Horizon Europe

Research & Innovation Program

HORIZON-CL4-2021-DATA: Future European platforms for the Edge: Meta Operating Systems

NEMO

Next Generation Meta Operating System

Version 1.0

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Disclaimer

The NEMO Consortium is the following:

Participant	Participant organisation name	Short name	Country
1	Atos Spain S.A.	ATOS	Spain
2	Atos IT Spain	ATOS IT	Spain
3	Thales Six GTS France S.A.S.	TSG	France
4	Engineering-Ingegneria Informatica SPA	ENG	Italy
5	Software Imagination & Vision SRL	SIM	Romania
6	INTRASOFT International S.A.	INTRA	Luxemburg
7	Maggioli Group SPA	MAG	Italy
8	Space Hellas S.A.	SPACE	Greece
9	Telefonica I+D	TID	Spain
10	Hellenic Telecommunications Organization S.A.	OTE	Greece
11	WIND TRE SpA	WIND	Italy
12	Continental Temic Microelectronic GmbH	CONTI	Germany
13	Entersoft S.A.	ESOFT	Greece
14	ASM Terni SpA	ASM	Italy
15	Foundation of Hellenic World	FHW	Greece
16	Novoville Ltd	NOVO	UK
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20	Sphynx Technology Solutions AG	STS	Switzerland
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22	Sorbonne Université	SU	France
23	Universidad Politécnica De Madrid	UPM	Spain
24	Institute of Communication and Computer Systems	ICCS	Greece
25	Rheinisch-Westfälische Technische Hochschule Aachen	RWTH	Germany
26	Eclipse Foundation Europe GmbH	ECL	Germany

The NEMO project, funded from the European Union's HORIZON-CL4-2021-DATA: Future European platforms for the Edge: Meta Operating Systems Call foresees as an eligible activity the provision of financial support to third parties, as a mean to achieve its own objectives.

Funding Scheme: Research & Innovation Action (RIA) ● Theme: HORIZON-CL4-2021-DATA
Start date of project: 01 October 2022 ● Duration: 36 months

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List of Abbreviations and Acronyms

AI	Artificial Intelligence
AIoT	Artificial Intelligent Internet of Things
CET	Central European Time
CF-DRL	Cybersecure Federated Deep Reinforcement Learning
CMDT	Cybersecure Micro-services' Digital Twins
DLT	Distributed Ledger Technology
DRL	Deep Reinforcement Learning
DT	Digital Twin
FML	Federated Machine Learning
EC	European Commission
EU	European Union
ML	Machine Learning
mOS	Meta-Operating System
mNCC	meta Network Cluster Controller
RES	Renewable Energy Sources
RTD	Research and Technological Development
SEE	Secure Execution Environment
SLO	Service Level Objective
SME	Small and Medium-sized enterprises
SSI	Self-Sovereign Identity
TL	Transfer Learning
TRL	Technology Readiness Level
VAT	Value Added Tax

1 Introduction

NEMO (Next Generation Meta Operating System) is a project funded under the Horizon Europe framework. Its strategic objective is to unleash the power of AIoT (Artificial Intelligence

IoT) in an IoT-to-edge-to-cloud continuum to increase European autonomy in data processing required by future AIoT and hyper-distributed applications.

As a mean of enhancing the public awareness, boosting massive adoption and sustainability and ensuring engagement of 3rd parties, NEMO will organize 2 open calls and embrace new members in the NEMO ecosystem. The objectives of the open calls are:

a) to enhance NEMO with additional (HW/SW) edge cloud/IoT components and plugins that realize or extend NEMO metaOS solution,

b) to increase awareness and interest on NEMO metaOS components and solutions,

c) to motivate DIHs and clusters to promote NEMO metaOS to their members and

d) to engage SMEs active as edge computing, edge cloud software development, native cloud, operating systems, full stack development, IoT applications development stakeholders, decision makers to enter and make sustainable the NEMO ecosystem.

This is the implementation of the 1st Open Call. The total amount of funding that will be provided is €900,000 while each entity may receive up to €150,000. It is expected that at least 6 applicants will be selected via this open call to enter the process and demonstrate the NEMO functionality.

NEMO Open Call#1 invites SMEs active as edge computing, edge and/or native cloud software development, operating systems, IoT/5G networks and IoT manufacturing entities to join the NEMO ecosystem by offering:

a) NEMO meta-architecture extensions

b) software components/plugins not covered by current NEMO implementation plan

c) new network or service/resources metering/automated control components or

d) porting NEMO on new, highly heterogeneous IoT devices.

1.1 Background information on NEMO project

NEMO pursue a close collaboration among semi-autonomous IoT nodes, IoT fog clusters, far-edge and near-edge cloud, national and federated cloud infrastructures. Following a ***flexible collaboration model***, new generation AIoT nodes will be equipped with intelligence to function in a semi-autonomous mode, reducing the latency and performing a number of complex operations locally, without transporting raw data. Federated *on-device* learning and data sovereignty and trusted, explicitly attested (edge) cloud nodes will bring AI to environments with limited network coverage. ***Local AI models execution (FML, DRL and TL) will result in reduced latency***. This will enable, for example, an industrial wind turbine to be shut down in milliseconds when it recognises an imminent problem, thereby preventing significant damage and saving expensive downtime; an autonomous car to avoid crashing or injuring a pedestrian, even if network connectivity is temporarily or accidentally lost. In parallel, powered by envisioning "free will" based communication, ***IoT devices may get support from other IoT nodes in vicinity or a trusted edge cloud node, or the cloud realizing a transparent AIoT-Edge-Cloud continuum***. During off-line training, the federated ML models will be aggregated at an edge node, to be processed and combined through TL. The inter-DLT transactions and the smart contracts will be facilitated by trusted edge nodes, allowing resource constrained nodes to acquire a full "ground truth". Complex and potentially

malicious functions will be executed at the edge nodes using a secure micro-services framework and container-based sandboxing techniques.

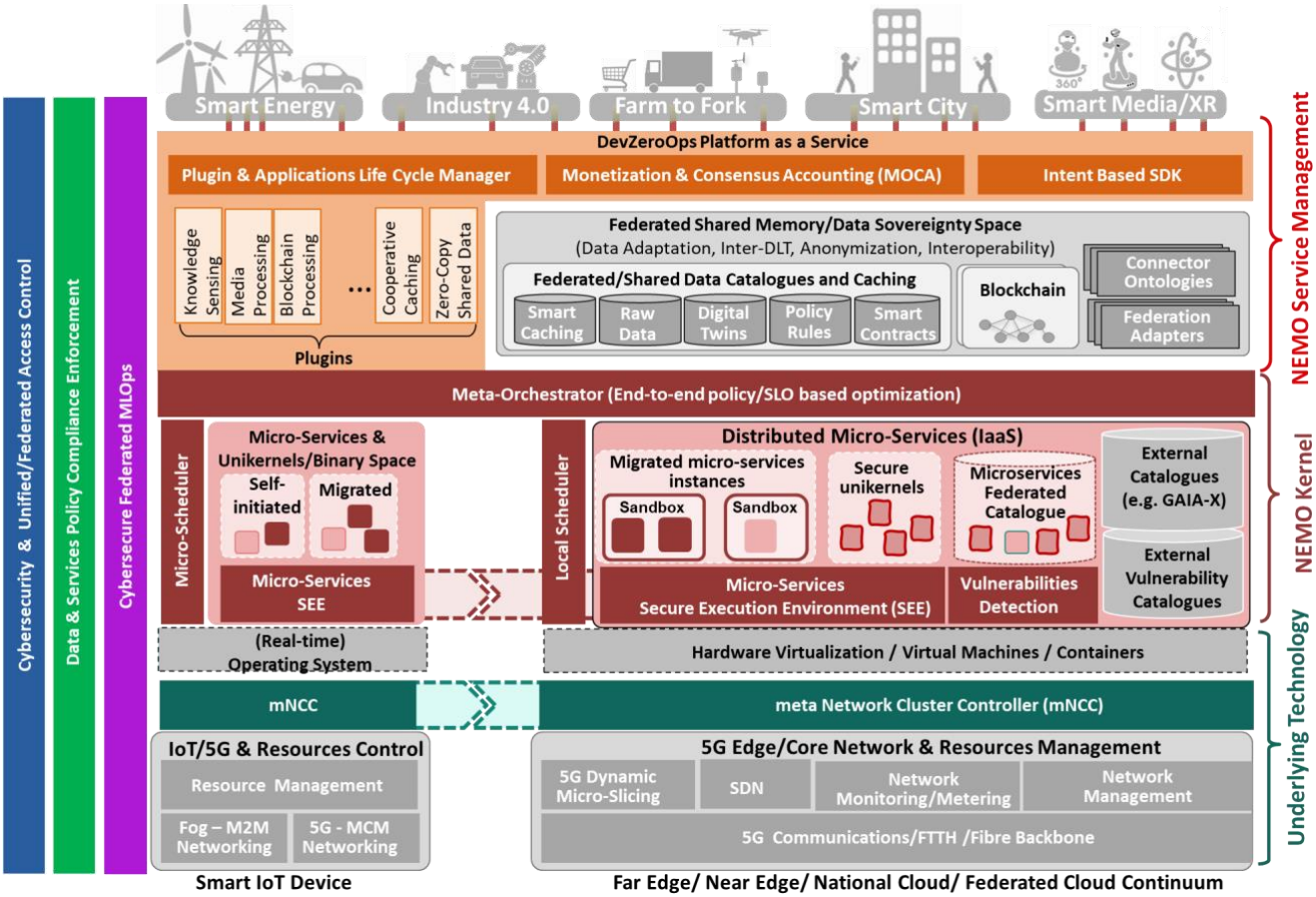

Figure 1: NEMO Functional Stack Vision

Based on the above principles, the core of NEMO will be based on a *loosely-coupled set of components*. As shown in Figure 1, though the lower layers are split between the Smart IoT and the Edge/Cloud Infrastructure, due to the IoT devices constrained environment, in the upper layers there is a "unified" federation that enables transparent execution of vertical semi-autonomous applications and data sharing. In a bottom up approach, NEMO foresees:

- Realisation of ***transparent network connectivity***, consisting of a set of IoT/5G/6G network optimization functions and dynamic allocation of self-aware resources into self-constructed/ self-healing and zero-delay failback network clusters. Instead of a single communication technology, NEMO introduces a ***meta Network Cluster Controller (mNCC)*** that is able to interface independent and different tools and protocols and, where it is possible, to replace one technology with another. To gain accurate information from network resources but still keep flexibility and openness, NEMO interfaces existing Monitoring and Network Management tools to directly request dedicated resources (i.e. micro-slices with specific bandwidth, delay and encryption characteristics), while FML algorithms are utilized for enabling advanced multi-path, multitenant connectivity over IoT and 3GPP data flows. NEMO also leverages on TSN bridge technology and time synchronization aspects to validate service stability, quality and compatibility with IEEE TSN.
- NEMO meta-Architecture features an AI-based ***meta-Orchestrator***, which automatically, and in real-time, re-configures the mOS setup at each node (either IoT, Edge, Cloud, ad-hoc or hybrid Clouds), so that the end-to-end federation operates optimally, matching the applications' SLOs and the policies set by the mOS administrators. The meta-

Orchestrator considers a number of existing solutions such as open source containers' platforms and orchestrators (i.e. Docker, Kubernetes, Minikube, K3S), technological, business and policy priorities, ranging from high availability and low latency to reduced energy consumption and CO_2 footprint to cost and community incentives trade-offs and will dynamically (re-)render micro-service and unikernels or even update automatically the hosting clusters. Of significant importance in the decision making will be the ***volume and "greenness" of the consumed energy and the CO_2 footprint***. NEMO introduces transparent migration of containers between federated Data Centres, considering not only the required electricity consumption for IT processing and communications, but also the RES mix and required cooling energy.

- NEMO ***Secure Execution Environment (SEE)*** implementing operational tasks in close interaction with the micro-services. NEMO SEE manages the complete micro-service life cycle, from image migration and storage to hosting, execution and supervision of both fully trusted/digitally signed micro-services instances along with potentially malicious ones.
- **Federated Data Sovereignty Space.** Though not focus of NEMO, the project follows GAIA-X approach and adopts some of the emerging Self-Sovereign Identity (SSI) technologies. The cybersecurity of data sharing federation is based on DLTs. NEMO introduces the ***Cybersecure Micro-services' Digital Twins (CMDT)*** concept to offer DLT traceability and Digital Twin (DT) scalability to micro-services instances. Moreover, NEMO ***Data Space*** is open to support technologies for green and responsible data management (results of the projects accepted respectively in calls DATA-01-01 and DATA-01-03).
- NEMO realizes a **DevZeroOps layer** offering full-stack automated operations, greatest flexibility, improved developers' productivity and direct monetization and sustainability. A key component for NEMO success is the flexible ***Plugin & Applications Life-Cycle Manager*** that enables over the air and on-time deployment of required plugins. This approach will keep NEMO "kernel" size tiny, while enabling cognitive auto-configuration. NEMO will also interface external plugins and microservices catalogues (e.g. GAIA-X, SONATA) to offer a "living" collection of functionalities, published under open source license. This approach will also allow 3rd parties to select among the components and create new IoT services.

Beyond horizontal, NEMO also introduces 3 vertical layers that support all metaOS activities:

- NEMO introduces a **Cybersecure Federated ML Operations (MLOps)** layer to offer efficient on-device intelligence in the form of decentralized, cybersecure FML/DRL to be used as integral part of any IoT node decision or (semi-) autonomous operation.
- NEMO enforces ***PRESS & Policy compliance*** via multi-faced policies able to cope with the different aspects of the applications life cycle (security, privacy, costs, environmental impact, etc).
- ***Cybersecurity & Unified/Federated Access Control Layer.*** Beyond "by design" traceability and cybersecurity, NEMO offers cloud native cybersecurity, by interfacing various authentication and authorization frameworks (e.g. 5G-AKA, EAP-AKA) and adopting the federated ID approach of GAIA-X, along with encryption and identity verification, adapted to the AIoT capabilities.

The NEMO outcomes will be validated across a multitude of real-life use cases through 6 trials:

- Trial #1: NEMO Integration Infrastructure Technology Lab
- Trial #2: Smart Farming Living Lab

- Trial #3: Smart Energy & Smart Mobility/City Living Lab
- Trial #4: Smart Manufacturing & Industry 4.0 Living Lab
- Trial#5: Smart Media/ City & XR Living Lab
- Trial #6: NEMO multi-Living Labs Federation

NEMO pilots will be federated to enable cross-NEMO services deployment and even cross-living labs micro-services mitigation. The federation will be further extended via the Open Calls. More information is available at https://meta-os.eu/.

1.2 Timeline – Open Call #1

Submission to the Open Call #1 will be enabled on Friday 1st of September 2023 and will end on Thursday 30th of November 2023 at 17:00CET time (Brussels time). Selected projects are expected to start on 1st of March 2024 and run for 18 months. Below are presented the dates for the different phases. The opening and closing dates of each phase can be subject to change in case of any modifications in the project's schedule.

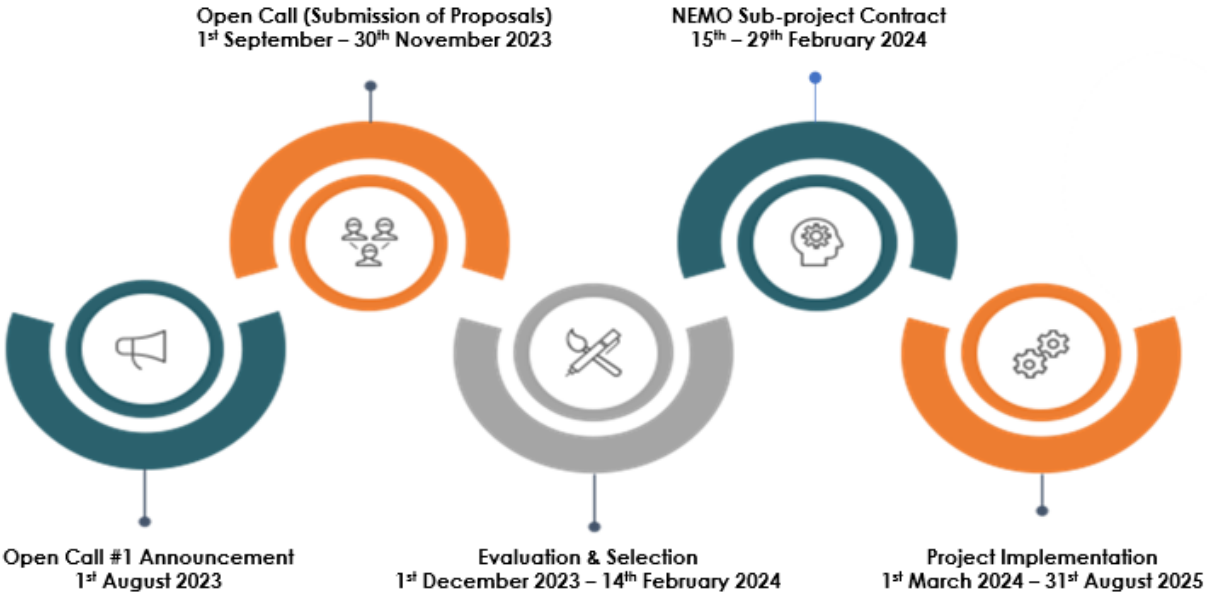

Figure 2: NEMO Open Call #1 timeline

1.3 Origin of the funds

Any selected proposer will be associated with NEMO via a sub-project contract.

The funds to the selected applicants come directly from the funds of the European Project NEMO, funded itself by under the EC Horizon Europe Framework Programme (HORIZON), and remain therefore, property of the EU until the payment of the balance, whose management rights have been transferred to the project partners in NEMO via European Commission Grant Agreement Number 101070118.

This relation between the new partners and the EC carries a set of obligations[1]

[1] More information at https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/guidance/programme-guide_horizon_en.pdf

1.4 NEMO Phases and Funding Scheme

As already explained, NEMO will organize two open calls. This is the **1st Open Call** aims to ***extend NEMO scope and technology***. The sub-projects selected via Open Call #1 will run for 18 months (1/3/2024 – 31/08/2025) following a "DESIGN-DEVELOP-VALIDATE" stages' program as shown in the next table.

Table 1. NEMO Open Call #1 stages

Stage	*Overview*
DESIGN 	• *Duration:* 3 months, the applicant will work remotely and occasionally participate in integration and testing activities • *Activities*: The applicant will fine-tune their application concept, prepare a detailed design deliverable (potentially including a mock-up or early prototype) and tech-business presentation • *Funding*: 30% (lump sum) per sub-project, associated to successful completion of the DESIGN phase, assessed by external reviewers.
DEVELOP 	• *Duration*: 10 months, the applicant will work remotely and occasionally participate in integration and testing activities • *Activities*: The applicant will be developing the proposed SW tools or application, provide a MVP (Minimum Viable Product) and validate it. Delivery of open-source versions of tools and/or applications (under proper license) is mandatory. • *Funding*: Up to 80% (lump sum) per sub-project, associated to successful completion of the DEVELOP phase, assessed by external reviewers.
VALIDATE 	• *Duration*: 5 months, the applicant will perform extensive testing and validation of the solutions at NEMO pilots. Moreover, they participate in several meetings and events where they can promote their projects goals and outcomes. • *Activities*: The applicant will realize activities associated with the testing and validation of their solution and support the open call #2 applicants. Moreover, they should promote and exploit their project, aiming to engage new customers and/or partners and/or investors. • *Funding*: Up to 100% (lump sum) per sub-project, associated to successful completion of the VALIDATE phase, assessed by external reviewers.

The funding for each new participant will be up to 150K€ and it is expected that at least 6 new companies will join the NEMO ecosystem via this open call. The selected partners of Open Call #1 will be funded as follows:

Table 1: NEMO Open Call #1 funding schema

Phase	Schedule	Cumulative Funding%	Condition / Event	Justification
DESIGN	May 2024	Up to 30%	Successful project design phase review	Acceptance of DESIGN phase deliverable(s)
DEVELOP	Oct 2024	Up to 50%	Successful project MVP sub-phase review	Acceptance of MVP sub-phase deliverable(s)
	March 2025	Up to 80%	Successful project Integration sub-phase review	Acceptance of Integration sub-phase deliverable(s)
VALIDATE	Aug 2025[2]	Up to 100%	Successful project final review	Acceptance of VALIDATE phase deliverable(s)

*It should be noticed that:

- All payments to be made promptly after the coordinator receives the same from EC.
- The Coordinator is entitled to withhold any payments due to a Defaulting Party except the amount of contribution that the Funding Authority, after acceptance of reporting, decides to be provided to the Defaulting Party

It should be noticed that the above payments will be associated with NEMO funding. Especially the last payment will be made after EC has made the final NEMO payment.

[2] The final payment will take place after NEMO coordinaor has received the final payment from EC

2 Open call overview

Table 2 provides a summary of the NEMO Open Call #1

Open Call item information	Open Call item information
Call title:	NEMO – Open Call #1
Full name of the EU funded project:	Next Generation Meta Operating System
Project acronym:	NEMO
Grant agreement number	Horizon - 101070118
Call publication date:	1st August 2023
Call deadline:	30th November 2023
Expected duration of participation:	18 months (1st March 2024 – 31st August 2025)
Total EU funding available (Open Call #1):	€ 900.000
Submission & evaluation process:	The objective of the NEMO – Open Call #1 is to extend NEMO scope and technology by inviting SMEs active as edge computing, edge and/or native cloud software development, operating systems, IoT/5G networks and IoT manufacturing entities. The open call will have three phases: • DESIGN (3 months duration) allowing the applicant to fine-tune their application concept. • DEVELOP (10 months duration) allowing the applicant to develop the proposed SW tools or application providing a MVP. • VALIDATE (5 months duration) allowing the applicant to proceed on activities associated with testing and validation of their solution. The total amount of funding that each SME will receive is up to €150.000. Submissions are available via https://www.f6s.com/nemo-1st-open-call/apply
Further information	Details available at https://meta-os.eu/index.php/open-calls/

3 Contacts

The NEMO consortium will provide information to the applicants only via the F6S blog, so that the information (question and answer), will be visible to all participants.

No binding information will be provided via any other means (e.g. telephone or email).

More info at: https://meta-os.eu/index.php/open-calls/

Apply via: https://www.f6s.com/nemo-1st-open-call/apply

F6S support team: support@f6s.com

Online Q&A: https://www.f6s.com/nemo-1st-open-call/discuss

Other support[3]: opencalls@meta-os.eu

[3] For non-binding information

4 References

[1] European Commission , "Recommendation 2003/361/EC," 2003. [Online]. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:124:0036:0041:en:PDF.

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[6] European Commission, "EU Funding & Tenders - Rules for Legal Entity Validation, LEAR Appointment and Financial Capacity Assessment," 2022. [Online]. Available: https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/common/guidance/rules-lev-lear-fca_en.pdf .