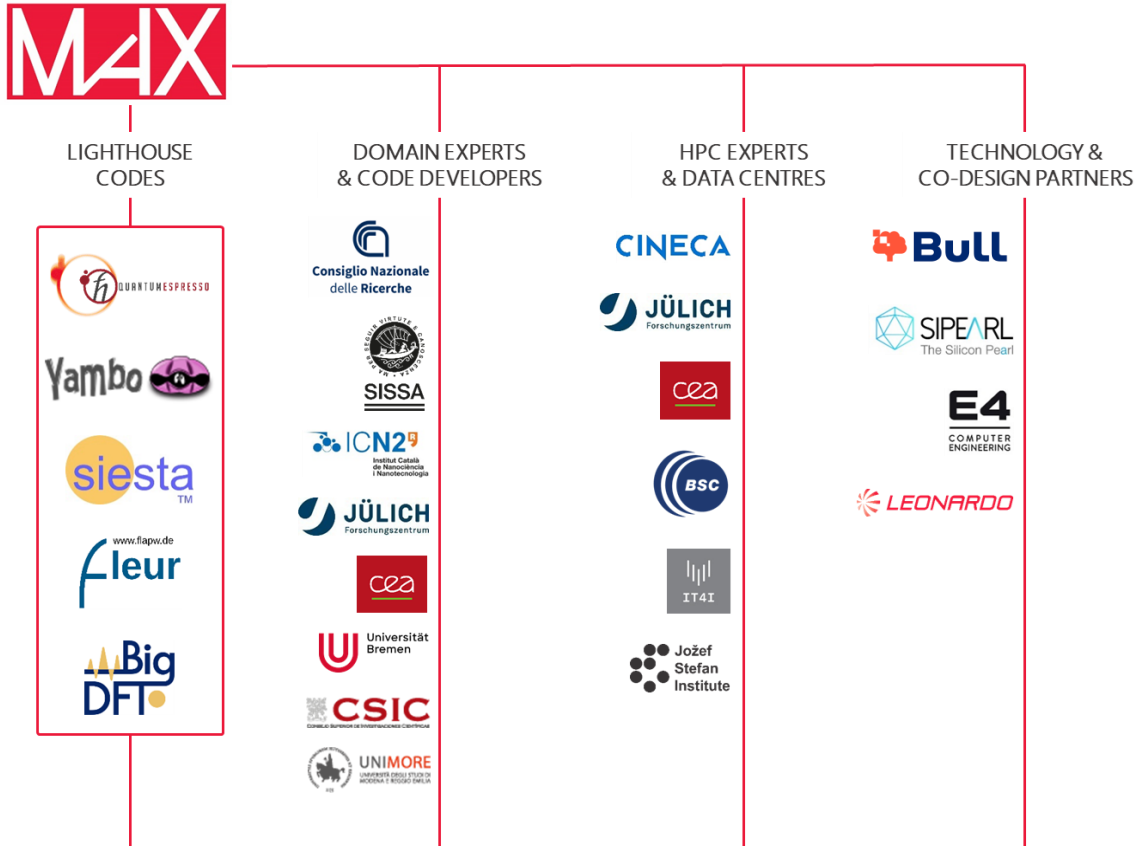
	Pluto	Open GADGET	iPIC3D	RAMSES	BHAC	FIL	ChaNGa
SPR w. DDR	-9% / 102% -10% / 106%	-7% / 102% -7% / 102%	-7% / 102% -9% / 108%	-6% / 102% -7% / 104%	-10% / 103% -14% / 110%	-6% / 102% -7% / 103%	-14% / 103% -20% / 107%
SPR w. HBM	-4% / 101% -6% / 105%	-9% / 94% -11% / 98%	-7% / 101% -7% / 101%	-7% / 102% -8% / 104%	-4% / 99% -4% / 99%	-4% / 100% -6% / 104%	-12% / 102% -13% / 103%
Grace CPU	-22% / 101% -35% / 122%	-13% / 103% -33% / 128%	-9% / 103% -29% / 126%	-19% / 101% -28% / 137%	-26% / 103% -36% / 109%	-8% / 102% -20% / 117%	-16% / 102% -30% / 135%



4 MaX CoE

MaX CoE - MAterials design at the eXascale

Overview



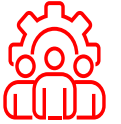
European leadership in Exascale Applications in the Materials Domain



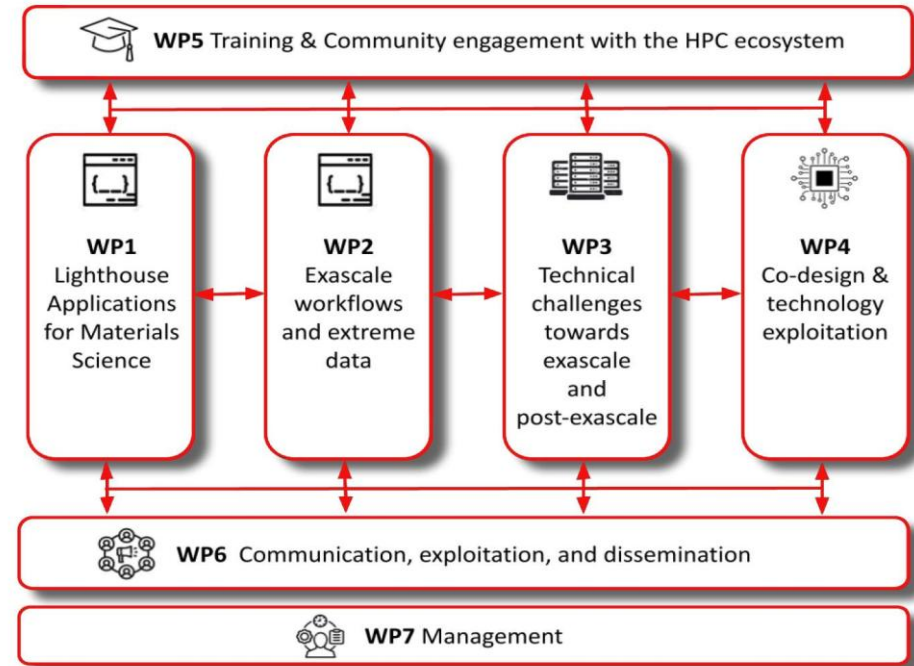
Key scientific and industrial applications and societal challenges for MAX impact



Building a stronger European HPC ecosystem



Improving the access to the MAX computing applications and their performance data



MaX CoE - MAterials design at the eXascale

Notable Results and Experiences from MaX

- HBM vs DDR:
 - By setting the memory affinity of the processes/threads, only the HBM or only the DDR is used
 - IT4I is developing a tool that helps at identifying the optimum data repartition between HBM and DDR
- Vectorisation optimization:
 - Quantum Espresso execution time gains (%) depending on compiler and microarchitecture

MaX Code (* = Mini-App)	Maximum HBM Gain observed over DDR [%]
QE*	35
Yambo*	80
BigDFT	14
FLEUR	33
Siesta	49

	X86 (SPR HBM)	AARCH64 (Ampere Altra)
Intel OneAPI	6.3%	
GNU	21%	8.7%
ACFL		10.6%



5 ChEESE CoE

ChEESE - Centre of Excellence (CoE) for Exascale in Solid Earth

Overview

- ChEESE covers 3 approaches to exascale
 - **Capability Computing:** solving complex problems that typically require parameterization due to the limitations of current hardware.
 - **Capacity Computing:** solving multiple individual problems that can be managed by petascale-range machines, but when combined, they form an exascale workflow (data inversion, data assimilation, and uncertainty quantification)
 - **Urgent Computing:** solving capability/capacity problems under strict time constraints (ex: emergency situations)



ChEESE

Domains:

- Seismic Wave Propagation
- Volcanology
- Geodynamics
- Tsunami Modeling
- Coupling Physical Processes
- Fluid Dynamics and Planetary Atmospheres

Codes:

- SeisSol
- SPECfEM3D
- ExaHyPE
- Tandem
- xSHELLS
- Tsunami-HySEA
- FALL3D
- OpenPDAC
- LaMEM
- pTatin3D
- ELMER/ICE

Consortium Composition



ChEESE - Centre of Excellence (CoE) for Exascale in Solid Earth



ChEESE

Notable Results and Experiences from ChEESE

- Successful porting to Neoverse-v2 with GNU, NVHPC and LLVM compilers
- Main optimization levers:
 - Loop vectorization
 - Vectorization hints for data dependency
 - Data organization for unit stride memory access
 - Increased loop size for better vectorization efficiency

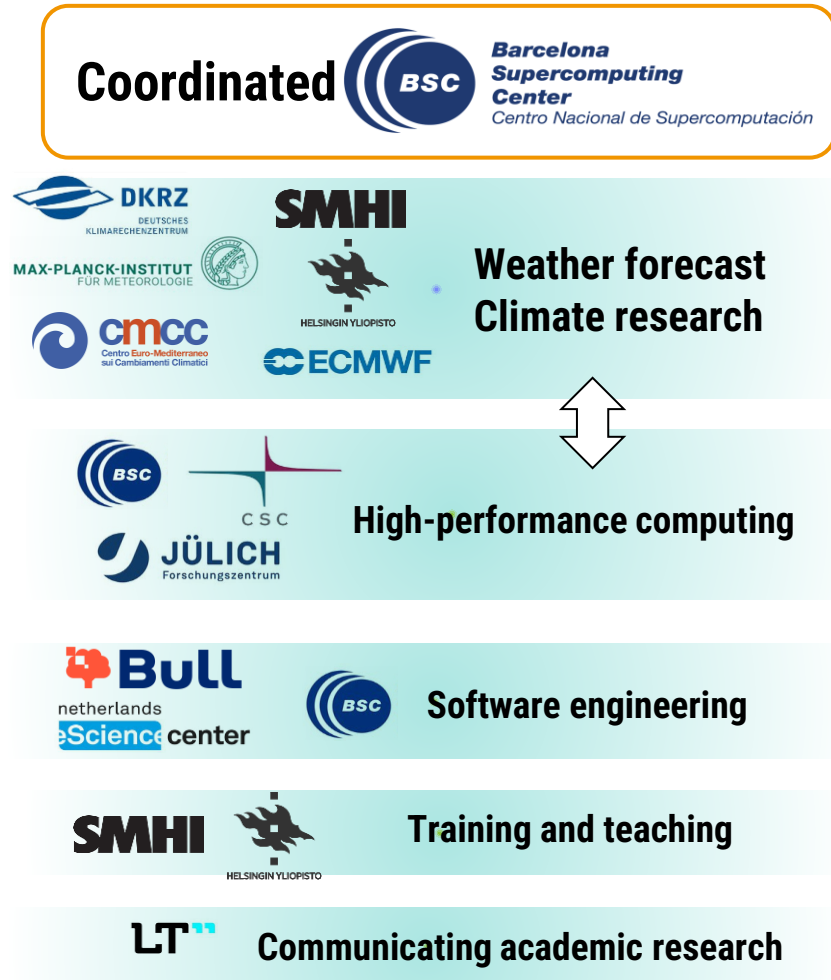
Mini-app	HBM gain on x86_64	Vectorization on aarch64 (SVE2)	Energy monitoring	Optimizations
ExaHyPE	20%	✓	✓	Optimized
FALL3D	17%	✓	✓	12% speedup
OpenPDAC	14%	✓	✓	-
pTatin3D	22%	✓	✓	Identified, to be implemented
SeisSol	8%	✓	✓	Optimized
SPECFEM3D	44%	✓	✓	60% speedup
Tandem	45%	✓	✓	-
Tsunami-HySEA	13%	✓	✓	-
xSHELLS	17%	✓	✓	Optimized



6 ESiWACE CoE

ESiWACE - Center of excellence for weather and climate

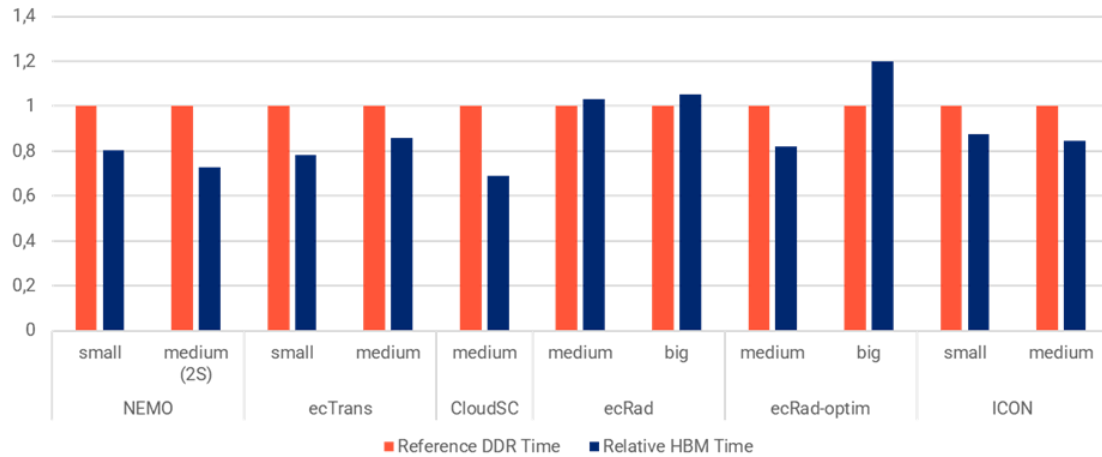
Overview



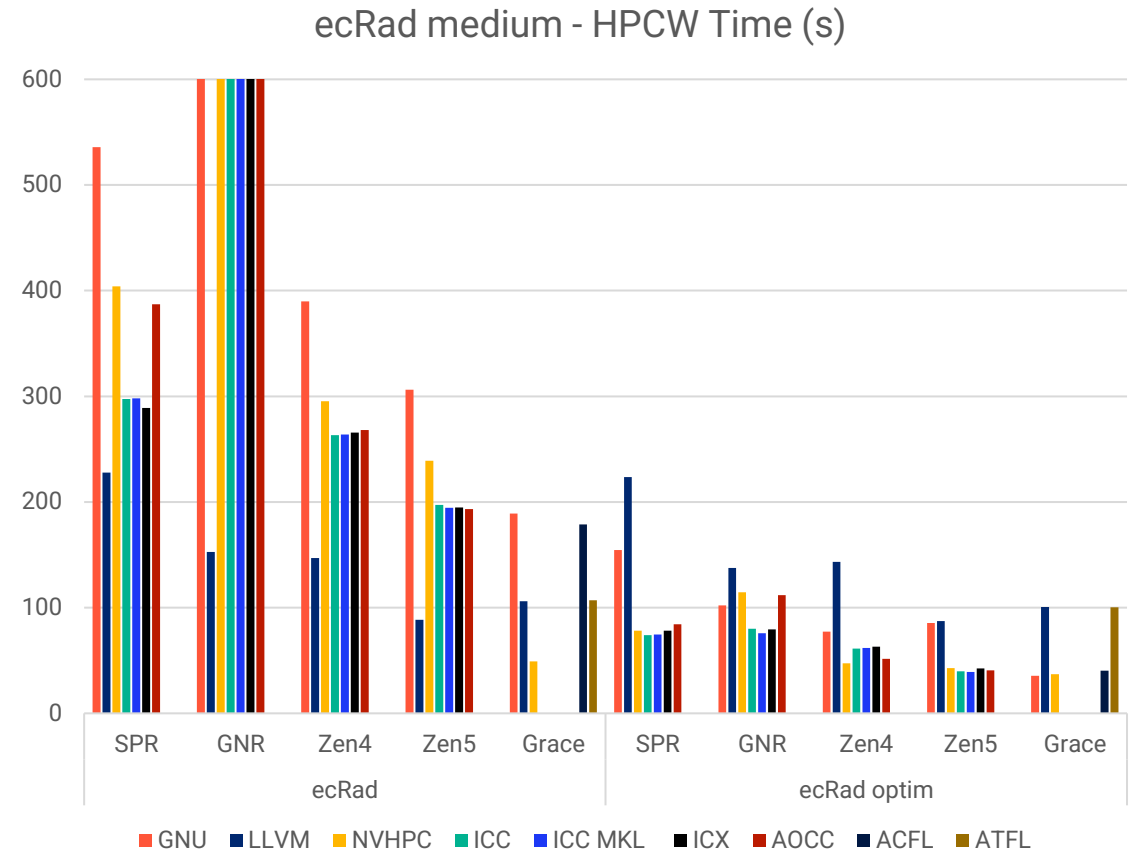
ESiWACE - Center of excellence for weather and climate

Notable Results and Experiences from ESiWACE in collaboration with EPI

- HBM vs DDR5



- ecRad IFS Dwarf optimization





7 Feedback and Conclusion

Feedback and Conclusion

In a nutshell

- After many years focused on the embedded market, Arm CPUs are now competitive in HPC
 - Several contenders: AWS Graviton 3/4, Nvidia Grace, LineShine LX2, SiPearl Rhea
- EUPEX led the way for CoEs to port on Arm
 - “x86 dogma” took its roots deeper than expected: source code, but also libs and build systems
 - Vectorizing for SVE requires the same effort as vectorizing for AVX
- European flagship codes benefit from HBM ; results depend on the application memory patterns
 - HBM cost remains high, tradeoffs to consider
 - HBM used in LineShine the 1st in top500 (June 2026)
- Codes are ready for running on the first European CPU tailored for HPC
 - Also ready for the first exploitation on Jupiter: the first exascale cluster in Europe runs on Arm
- Domain Specific Benchmark (DSB) representing HPC requirements from scientific flagship code developers

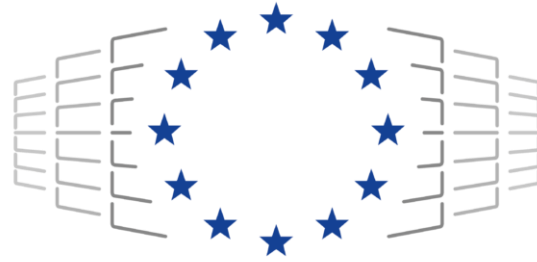
Take Away Message

Collaboration is key!



Questions

Acknowledgment



EuroHPC
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ChEESE

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Thank You

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