A new sustainable R&D strategy for advancing European leadership in sovereign cyber-infrastructures

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New generations of giant cyber-infrastructures are being designed to address grand challenges for humankind in Big Science (e.g. the Square Kilometer Array - SKA[1] giant radio telescope and the High Luminosity Large Hadron Collider from the European Organization for Nuclear Research - CERN HL-LHC[2]), new energy development (e.g. International Thermonuclear Experimental Reactor - ITER[3]), next generation telecommunication networks (e.g. 5G and 6G networks), pan-European supercomputing infrastructure (e.g. EuroHPC), mobility (rail & road) and aerospace applications, earth observation (for research, climate change adaptation and resilience, security and industrial applications) as well as regional power grids control & management. These large projects, where academia and industry meet and cooperate, share the same overall "Trans-Continuum" design, from the edge to users, leveraging a wide range of technologies.

The convergence of data, networking and compute capabilities in these leading edge industrial and scientific use scenarios requires to efficiently design systems of systems encompassing millions of compute devices and data logistics distributed over scientific instruments, Internet of Things (IoT[4]), edge computers, centralized High Performance Computing (HPC) in supercomputers as well as cloud systems through LAN, WLAN[5] and 5G networks.

The strong inter-dependencies between sub-systems, requires converging interoperability at functional and non-functional levels together with high efficiency, Reliability Availability Serviceability (RAS) as well as cybersecurity across the whole value chain.

As such, challenges along the continuum must be addressed at the global system level rather than through a collection of local optimizations, since improving one aspect of one given component or sub-system impacts other parts of the continuum and may impede operations. Moreover, jointly developing sub-systems, considering their complex interactions is the best way to maximize the overall efficiency. A truly multidisciplinary and trans-sectoral co-design effort is therefore needed, as well as a shaping strategy including governance and policies, covering many domains including access to energy, Total Cost of Ownership (TCO[6]) containment, supply chain management, predictive maintenance strategies, etc... beyond the many technologies required to implement these facilities (artificial intelligence, cyber-security, smart sensors / IoT devices, extreme scale data transport / distribution / access & federation, etc...).

Challenges span from the architectural building blocks down to global workflow design as well as applications analysis and a Trans-Continuum work program would include the following core technology developments among others:

- scalable data emulators leveraging efficient AI tools and trading-off accuracy with energy efficiency;
- new modular hardware platforms based on European technology;
- self-configurable systems minimizing resource wasting;
- global energy consumption optimization module;
- advanced data management and resources federation enabling secured access;
- optimized usage of distributed large scale cyber-infrastructures.

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[1] https://www.skao.int/en
[2] https://hilumilhc.web.cern.ch/content/hl-lhc-project
[3] https://www.iter.org/
[4] https://en.wikipedia.org/wiki/Internet_of_things
[5] https://en.wikipedia.org/wiki/Local_area_network ; https://en.wikipedia.org/wiki/Wireless_LAN
[6] https://en.wikipedia.org/wiki/Total_cost_of_ownership

Moreover, the Trans-Continuum approach described above is the pathway to sovereign sustainability as it addresses jointly the 3 following dimensions and their inter-dependencies:

- societal: by enhancing access to affordable services and knowledge, in particular through cross-fertilization across application domains;
- environmental: by enabling global energy efficiency, across the continuum, reducing the impact of major infrastructures and addressing a genuine operational constraint;
- economic: by promoting joint public-private development of sovereign strategic core technologies, increasing business opportunities and fostering jobs creation together with capacity building among the youngest generation. It also represents a very powerful means to reduce development and maintenance cost of giant facilities and secure the supply chain at regional level.

A concrete example of trans-sectoral collaboration has recently materialized through the SKAO-CERN-PRACE-GÉANT collaboration agreement[7] to take advantage of joining forces between research domains and prepare for the upcoming Exascale (ExaFlops and ExaBytes) challenge.

These communities built a R&D project, supported by a consortium of 25 partners including the pan-European research infrastructures (ESFRIs[8]) mentioned above, the Trans-Continuum Initiative[9], together with a group of European very large (Tier 0) supercomputing centers and some of the most advanced and innovative European deep tech companies, to address a number of challenges spanning the full digital continuum. With a budget of 25 M€, the project seeks to develop new system-level intelligent mechanisms for accessing, moving, converging, processing, reducing and storing large, structured, unstructured and time-varying data streams while enabling the scalable and efficient federated execution of dynamic, wide area analytics workflows, orchestrating HPDA[10], HPC and AI. The project is also perfectly aligned with the EU strategy for improving its position to compete with other regions in the area of HPC/HPDA technologies provision, embodied by the EuroHPC Joint Undertaking.

However, it appears that presently no R&D pathway exists to implement such project as work programs at European levels are currently mostly organized through channels addressing only one aspect of the Trans-Continuum cyber-infrastructure challenges. There is thus an urgent need to implement new global research pathways to provide adequate support to address the full complexity over the complete continuum. Moving forward, two actions could be envisioned on the short term: first, establish a European Center of Excellence acting as entry point and capitalizing knowledge and second, enable a large Trans-Continuum pilot project implementing new methodologies and providing learning experience. We need to rethink the way R&D is presently organized and to reshape it to tackle properly such challenges.

It is critical for Europe to build mechanisms now to enable such strategic Trans-Continuum research and technology development

[7] https://home.cern/news/news/computing/cern-skao-geant-and-prace-collaborate-high-performance-computing

[8] https://www.esfri.eu/

[9] The Trans-Continuum initiative is a horizontal collaboration between 8 European associations and projects involved in IT technology, application and services provisioning for the Digital Continuum: https://www.etp4hpc.eu/transcontinuum-initiative.html

[10] High Performance Data Analytics