THE LINUX FOUNDATION

Software-Defined Vertical Industries: Transformation Through Open Source (2024)

How innovation speed, interoperability, and cost are the top drivers for shared software creation in the telecom, energy, automotive, financial, agriculture, and 3D graphics and motion picture industries.

Table of Contents

"When I say that innovation is being democratized, I mean that users of products and services-both firms and individual consumers-are increasingly able to innovate for themselves. User-centered innovation processes offer great advantages over the manufacturer-centric innovation development systems that have been the mainstay of commerce for hundreds of years. Users that innovate can develop exactly what they want rather than relying on manufacturers to act as their (often very imperfect) agents."

— Eric von Hippel, Democratizing Innovation

Overview

What do some of the world's largest, most regulated, most complex, centuries-old industries, such as finance, telecom, and energy, have in common with rapid-development, bleeding-edge innovative, creative industries such as the motion pictures industry?

They're all increasingly dependent on open source software (OSS) and are building open source into the fabric of their R&D and development models. Almost every industry sector in the global economy today relies on software and hardware products whose codebases contain open source code, and the

percentage of open source versus proprietary code is growing.

In addition to increasing software consumption, a recent McKinsey & Co. report said that the "biggest differentiator" for top-quartile companies in an industry vertical was "open source adoption," where companies shifted from users to contributors. In fact, the report's data shows that top-quartile company adoption of open source has three times the impact on innovation than companies in other quartiles.
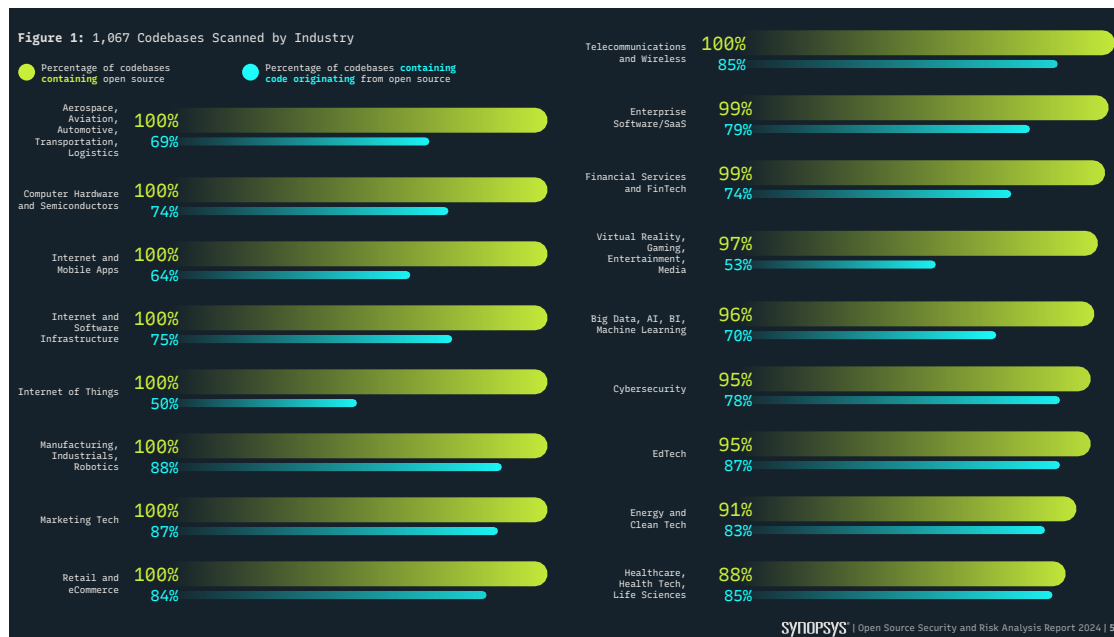
Codebases scanned by industry. Source: 2023 OSSRA Report by Synopsys

In 2015, the United Nations introduced 17 Sustainable Development Goals (SDGs) in its "2030 Agenda for Sustainable Development," representing a plan of action for organizations and institutions to progress toward economic, social, and environmental sustainability. The relevance of open source in this endeavor was clear: The U.N. Global Compact stated that digital technology—particularly open source—would be instrumental in achieving the U.N. SDGs.

Role of the Linux Foundation

Over the last 20+ years, the Linux Foundation has expanded from a single project, the Linux kernel, to hundreds of distinct project communities. The "foundation as a service" model developed by the Linux Foundation supports communities collaborating on open source across key horizontal technology domains, such as cloud, security, blockchain, and the web.

LF-hosted project communities are at the forefront of helping industries to become increasingly software defined. From meeting the global demands for secure, scalable data networks to creating standards that solve common regulatory challenges, industry-focused open source projects enable common, accessible, secure, and cost-effective solutions that create shared value for all.

Linux Foundation surveys have consistently shown that demand for open source technology skills continues to grow. In 2023, cumulative trainee enrollments exceeded 3 million, with over 1,000 people taking an LF Training exam each week on average.

Learning Together

Many Linux Foundation project communities align across vertical industry groupings. While they may have started as individual efforts looking for a neutral home at the Linux Foundation, many projects have found that collaborating and learning from each other is quite useful. Cybersecurity and artificial intelligence (AI) are increasingly vital to all areas of the digital economy, and success in one vertical can lead to innovation in another. The energy sector, for example, is following a similar, proven trajectory as the telecom sector. In these cases, OSS best practices guide these industries toward their full potential and a software-defined future.

This paper will delve into the major vertical industry initiatives served by the Linux Foundation. We highlight notable open source projects and why these key industry verticals, some over 100 years old, have transformed themselves using OSS.

What is driving vertical industries to collaborate in open source?

Many vertical industries are under constant pressure to innovate. Still, there are challenges of supply chains, diverse customer requirements, regulations, and a lack of talent to do everything leadership may envision in any complex business. Some organizations choose to do the same things they've always done over and over but try moving faster or investing more than their peers. They often develop strategic frameworks built around a core competitive advantage that they believe gives them an edge.

Some companies choose to execute their vision differently, often relying on software to redefine their processes and assets. They take the core of their business and transform it into APIs, functions, and cloud assets. Once these processes and assets are software defined, companies often see the opportunities for converging various business functions. The trend is similar to what the world saw in the convergence of voice, text, data, and the Internet in telecom.

"The data shows that top-quartile company adoption of open source has three times the impact on innovation as compared with companies in other quartiles."

— McKinsey & Co.

When an organization's core strategic functions shift to a software-defined model, many companies find that they increasingly depend on software developers. At least one tech industry analyst refers to this realization as "The New Kingmakers." This change toward software-defined infrastructure is a fundamental shift for vertical industry organizations.

Telecommunications

LF Networking & Adjacent Communities

Now a century and a half old, the pace of innovation in the telecommunications industry has accelerated rapidly thanks to end user–driven innovation, industry collaboration, and the convergence of technologies— all enabled by open source. Networking spans other industry verticals as a unifying technology universal to modern communications, ranging from simple web transactions to complex service chains. Some of the world's largest telecom companies today participate in developing open source networking products to ensure that the network evolves in lockstep with emerging technology products and business models.

But historically, telecom networks have been vendor led, proprietary, and slow moving with standards-based black box equipment deployed globally. Recognizing the importance of networking to our digital societies and economies as well as the opportunities presented by integration with cloud networks, the industry is now in the throes of massive capital infrastructure investment on the order of hundreds of billions of USD worldwide.

As telecom providers move away from proprietary networking hardware, they are embracing the software-defined model and avoiding the level of effort, complexity, and cost required to "go it alone" by developing siloed network software stacks. While telecom providers are fiercely competitive with each other, they are also all trying to solve similar problems with the move to cloud native, 6G/NextG, AI-native networks, and beyond.

In 2013, the Linux Foundation hosted an initial OSS project to enable this transformation by creating OpenDaylight, a software-defined networking (SDN) controller. In 2017, when global telecom providers AT&T and China Mobile realized that they were solving the same "undifferentiated" problem of network automation, they joined forces to create the Open Networking Automation Platform (ONAP) project, and soon after, the Linux Foundation Networking (LFN) project umbrella was formed. At inception, LFN encompassed a handful of existing networking projects already hosted by the Linux Foundation (such as Anuket, FD.io, OpenDaylight, and ONAP—all working to solve challenges at different layers of the networking stack), marking a new era of end user–driven innovation.

LFN was one of the first project umbrellas at the Linux Foundation. Its software and projects provide the foundations for network infrastructure and services across service providers, cloud providers, enterprises, vendors, and system integrators that enable rapid interoperability, deployment, and adoption.

Today, LFN serves as the collaboration hub that unifies the entire open networking stack, from cloud to core and beyond. It hosts 10+ projects under the official umbrella and collaborates closely with countless other, related open source groups within and outside of the Linux Foundation ecosystem (such as the Linux Foundation's Sylva, SONiC, CAMARA, and O-RAN Software Community (SC) plus industry groups such as Open Compute Project and IOWN Global Forum).

LFN is a collaboration hub that unifies the stack
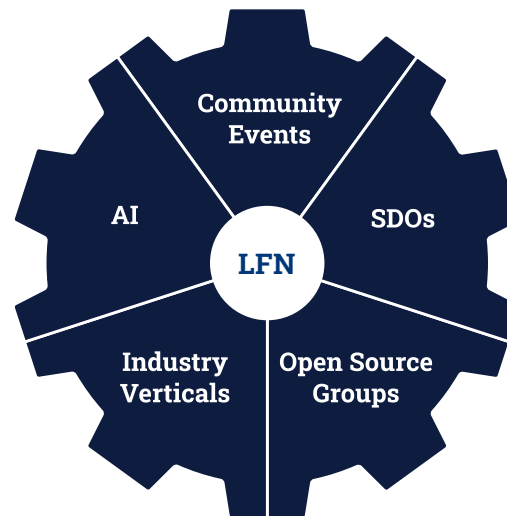
LFN's role as industry collaboration hub across the entire stack is pivotal in cross-industry network transformation.

Shift to Cloud Native

Communications networks are extremely expensive to build and maintain, especially as they're built to handle more traffic, consume more spectrum, and integrate a wider range of technologies. Consumer demand for all things digital, along with mobile traffic generated from apps such as TikTok, continues to grow year after year. This requires telecom operators to continuously augment the efficiency, capacity, and capabilities of their networks. Companies looking to break out of "business as usual" embraced open source as a way to collaborate, innovate, and work toward common goals. Through this approach, telecom operators became more agile, flexible, and automated and increasingly interoperable with ecosystem offerings built on open source.

The rise of cloud computing—which has been a game changer for nearly all enterprise verticals—has also been transformative for today's global networks. Network architects today require the freedom to choose between private, public, and hybrid clouds as they integrate cloud computing into their overall networking strategies.

Cloud service providers such as Amazon and Google are looking to expand their customer reach and revenue opportunities through telecom networks; at the same time, telecom operators look to leverage the power of cloud-based services in their offerings to generate enterprise demand and revenue. How this "coopetition" plays out will be a key pivot point for the industry going forward.

This type of network transformation is only possible through cloud native approaches to developing, building, and deploying workloads at scale in a programmatic and repeatable manner. Per the CNCF, cloud native technologies and architectures typically consist of some combination of containers, service meshes, multi-tenancy, microservices, immutable infrastructure, serverless, and declarative APIs. A true transformation to cloud native networks and an open, healthy ecosystem involves the use of cloud native networking end to end. This approach helps ensure systems in which applications interoperate in a manner that is secure, resilient, manageable, sustainable, and observable—all required for a healthy SDN ecosystem.

The Nephio project is a great example of bridging the gap between traditional networks and cloud native approaches using Kubernetes-based cloud native intent automation across large-scale cloud and edge deployments. It was developed by Google and donated to the Linux Foundation, and it has now found a home under the LFN umbrella. Nephio enables faster onboarding of network functions to production, including the provisioning of underlying cloud infrastructure with a true cloud native approach that reduces the costs of adoption of cloud and network infrastructure.

To further the advance of cloud native approaches, LFN—in partnership with CNCF—launched the Cloud Native Telecom Initiative (CNTI) in 2023. The initiative brings together telecom networking and cloud native thought leaders from across LFN and CNCF all working together toward the same goals: to advance cloud native networking confidence and adoption through best practices, test catalogs, and certification.

Network APIs & Programmability

APIs allow for network programmability by enabling applications to interact dynamically with network infrastructure. By creating interoperability between applications, systems designers can assemble software stacks suited to their particular needs at any given time. For instance, APIs provide a structured method for accessing telemetry data showing network performance, potential system bottlenecks, and more. By tapping into this data, applications can improve performance through better decision-making for things such as load balancing across the network. APIs also drive monetization for telco operators and enterprise customers by allowing new revenue-generating services.

"In just 12 short months, we have seen strong growth [in Open Gateway]. Today, almost 240 operators representing over 65% of the mobile connections have joined Open Gateway. Forty operators have commercially launched over 90 CAMARA APIs that are ready to be used."

— Mats Granryd, director general, GSMA

The CAMARA Project

CAMARA is an open source project within the Linux Foundation to define, develop, and test APIs. CAMARA works in close collaboration with the GSMA Operator Platform Group to align API requirements and publish API definitions and create (service and service management) APIs. Harmonization of APIs is achieved through fast and agile created working code with developer-friendly documentation. The on-demand, secure, and controlled exposure of the capabilities exposed via network APIs paves the way for transforming operator networks into service enablement platforms, facilitating the application-to-network integration, which will be key to delivering enhanced and service-tailored customer experience in the 5G+ era. In other words, this work is critical to unleashing the full potential of modern network environments across telecom, cloud, and the edge.

AI

The future of intelligent networking and AI lies in the hands of individuals and organizations willing to contribute to new and existing projects. Whether they are involved in network building, network technology development, or network services consumption, contributing to AI-centric open source projects is an educational and rewarding way to shape the future of intelligent networking.

In the ever-evolving landscape of technology, OSS projects and initiatives play a pivotal role. Understanding their origins and current state is crucial to appreciating how OSS can effectively tackle the challenges posed by intelligent networking.

Several open source initiatives have paved the way for network AI solutions. These projects, either already established or in active development, form the groundwork for intelligent networking.

The industry is seeing a tangible networking industry shift into the enterprise, already coming to fruition: The L3AF project, which Walmart donated to the Linux Foundation in 2021 with the support of other leading tech companies, enables kernel function as a service with lifecycle management of eBPF networking application programs.

By leveraging these foundations, LFN envisions a future where OSS becomes a driving force in unlocking the potential of AI for networking generations to come. Within the networking industry, certain AI technologies are specific to their domains, and existing OSS projects within this landscape must address these unique requirements. Simultaneously, more generic technologies—essential for AI-driven networking—will emerge from the broader community of AI OSS. The collaboration between these two realms will shape the future of networking technology.

OSS and Networking AI Layers

- **Data Models and Infrastructure:** OSS projects contribute to building a common understanding of underlying data models and developing infrastructure blueprints.

- **Integration and Interoperability:** Existing projects bridge the gap between diverse networking components, ensuring seamless integration.

- **Security and Resilience:** OSS initiatives enhance security practices and resilience mechanisms.

- **AI Algorithms and Frameworks:** The broader AI community provides generic AI technologies that can be harnessed for networking purposes.

LFN and open source play a pivotal role in fostering intelligent networking technologies. Key projects within LFN focus on various aspects, including data models, infrastructure, and integration blueprints. The April 2024 "Intelligent Networking, AI and Machine Learning for Telecommunications Operators" white paper from LFN provides more insight into these trends.

Technology Disruption
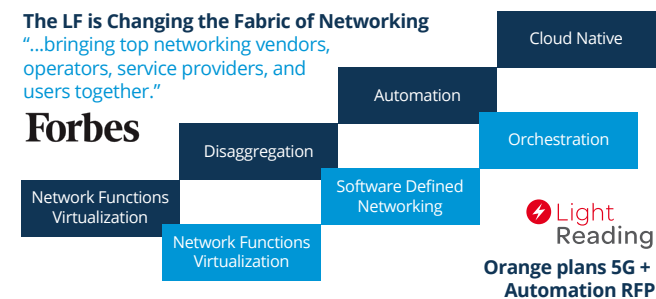
How LFN has changed the telecommunications industry.

The industry has seen tremendous support for open source in network automation, 5G/6G, AI/machine learning (ML), edge, and open radio access network (RAN) in the last five years. This is truly end user–driven innovation but with a twist: It is a global collaborative effort across telecom providers, their vendors, and system integrators, all harmonized by implementing standards from ETSI, MEF, 3GPP, TMF, GSMA, O-RAN, etc.
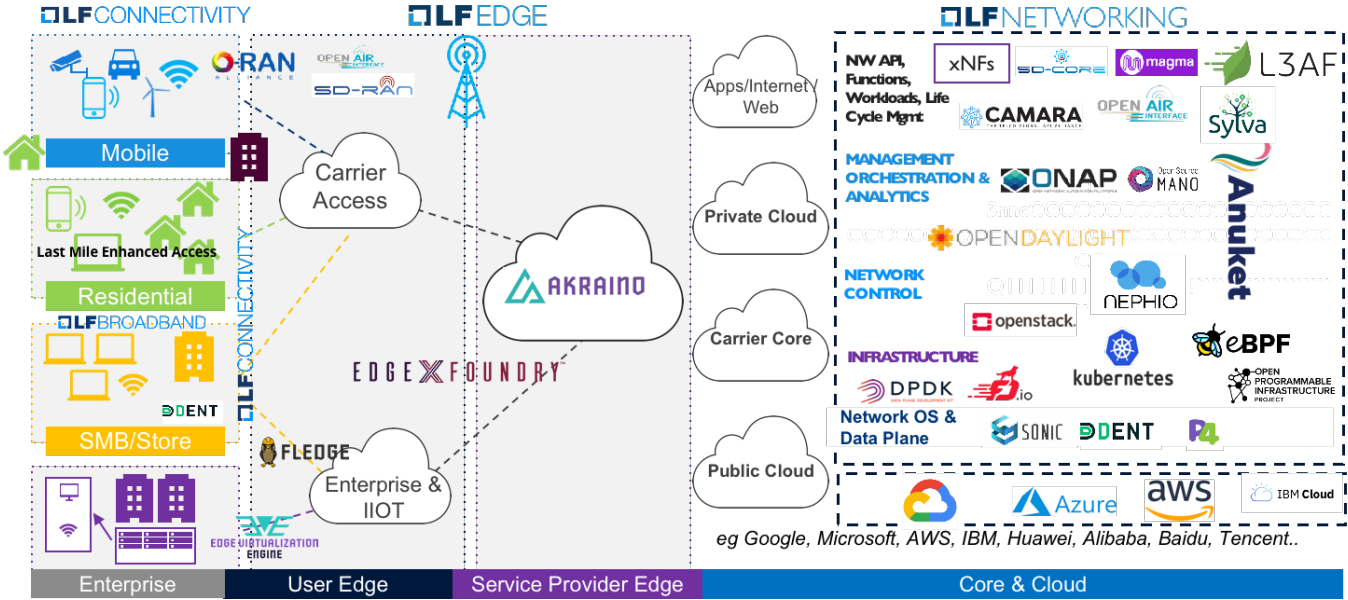
Today, LFN's open source networking projects provide a full network stack of software created in open and neutral governance, enabling providers to automate networks and innovate in weeks and months versus years, all while driving the cost of interoperability down.

The focus today has clearly shifted from specific projects that solve one problem or address one domain to end-to-end integration projects that provide a complete service. Initiatives such as the 5G Super Blueprint took center stage by showing how various open source projects can be used to build a network architecture that delivers on the potential of 5G and edge computing with a high degree of automation. The "super blueprint" approach is expected to grow and evolve into a broader swath of use cases, such as enterprise networking.

Cross-Stack Integration

When visualizing the open networking "stack" that underpins a modern telecommunications provider's infrastructure, one sees that many elements are enabled by projects hosted by LFN and the Linux Foundation. Supported by a diverse member base, these projects enable the industry to work together as well as collaborate closely with industry standards bodies, industry consortiums, other open source communities, and open hardware initiatives.

This diagram indicates how an open source vision of end-to-end solutions is realized across the industry, with an increasing number of real-world deployments coming to fruition.

Open source networking and edge ecosystem stack from end to end.

LFN in Deployment

verizon✓ ✳ OPENDAYLIGHT	**netgate.** FD.io	**AARNA NETWORKS** Capgemini	**Walmart** L3AF SONiC
OpenDaylight is Verizon's foundational and directional SDN controller with two use cases in production across the network. Future integration will include different types of data modeling technology, open APIs, rest platforms, and more.	Netgate and Intel's Arkansas State University Three Rivers user story discusses how to provide real-world computing infrastructure and real-time access to data, the Internet, and other resources to students based on FD.io Vector Packet Processing (VPP.)	Capgemini was approached by a large enterprise customer in Japan who needed a RAN and core for a new private 5G network. They chose to build upon the work of the 5G Super Blueprint for an IoT and mobile broadband use case.	Walmart leverages open source technologies to efficiently manage its massive network infrastructure. It's deployed Enterprise SONiC at scale in its data centers and is looking to use it across stores, distribution centers, campuses, and beyond. LFN's L3AF is also deployed and is crucial for Walmart's observability, network functions, security, and business impact.

Learn more and see additional examples of how LFN projects are being deployed in production.

Telecom has hit a tipping point, with a broader swath of industry organizations now reaping the benefits of open source technologies in production, saving on CAPEX, OPEX, R&D, and more.

LFN Projects & Initiatives

- **Anuket:** Anuket delivers a common model, standardized reference infrastructure specifications, and conformance and performance frameworks for virtualized and cloud native network functions, enabling faster, more robust onboarding into production, reducing costs and accelerating communications digital transformations.

- **CNTI (an LFN initiative):** The Cloud Native Telco Initiative (CNTI) brings telco networking and cloud native thought leaders together to advance cloud native networking confidence and adoption.

- **FD.io:** FD.io (pronounced "Fido") is an open source, high-performance I/O services framework for dynamic computing environments. Its VPP platform enriches data plane leadership and deployment efficiency.

- **L3AF:** L3AF's vision is to create a marketplace for eBPF programs (kernel functions) where users and developers can share their own signed kernel functions and download kernel functions from others.

- **Nephio:** Nephio merges cloud's simplicity and flexibility with telecom's reliability and connectivity, delivering robust, cloud native intent automation. Nephio acts as a lightweight Kubernetes add-on bridging the gap between telco and enterprise by offering key network services.

- **OpenDaylight:** OpenDaylight is a modular open source SDN platform for customizing and automating networks of any size and scale.

- **ONAP:** ONAP is a comprehensive platform for the orchestration, management, and automation of network and edge computing services for network operators, cloud providers, and enterprises. It serves as a database of components that operators can tailor to create customized solutions based on their specific needs.

- **XGVela:** XGVela is an open source, cloud native PaaS for applications and telco network functions that enables new services and helps mobile operators to seize the business opportunity from vertical industries in the 5G era.

- **5G Super Blueprint (an LFN initiative):** The 5G Super Blueprint gives global communications providers and businesses a full architecture of how to deliver a total solution—replete with high-bandwidth, low-latency, scalable, and cost-effective digital networking infrastructure—from end-user device to cloud application destination.

Other networking ecosystem projects:

- **CAMARA:** CAMARA is an open source networking API project hosted by the Linux Foundation that can be combined to directly affect change on the network from within an application.

- **DENT:** DENT is an open source network operating system utilizing the Linux Kernel, Switchdev, and other Linux-based projects, hosted under the Linux Foundation.

- **Data Plane Development Kit:** The Data Plane Development Kit (DPDK) consists of libraries that accelerate packet-processing workloads running on a wide variety of CPU architectures.

LF CONNECTIVITY

- **Linux Foundation Connectivity:** Linux Foundation Connectivity is an open source project under the Linux Foundation focused on advancing technologies that will accelerate emerging network and connectivity applications.

OPEN PROGRAMMABLE INFRASTRUCTURE PROJECT

- **Open Programmable Infrastructure (OPI):** The OPI project provides open ecosystems for next-generation architectures and frameworks. OPI's objective is to foster a community-driven, standards-based open ecosystem for next-generation architectures and frameworks based on DPU-/IPU-like technologies.

O-RAN ALLIANCE

- **O-RAN SC:** O-RAN SC is a collaboration between the O-RAN Alliance and Linux Foundation with the mission to support software creation for the RAN. O-RAN SC plans to leverage other LF network projects while addressing the challenges in performance, scale, and 3GPP alignment.

paraglider

- **Paraglider:** Paraglider is a cross-cloud control plane for configuring cloud networks that aims to evolve cloud networking by simplifying the creation and management of single and multicloud networking.

SONiC

- **SONiC:** SONiC is an open source network operating system based on Linux that runs on over 100 different switches from multiple vendors and ASICs. It offers a full suite of network functionality that has been production-hardened in the data centers of some of the largest cloud service providers.

Sylva

- **Sylva:** The Sylva project is designed to create a new, open source production-grade telco cloud stack. Sylva's common cloud software framework and adjacent reference implementation reduces fragmentation of the cloud infrastructure layer for telecommunication and edge services.

Looking Ahead

Open source approaches and code continue to gain traction and adoption across the networking stack. O-RAN represents one of the final frontiers for telecom operators' interoperable, virtualized, and disaggregated hardware and software solutions. By embracing O-RAN, network operators can break free from the traditional closed and proprietary network architectures and gain the ability to select and integrate components from different vendors, promote innovation, reduce costs, and enhance security. O-RAN SC is helping to make this happen.

Another area of growth and integration can be seen at the network edge. There are many advantages to bringing compute and storage closer to the devices producing data and the end users consuming it. Companies today are increasingly taking advantage of edge technologies that improve performance, reduce latency, and provide real-time system insights. AI workloads are a great example of how edge computing working harmoniously with the network can deliver optimal performance and efficiency. In the near term, we can expect AI workloads to be the driving force and create new synergy opportunities for edge and networking technologies.

Networks will need to adapt to these use cases, characterized by demands for ultra-low latency and higher bandwidth. This will require highly decentralized networks with more compute and networking power at the edge. LFN and LF Edge are already addressing such use cases, and we will likely see this architecture becoming mainstream in the future.

Energy

LF Energy

On September 4, 1882, Thomas Edison turned on a series of interconnected generators at the Pearl Street Station in Lower Manhattan, lighting up America's first electrical grid. Throughout the late 1800s into the middle of the 20th century, we experienced a great wave of innovation driven by electrons from fossil fuel that has accelerated economic growth across every industry, resulting in 150 years of prosperity.

With that prosperity, the world saw a massive increase in the demand for energy production components, specifically carbon-based fuels. As a result, the energy industry is responsible for considerable carbon emissions generated yearly.

Aside from a slight dip in 2020 due to the COVID-19 pandemic, fossil fuel consumption has grown exponentially in recent decades.
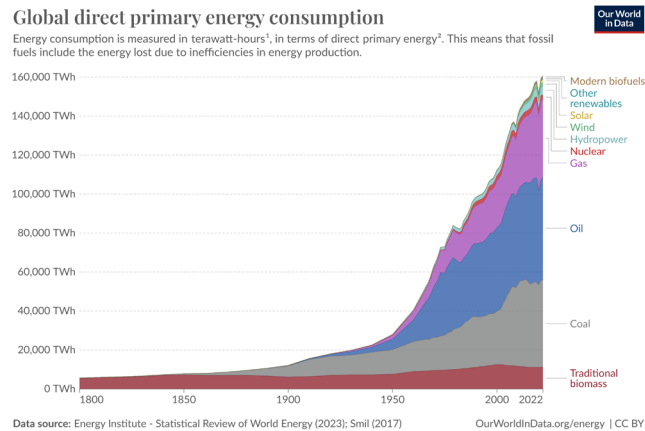
Global energy consumption by carbon fuel source.[1]

Nearly three-quarters of global carbon emissions come from the energy sector, including electricity, heat, and transportation.
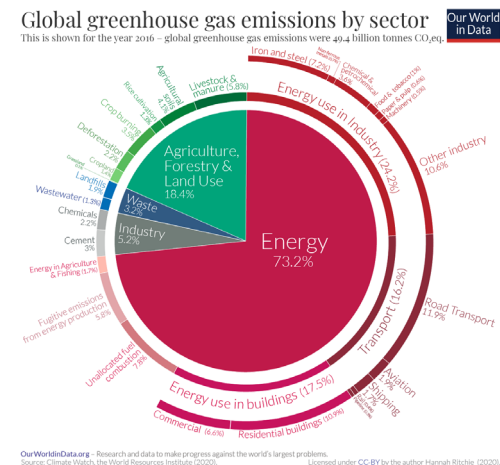
Sources of highest CO2 emissions.[2]

In the 21st century, we face the unintended consequences of using carbon-intensive fuels. Today, we are discovering the impact of CO_2 emissions that are causing climate chaos, as evidenced by the rapid acceleration of fires, droughts, hurricanes, floods, and the melting of the polar ice caps. Real economic consequences are resulting from these changes in our environment. Countries and organizations in the energy industry are calling for urgent collective action.

> "The energy transition requires digitalization and open collaboration on shared problems, and is the proven best way to accelerate innovation. This is a multi-decade effort, and we're just getting started."
>
> — Alex Thornton, Executive Director, LF Energy

LF Energy (LFE) was founded in 2018 by the late Dr. Shuli Goodman with a vision to create a technology ecosystem that enables decarbonization of the energy sector through innovation and interoperability. This includes the entire technology stack used by those producing, transmitting, distributing, and using energy over large grids, microgrids, distributed energy resources and storage, electric vehicles (EVs), and more.

Similar to telecom, the energy industry is traditionally heavily regulated and slow moving, with a myriad of overlapping and competing global standards and protocols. By embracing open source and the best practices for software development that come with it, the energy ecosystem is set to follow the networking ecosystem's proven path for open source adoption and industry transformation.

LFE's mission is to accelerate the energy transition by building communities to develop open technologies and standards. LFE leverages transparent, open source development best practices and existing and emerging standards to efficiently scale, modernize, and digitally transform the power systems sector. By providing frameworks and reference architectures, LFE minimizes pain points such as cybersecurity, interoperability, control, automation, network functions virtualization, and the digital orchestration of supply and demand management. LFE strives to be the place for these techniques to be developed together and for high-value, high-quality open benchmark datasets to be made available for open, use case–driven, peer-reviewed collaborative research and innovation.

LFE is partnering with the [U.S. Joint Office of Energy and Transportation](#) to build an open source reference implementation for EV charging infrastructure. LFE's EVerest project will develop and maintain an OSS stack for energy communications across charging stations, vehicles, generation resources, batteries, adjacent chargers, power grids, back-end payment systems, user interfaces, and mobile devices. This will reduce instances of incompatibility that result from proprietary systems and make charging more reliable for EV drivers.

Spotlight on AI

AI has massive potential to accelerate the transformation and decarbonization of energy systems in the following principal ways:

- Tackling complexity and variability as climate change and the energy transition make power systems even more complex

- Handling rising volumes of data as power grids are increasingly digitalized and decentralized

- Allowing further optimization and automation of processes, thereby improving performance and pushing the limits of existing systems

Stakeholders in the energy industry are looking for ways to tap this potential—from enterprise-level applications all the way to real-time critical processes. The potential of AI relies heavily on access to data, and much of the granular data in energy involves some degree of privacy, confidentiality, cybersecurity, and critical infrastructure protection issues. Accordingly, facilitating access to realistic and relevant data was chosen as our number-one priority. Open innovation and collaboration in this area will bring new solutions: synthetic data generation based on real datasets, privacy-preserving techniques, and more.

The Path to Production

Putting LFE projects, platforms, and tooling into deployment signifies a certain level of maturity, directly benefits members, and evolves the energy ecosystem toward an open source future. Some examples of LFE projects being deployed in real-world environments follow:

- **CoMPAS:** A collection of Dutch grid operators developed the CoMPAS software tool in LFE to streamline the IEC 61850 data model for the Real Time Interface project. It is being used to remove unnecessary elements, reduce errors, and expedite the overall development process.

- **EVerest:** Seeed Studio, a leading IoT hardware company, recognized the growing demand for an efficient and customizable open source EV charging solution. The challenge was to develop a product-ready solution that aligned with the evolving market needs, offering scalability, security, and adaptability for diverse applications. Seeed used LFE EVerest's to provide energy management and grid integration focus, coupled with Zephyr's real-time operating system for IoT devices, creating a modular and customizable solution.

- **FledgePOWER:** French transmission system operator (TSO) RTE needed to build an updated control system; however, the problem of multiple protocol translation first had to be solved. RTE and its partner Dianomic determined that FledgePOWER, a multi-protocol translation gateway for power systems from LFE based on the industrial IoT LF Edge project Fledge, could be used to address this issue. The initial deployment of a FledgePOWER gateway in the first substation has verified that deploying it is significantly easier and less costly compared with migrating the existing remote terminal unit to a more recent version.

- **OpenSTEF:** Alliander, a Dutch distribution system operator, requires accurate forecasts of the load on the electricity grid, looking hours to days ahead. Alliander deployed the OpenSTEF project to anticipate congestion in the distribution grid, to allow for grid safety analysis for transmission, and to locally balance supply and demand.

- **Power Grid Model:** Alliander's Delvi Project utilizes cutting-edge modeling coupled with LFE's Power Grid Model tool to orchestrate vital upgrades to the low-voltage (LV) grid. By weighting thousands of predictions with granularity across different consumer types and local demand patterns, Alliander is empowered to proactively orchestrate capacity upgrades and ensure a seamless transition in LV grid capacity without disruption.

- **PowSyBl:** Artelys, an optimization, decision support, and modeling company, is setting up an operational security analysis platform for the European electricity network to facilitate cross-border energy exchanges. To coordinate exchanges between different TSOs, the PowSyBl framework is being launched over an HPC cluster to simulate thousands of contingencies and determine risks.

- **Real Time Data Ingestion Platform:** Real Time Data Ingestion Platform (RTDIP) can be a powerful tool for businesses looking to forecast energy usage. RTDIP defines example pipelines for meter data from ISOs such as MISO (Midcontinent ISO) and PJM (Pennsylvania-New Jersey-Maryland Interconnection). Meter data can include consumption patterns, load profiles, and real-time measurements. The sources and transformers in RTDIP can acquire and translate meter data into suitable data models for efficient storage and analysis.

- **SOGNO:** Areti, the grid operator in Rome, has adopted the SOGNO platform in its architecture to connect customers directly to the distribution management system with a blockchain layer and light node hardware deployed at the point of delivery. This first-of-its-kind deployment helps TSOs avoid local congestion and increase efficiency.

LFE is managed by its members, with a very active Technical Advisory Council and Governing Board made up of representatives from Strategic members—Alliander, Google, Microsoft, RTE, and Shell—as well as 60+ General and Associate members, including AVEVA, GE Vernova, Hydro-Québec, AspenTech, EPRI, ENTSO-E, NREL, and Stanford University.

Community Growth

Contributors ⓘ

Active Contributors are **increased by 27%** 📈 vs. the previous time period.

Legend: ● Active Contributors — Total Contributors
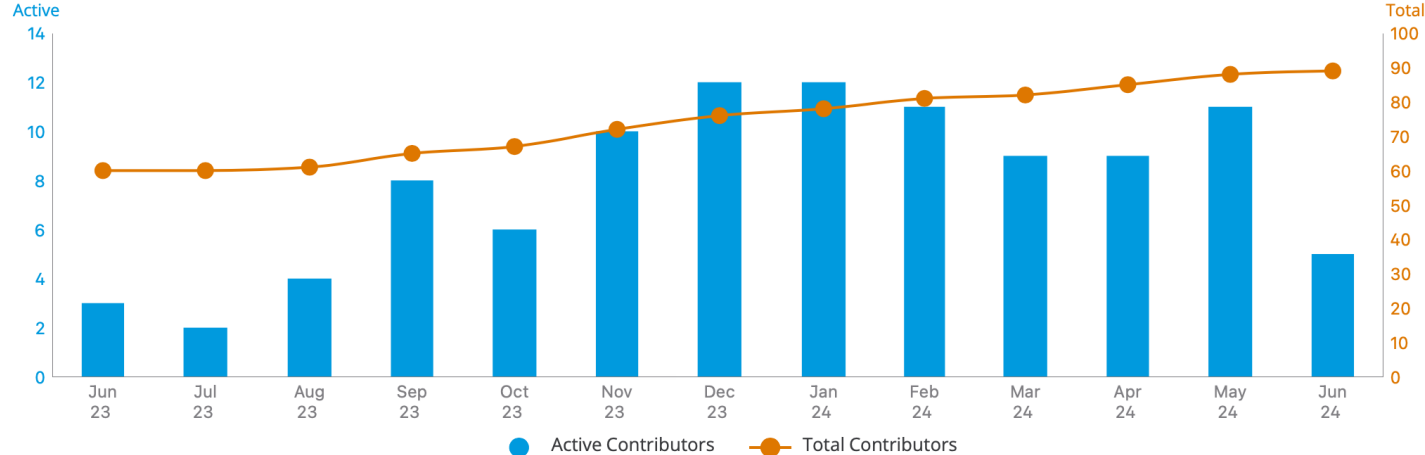
Commit Activities ⓘ

Commit activities **increased by 59%** 📈 vs. the previous time period.

Legend: ● New Commit activities — Total Commit activities
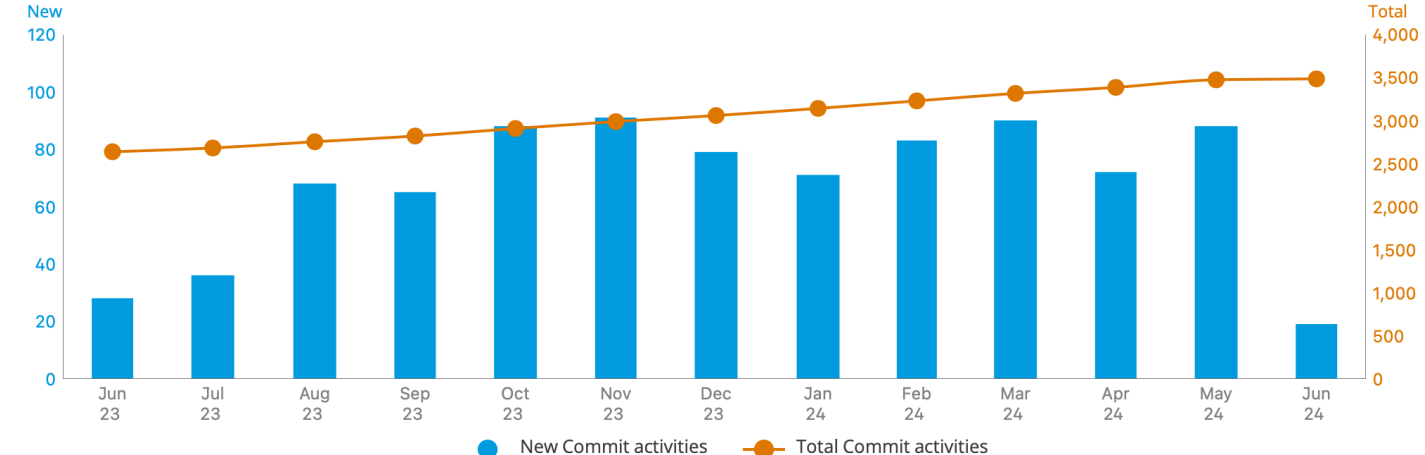
LFE has grown in key community metrics, including contributors and commits.

LFE Projects

LFE now comprises 30+ projects, ranging from the Sandbox (or formation process) to Early Adoption.

Early Adoption Projects:

- **OperatorFabric:** A modular, extensible, industrial-strength, and field-tested platform for use in electricity, water, and other utility operations, with system visualization, workflow scheduling and alerting, and more.

- **PowSyBl:** The code building blocks for the simulations and analyses of power systems, for horizons from real-time operation to investment planning, with a grid data model, Java classes for extensibility, a data management system, and more.

- **Grid eXchange Fabric (GXF):** A software platform that enables hardware monitoring and control in the public space. GXF provides several functions out

of the box, including scalability and high availability, high security, a generic design, and no vendor lock-in.

- **SOGNO:** SOGNO is creating plug-and-play, cloud native microservices to implement the next generation of data-driven monitoring and control systems.

- **SEAPATH:** Aimed at developing a "reference design" and "industrial grade" open source real-time platform that can run virtualized automation and protection applications for the power grid industry.

- **EVerest:** An OSS stack for EV charging infrastructure. By digitally abstracting the complexity of multiple standards and use cases, EVerest will run on any device, from AC home chargers to public DC charging stations.

Incubation Projects:

- **OpenEEmeter:** A library and software platform for private companies, utilities, and regulators to consistently calculate changes in energy consumption for building efficiency projects and portfolios with confidence in the methods and replicability of results.

- **CoMPAS:** A configurator for digital substations using IEC standard 61850. CoMPAS is the first project formed from the Digital Substation Automation Systems working group within LFE.

- **Shapeshifter:** Implements the Universal Smart Energy Framework for flexibility forecasting, offering, ordering, and settlement processes. This enables the fastest, fairest, and lowest-cost approach to efficiently connecting smart energy projects.

- **FlexMeasures:** An intelligent energy management system to support real-time energy flexibility apps in a rapid and scalable manner. It is a real-time decision support platform for project operation and a highly effective simulation tool for project design.

- **OpenSTEF:** A complete software stack that forecasts the load on the electrical grid. Given a time series of measured (net) load or generation, a fully automated ML pipeline is executed, which delivers a probabilistic forecast of future load.

- **Power Grid Model:** Power Grid Model is a high-performance Python/C++ library for steady-state distribution power system analysis.

- **Dynawo:** The nature of power system dynamics is deeply evolving toward more diverse and difficult-to-predict behaviors due to the massive changes going on in power systems. Dynawo is a Hybrid C++/Modelica open source suite of simulation tools.

- **OpenLEADR:** A friendly and compliant OpenADR implementation for Python 3.

- **FledgePOWER:** A multi-protocol translation gateway for power systems based on the industrial IoT LF Edge project Fledge.

- **OpenSTEF:** OpenSTEF provides automated ML pipelines to deliver accurate, self-correcting, and explainable forecasts of the load on the grid for 48 hours.

Sandbox Projects:

- **Arras:** A power distribution system simulation and analysis tool for users who design and operate distribution systems and utilities. It incorporates the most advanced modeling techniques, with high-

performance algorithms to deliver the best in end-user modeling.

- **RTDIP:** RTDIP aims to provide easy access to high-volume, historical, and real-time process data for analytics applications, engineers, and data scientists wherever they are.

- **Battery Data Alliance:** Building sustainable OSS and best practices and delivering standards for the battery industry. The project can integrate with any energy data source.

- **CitrineOS:** Open source charger network software for rapid OCPP 2.0.1 and NEVI-compliant EV charge management.

- **Grid Capacity Map:** Grid Capacity Map is a map that provides public information about grid capacity and grid connection cost to give an early indication to customers seeking grid connection.

- **Grid Resilience and Intelligence Platform (GRIP):** A cutting-edge software platform designed to help electric grid operators anticipate, mitigate against, and recover from the effects of extreme weather events.

- **OpenSCD:** The OpenSCD project signifies a significant advancement in Substation Configuration Language editing, specifically tailored for utilities, integrators, and vendors aiming to transition seamlessly into the era of fully digital substations.

Standards Projects

- **Carbon Data Specification Consortium:** A data dictionary for raw data and a standard for data requirements that enable energy data access for measuring, quantifying, and tracking carbon emissions from energy production and consumption.

- **Super Advanced Meter:** An open source specification project focusing on a widely applicable smart meter data gateway. It aims at the central device that is installed with almost every energy consumer and thereby serves as the edge device to provide services to customers worldwide.

- **TROLIE:** Establishing an open conformance standard and cultivating a software ecosystem to accelerate the implementation of reliable, secure, and interoperable systems for the exchange of transmission facility ratings and related information.

LFE is building the technologies necessary to accelerate the energy transition and help the planet avoid the worst consequences of climate change. This includes the entire technology stack used by those producing, transmitting, distributing, and using energy over large grids, microgrids, distributed energy resources and storage, EVs, and more.

The LFE community has made tremendous progress since its founding in 2018 in pursuit of this goal. The year 2023 alone saw tremendous growth, with nine new projects added to bring the total to 30. Nine new members also joined, contributor strength grew by 30%, and lines of code hosted grew by 22%. However, progress cannot come fast enough. An open source methodology and community of collaborators is the best way to ensure that energy systems evolve to meet the challenges of electrification and decarbonization.

Automotive

Automotive Grade Linux

Automobiles today contain more than 100 million lines of code and represent the largest mobile computing devices that most people will ever purchase in their lifetimes. Accustomed to the frequent software updates and user experience found in laptops, tablets, and mobile phones, consumers have come to expect their modern new cars to keep up.

Historically, the embedded systems in an automobile have been less functional or up to date than what consumers can get in their smartphones, such as onboard navigation and audio/video entertainment systems. The reasons for these gaps in functionality can be traced to a long production cycle during which car companies would write a specification for what a particular car model needs regarding support systems and then provide that specification to a supplier with desired feature sets. In turn, the supplier provided to the manufacturer what amounts to a "black box"—a proprietary solution that, in many cases, cannot be reused on other models of automobiles. The problem was magnified and repeated across different automotive manufacturers using dozens of suppliers to produce in-car systems, thereby creating fragmentation throughout the industry and even between car models.

As automakers raced to roll out new features and functions to keep pace with consumer demand, it became clear that the old supply chain did not work. That's why in 2012, the Linux Foundation worked with industry leaders such as Toyota to launch Automotive Grade Linux (AGL) and build a common OSS platform to eliminate the fragmentation plaguing the automotive industry. AGL is the only organization with a mission to address all in-vehicle software, including infotainment, instrument cluster, telematics, heads-up display, and advanced driver assistance systems.

Now more than a decade old, AGL is supported by more than 150 members and 10 automotive manufacturers. AGL-based infotainment systems are on the road in Toyota, Lexus, and Subaru vehicles globally, with additional automakers including AGL in their production plans.

By embracing open source technology, automakers have realized that they can develop systems faster, become interoperable and less dependent on any one vendor, and more closely align with modern software approaches and best practices, including the cloud and containers. In fact, it's the only way to keep up with modern software development.

AGL areas of focus.

AGL Unified Code Base

Automotive companies, like companies in other industries, naturally want to take ownership of the software in their products and heavily customize it with value-added features. But this requires that the underlying plumbing and systems (architecture, kernel, middleware, application services, and security services) have a common foundation. This is roughly analogous to operating systems for smartphone manufacturers building diverse application ecosystems with a common operating system foundation.

Built from the ground up by the AGL community, the AGL Unified Code Base (UCB) is an OSS platform that includes an operating system, middleware, and an application framework, providing approximately 70%–80% of the starting point for a production project. Sharing an open source platform enables code reuse and a more efficient development process. Developers and suppliers can build their solution once and deploy it for multiple automakers.

With major contributions from automakers and suppliers, the UCB has become the de facto industry standard for infotainment, telematics, and instrument cluster applications.

Additionally, automotive manufacturers can use AGL-based systems across their entire product line, from entry-level to luxury vehicles, thereby eliminating the software fragmentation that has plagued the industry for decades.

The AGL community has consistently put out two major software releases each year in a tick-tock cadence, the first being feature rich for those users eager to access the latest code and the second with hardening and bug-fixing making it production ready. Recent technical milestones include:

- Integration of VirtIO, a virtualization framework, to enable multiple applications to run on a single microprocessor using containers as well as hardware independent and cloud-native AGL applications.

- New user interface (UI), including Toyota's automotive embedded version of Flutter, an open source app and UI development toolkit, which will allow manufacturers to cut the development time and cost of deploying new applications in the vehicle.

- Support for the open RISC-V architecture, enabling hardware developers to create custom processors for individual automotive functions that all use the same architecture, enabling greater scalability, simplified software deployment, and faster time to market.

"With Toyota's Flutter contribution, the AGL UI and reference applications were completely rewritten from start to finish in just eight weeks, a testament to its power and ease of development. AGL is now the home for automotive embedded Flutter, which we believe will become the de facto standard for developing in-vehicle applications."

— Dan Cauchy, GM, AGL

TOYOTA

Recognizing the importance of open source to its future, long-time open source contributor Toyota created an official Open Source Program Office (TOYOTA OSPO) in 2024. Key activities will be information sharing, education, and rewards. Learn more.

Software Defined Vehicles

In early 2023, two AGL Expert Groups (EG), the Containers and Mesh EG and the Virtualization EG, merged to form a new Software Defined Vehicle Expert Group (SDV EG). The SDV EG's goal is to ultimately simplify the deployment and management of the vehicle software with the ability to push software and security updates to vehicles using standardized industry technologies such as containers and virtualization.

Led by experts from Panasonic, the SDV EG has made significant progress toward defining the requirements and use cases for AGL regarding SDVs, standardizing the VirtIO virtualization framework across various automotive architectures, and laying the groundwork for workload orchestration for on-board automotive systems.

The AGL platform now includes support for Amazon Web Services (AWS) Graviton processors, a family of processors designed by AWS to deliver the best price performance for cloud workloads running on Amazon Elastic Compute Cloud (Amazon EC2). This enables AGL to run in a cloud-based environment. Combined with the work being done by the AGL Software Defined Vehicle (SDV) Expert Group to decouple the hardware from the software using virtualization and VirtIO, engineers can now develop and

test AGL software from anywhere in the world without needing access to the physical hardware.

Running AGL in the cloud supports a software-first development approach, reducing the need for expensive hardware and enabling a high level of software reuse and scalability. It also improves the continuous integration and continuous development/deployment process by allowing for frequent software iteration and testing across global teams.

UX/UI for AGL's In-Vehicle Infotainment System Demo (photo courtesy of ICS).

AGL allows users to tackle complexity and take advantage of these environments and industry trends. New use cases are now emerging, including AGL Instrument Cluster, In-Vehicle Infotainment, and Advanced Driver Assistance Systems.

Project Spotlight: Zephyr

The Zephyr Project is an open source, scalable real-time operating system (RTOS) supporting multiple hardware architectures. It is product ready, available through the Apache 2.0 open source license, and is free to use in commercial and non-commercial solutions. Zephyr connects devices using all major industry standards and is developed with security best practices. It is easy to deploy, secure, connect, and manage and has efficient power consumption.

Zephyr RTOS is also extremely versatile and more lightweight than, say, a Linux distribution. It is supported in over 600 circuit boards and eight of the leading hardware architectures. It is integrated with 190+ sensors and is now running in hundreds of commercial products, such as Google Chromebooks, Oticon Hearing Aids, and Vestas Wind Turbines with Long Term Support.

"The growth we're seeing in Zephyr today is the result of diligently applying open source project best practices and building community over several years. Zephyr's transparency is key to its applicability growing appeal across many industry verticals today."

— Kate Stewart, VP, Dependable Embedded Systems, Linux Foundation

Steady Growth

Zephyr's consistent and steady growth since inception is a great example of organic, transparent, community-led growth that compounds over time. Zephyr now ranks an astounding fifth in the Linux Foundation Project Velocity Report, behind only Linux, Kubernetes, Open Telemetry, and CNCF. This refers to the rate at which development tasks are completed and features are delivered in a specific amount of time.

- ● Linux (kernel.org) 4398 authors
- ● Kubernetes (kubernetes.io) 3569 authors
- ● OpenTelemetry (opentelemetry.io) 1467 authors
- ● CNCF (www.cncf.io) 1250 authors
- ● Zephyr (www.zephyrproject.org) 932 authors
- ● Argo (argoproj.github.io) 896 authors
- ● Hyperledger (hyperledger.org) 706 authors
- ● Node.js (nodejs.org) 635 authors
- ● Backstage (backstage.io) 602 authors
- ● Prometheus (prometheus.io) 458 authors
- ● Jenkins (jenkins.io) 455 authors

Zephyr ranked fifth in the 2023 Project Velocity Report from CNCF.

Device-Level AI/ML

Even with its small footprint, Zephyr is able to support AI/ML applications at the device level. An example is the Lisios WaterAlarm system, a non-invasive early warning system for water leaks. This sensor device can be easily attached to water mains from outside. Once the device is attached and connected to the local Wi-Fi, it continuously measures water consumption. Through ML algorithms running directly on the device, it is able to detect pipe bursts or micro-leakages and warn residents via an app on their phones.

LISIOS WaterAlarm System.

Clean Energy and U.N. SDGs

Zephyr is gaining traction across a variety of industries, including energy, which supports the transition to clean energy and helps meet the U.N. SDGs. For instance, Zephyr supports systems such as electrical grid monitoring with on-device ML. The RTOS supports the transition to renewable energy and helps improve the efficiency and dependability of electricity grids, thereby lowering carbon emissions.

Cross-Industry Best Practices

Zephyr is also a great example for how industries can learn from each other, apply best practices, and achieve success with open source. For example, Zephyr now includes three software bills of materials included by default in each build,

providing developers with a clear understanding for how to ensure security and interoperability. Zephyr also provides an auditable codebase, vulnerability registry, and project security documentation and has earned an OpenSSF Best Practices Gold Badge for its commitment to security. Developers who become familiar with Zephyr and open source best practices are well equipped to achieve success working with other open source projects, codebases, and communities across industry verticals.

Financial Services

Fintech Open Source Foundation

Financial services is another industry vertical being transformed by open source. Only a decade ago, this would have seemed unfathomable in an industry subject to intense regulation, legal requirements, complex systems, and a general resistance to sharing intellectual property. But rapid innovation and a growing strategic focus on technology have proven to be a strong enough impetus to break through these barriers.

Far from being newcomers to modern technology, financial services firms have always had plenty of software know-how: Consider the software you interact with every day, such as Internet banking, ATMs, and card payments. Behind the scenes, there are also settlements, balance sheets, electronic trading, risk management, and know-your-customer systems. Because of this, financial services firms are as reliant upon and invested in open source as anyone else and have been consuming it for a long time. However, the challenges mentioned above were holding back the industry from reaching its full potential.

The Fintech Open Source Foundation (FINOS) is an umbrella organization under the Linux Foundation, whose purpose is to accelerate collaboration and

innovation in financial services through the adoption of OSS standards and best practices. The foundation enables developers from organizations to collaborate on projects with a strong propensity for mutualization. It has enabled codebase contributions from both buy-side and sell-side firms and counts 80+ financial institutions, fintechs, and technology consultancies in its membership.

In a short time, FINOS has become the trusted forum for open source collaboration among major financial institutions who have recognized that much of their software and systems do not provide them with a competitive advantage and are costly to develop, implement, and maintain. This duplication of effort is a prime opportunity for open source collaboration and its benefits through a leveraged development model across the industry.

FINOS Research Reports

The shift in attitudes and practices around open source in the financial sector can be clearly seen in FINOS research reports. The State of Open Source in Financial Services annual report analyzes quantitative and qualitative data to understand industry-wide trends in open source adoption from banking to asset management and hedge funds.

The 2023 State of Open Source in Financial Services

90% of respondents agree that **open source is valuable to the future of the _financial services industry._**

65% of those surveyed report having **more time allocated to spend on open source contributions.**

"Learning & personal development" and "fun & enjoyment" are the top reasons respondents engage with open source software (OSS).

88% of respondents agree that **open source is valuable to the future of _their organization._**

"Open sourcing internally developed projects" is the top factor for **increasing productivity at work, with inner source close behind.**

78% agree that their organizations are getting more value from open source compared to 2022.

94% of organizations represented have policies that allow consumption.

Only **5% of organizations surveyed** prohibit open source contributions.

52% of respondents report having an OSPO in their organization.

Organizations with OSPOs are just over **80% more likely to have a formal review process** for evaluating OSS components.

A total of 91% of respondents are confident that the OSS they are consuming is **well-maintained and up to date.**

The most valuable open source technologies identified for the industry were **artificial intelligence (AI) / machine learning (ML), cybersecurity, and cloud / container technologies.**

Key Takeaways from the 2023 Report

- **Three years of steady improvement.** The last three years clearly show that the industry is maturing. There is consistent recognition that open source is valuable.

- **Open Source Program Offices (OSPOs) are on the rise.** Over half of survey respondents from financial services companies indicated that their organizations have an OSPO, and 65% have defined a clear and visible open source strategy, making them strong candidates to introduce OSPOs within their organizations in the near to medium term.

- **The industry recognizes the value of open source usage.** Almost all (94%) organizations allow some level of open source consumption, and 78% report increased value from open source usage compared with a year ago.

- **Contributions are becoming more permissible.** Two-thirds (65%) of respondents note an increase in the time and effort their organizations allocate for them to contribute to open source.

- **The problems aren't all solved, but opportunities abound.** Multiple factors still hinder contributions to this highly regulated industry. Despite the challenges, respondents identified AI/ML, cybersecurity, and cloud/container technologies as the most valuable open source technologies for the future of the industry.

"The accelerated pace of open source consumption underscores its pivotal role in modern finance. But true industry value in accelerating the digital transformation, time to market, and overall ROI lies in active contribution, as firms can influence the direction of open source projects and directly contribute upstream."

— Gabriele Columbro, Executive Director, FINOS

Strategic Initiatives

On a rolling quarterly basis, the FINOS Governing Board selects key areas of investment for FINOS budget and resources. Current initiatives include the following.

Open Source Readiness

Financial services organizations (mainly sell-side banks and buy-side firms) new to open source often don't know how to get started. They often wonder: How do banks operating within a highly regulated industry not only consume but contribute back to open source? What open source projects, and the communities that support them, are relevant to company technological, regulatory, and financial goals? Where do banks go to recruit top open source/tech talent, and how do they train and retain that talent?

FINOS has created the Open Source Readiness initiative to help financial services firms advance their open source programs, helping to ensure compliance, foster innovation, and promote collaborative development across financial institutions and technology companies.

To streamline this process, the Open Source Readiness SIG collects industry data and provides a knowledge base, various resources, and training.

AI Readiness

McKinsey is predicting a $200 billion impact on the banking industry from AI. Banks have processes for onboarding technology, but generative AI presents new challenges that existing processes may not be well suited for. Much work is needed to allow for the "safe" use of AI (where safety considers both the customer and the bank) and ultimately allow financial services organizations to rapidly adopt new technologies as they emerge.

In order to provide a space to discuss common AI challenges and opportunities, the AI Readiness SIG was formed, supported by Citi, Microsoft, Morgan Stanley, and more. The group plans to develop a governance framework that manages the onboarding, development, and running of AI-based solutions within the financial services industry ahead of future regulations.

Open RegTech

Open source software, standards, and best practices have the potential to unlock significant value for financial regulators and the entire financial ecosystem, laying the foundation for a robust market infrastructure. Increased automation, standardization, transparency, efficiency, and access to top tech talent boost innovation and welfare for the industry.

The Open RegTech Initiative is raising awareness on a novel approach to regulatory technology based on open source and standards and hosting projects. The FINOS Regulation Innovation SIG is a community creating open source solutions for regulatory and compliance issues in financial services. The initiative promotes industry collaboration to drive innovative approaches to regulatory compliance. A RegTech Council sponsors projects based on selected regulatory priorities. The community has focused on infrastructure-based and business-focused projects with the introduction of the FINOS Common Cloud Controls (CCC) and the Common Domain Model (CDM) projects.

FINOS CDM

In order for financial products to be traded and managed across the transaction lifecycle, a common model is required for baseline interoperability between systems and services. Transparency and alignment between regulators and market participants is also critical.

The CDM is a standardized, machine-readable, and machine-executable data and process model based on cross-industry collaboration supported by three industry trade associations and a broad community. CDM facilitates trade processing of repo, securities lending, bond, and derivatives transactions and is available as code in multiple languages, facilitating easy implementation across various technologies. The project has made significant strides in areas such as regulatory compliance and trade lifecycle management.

FINOS CCC

Cloud computing is omnipresent in today's technology landscape, and how well financial services are leveraging it is becoming a competitive advantage.

But a lack of a unified set of mitigations and controls for FSIs deploying on common cloud services along with risks arising from fragmented, complex, and often conflicting regulations represent significant barriers to entry. At the same time, regulators are increasingly concerned about systemic risks of cloud concentration and vendor lock-in.

FINOS CCC is a pioneering initiative aimed at standardizing cloud deployments within the financial services sector. By establishing consistent controls for compliant public cloud deployments with an open standard, FINOS CCC ensures security, compliance, and resilience across major CSPs, setting a new benchmark for secure and reliable cloud usage in the industry. Originally proposed by Citi, it now has the support of 20+ FINOS Members.

FINOS FDC3

Siloed application environments in financial services require custom integrations and often result in a myriad of systems and others that don't share context or information with each other. The lack of a standardized framework and bilateral agreements prevents teams across the industry from extending APIs across applications and hinders the benefits of collaboration between organizations.

FINOS FDC3 is a set of standards for interoperability and communication among financial applications aiming to create a common language and protocol for financial services software. It is designed to allow a suite of applications written by different parties to share contextual data via broadcasting and raising intents to each other. FDC3 intents define a standard set of verbs that can be used to put together common cross-application workflows on the financial desktop and extend APIs from one application to another. Applications can launch, respond to activity in other apps, and request functionality from each other. This facilitates innovation, reduces integration costs, and enhances overall efficiency within the financial industry.

FINOS Diversity Equity Inclusion

In order for open source in financial services to reach its full potential in driving digital transformation, it is crucial to attract, nurture, and retain a diverse talent pool. Research shows that inclusive communities lead to better outcomes and innovation.

The FINOS Diversity Equity Inclusion (DEI) SIG is a collaborative initiative that aims to unite contributors committed to fostering diversity and inclusivity within the industry. The DEI SIG strives to create a more equitable and inclusive environment within the financial services open source ecosystem and ensure that its members advance diversity, equity, and inclusion as core operating principles, fostering a fairer, more resilient, and more impactful ecosystem.

Zenith SIG

Driven by technology, the financial services industry is changing fast, and it can be difficult for employees to keep up on new developments and remain competitive. Rather than go it alone, companies today are looking for environments with supportive communities who can collaborate on the many non-proprietary areas of innovation common to all.

Zenith is a SIG that focuses on exploring and promoting the adoption of emerging technologies and serves as a catalyst for innovation within the financial services industry. It is a collaborative platform where industry professionals, experts, and innovators come together to discuss, analyze, and drive advancements in technology relevant to finance. Zenith facilitates discussions, conducts research, and develops resources such as primers and analysis frameworks.

Agriculture

Digital Innovation in the 21st century

Data <=> Energy [gasoline / diesel / electrons]
- **Source of power**

Applications <=> Vehicles [car, truck, boat, airplane]
- **Value creation**

Infrastructure <=> Road [port/dock, airport]
- **Value *enablement***

AgStack

Agriculture is the world's largest industry, generating over $1.3 trillion a year and employing over 1 billion people. It is omnipresent, with pasture and cropland occupying half of the world's habitable places. The world's population is growing fast, and robust agricultural practices are needed to meet the U.N.'s SDGs, end extreme poverty, and feed a projected 10 billion people by 2050. Sustainable land management practices are also critical to maintaining clean water, fertile soil and protecting wildlife habitats.

Agriculture is grounded in ancient history, and many early farming practices are still used commonly around the world. But technological innovation has also been at work for millennia and has evolved in many ways. Today's agricultural industry is divided between small sustenance farmers, small- and medium-sized farms, and large corporate entities. While agriculture is certainly not the first industry that comes to mind when thinking of OSS, that is starting to change.

It all starts by us reimagining what digital infrastructure for agriculture really looks like. How can we enable this infrastructure to not only provide solutions but enable the creation of applications and data at scale?

The AgStack Foundation was founded in 2021, recognizing the tremendous potential for digital transformation in the sector. Just like many other industries, agricultural companies suffer from pre-competitive wastefulness, with 97% using the same underlying systems, making open source an ideal fit. The AgStack Foundation will improve global agriculture efficiency through the creation, maintenance, and enhancement of free, reusable, open, and specialized digital infrastructure for data and applications.

AgStack consists of an open repository to create and publish models, free and easy access to public data, interoperable frameworks for cross-project use, and topic-specific extensions and toolboxes. AgStack leverages existing technologies such as agriculture standards and open source projects such as Hyperledger, Kubernetes, Open Horizon, Postgres, and Django.

Unlike many open source projects, AgStack was not founded with an initial code donation. Starting from scratch, future Executive Director Sumer Johal identified a need and developed the code himself for a "smart geoid" registry (Asset-Registry 1.0). The project aims to solve fundamental "indexing" challenges in AgTech by providing unique geospatial "keys" for land-based stationary assets (e.g., field boundaries) in agriculture. Today, over 1,000 active users across tens of thousands of fields and more than 40 countries have adopted the registry. Asset-Registry v2.0 will "auto draw" polygons for users with machine-learned decision tools leveraging satellite data. The functionality will scale across geographies at a very low (or no) cost, which presents a massive positive impact opportunity for farmers in the Global South.

"The world's food supply needs a digital makeover. Open source and open data—through good governance—can unleash the power of AI and computing for the greater good—our food supply and farmer livelihoods—while improving our environmental footprint. Digitizing the industry by leveraging digital public infrastructure—purposed for agriculture—is the mission of AgStack. Through this, we can avoid wasting one-third of our food supply while one-third of the world goes hungry."

— Sumer Johal, Executive Director, AgStack

In early 2023, AGStack and CGIAR signed a memorandum of understanding to partner with one another to co-create digital tools and services that will transform the agriculture ecosystem globally by providing these as a "global digital public good." With its vast array of "on the ground" scientists around the globe (especially in the Global South), CGIAR is looking to AgStack's community to build and offer these digital infrastructure components to CGIAR and to the large agriculture ecosystem for farmers to maximize yields while minimizing pesticide use. They also released a new farm management and decision support tool, offering cost tracking and crop rotation planning features.

Registry → important for a context handle

http://asset-registry.agstack.org
Geoid: `ff93ad2470125dfe0f21b7b857140c94efa635c8b6f25104419e88129db9f682`

AgStack has also now launched the "field carbon model" sub-project incubation to improve the cost and transparency of traditional MRV techniques for the agriculture "carbon" space. Early model validations use a remotely sensed dataset and the NASA L4C model to estimate carbon flux on a given agriculture field (provided by the geoid). Early estimates look quite encouraging, with >80 correlation with reference data.

AgStack has received significant interest and investment from Europe, where one-third of the E.U.'s massive budget is allocated toward agriculture. Using AgStack, the E.U. is looking to reduce the impact of deforestation on food production via European Union Deforestation Regulations (EUDR), which require field boundaries. AgStack has received several grants from the E.U. and partners to participate in and co-create the pre-competitive stack for EUDR.

Accessible digital infrastructure tailored to agriculture, including open data, AI modeling, and software applications, means that farmers can manage such resources as water and field workers more effectively and make data-driven decisions to balance supply and demand. This infrastructure helps reduce poverty, hunger, and economic inequalities; increase the resilience of communities and business models; and reduce their impact on the climate and the land.

Media & Entertainment

The Linux Foundation hosts several open source projects and communities at the foundation of the exciting 3D computer graphics and motion pictures industries. They each fill a unique industry niche while also complementing the other and offering powerful open source tooling options to creators in this traditionally closed space.

Academy Software Foundation

The motion picture industry started incorporating Linux and OSS into their production pipelines in 2000, as there was a growing realization that sharing fundamental technology would be an advantage. But by 2016, "versionitis" had crept in, and it was challenging to align dependencies and versions. There was also no assurance that tools would be maintained and updated and continue to be production ready. Studios might have had to revert to building their own plugins for each piece of software.

Thus, in 2016, the Academy of Motion Picture Arts & Sciences began an investigation into the use of OSS in the motion picture industry. Led by the Academy Science and Technology Council, the survey found that almost 84% of the industry used OSS at that time, particularly for animation and visual effects, but barriers to adoption included siloed development,

managing multiple versions of OSS libraries (versionitis), lack of governance, and confusing licensing models. Additionally, many open source projects faced stagnation due to a lack of contributors and maintainers outside of the organization that initiated a project, which would often stall development and lead to underinvested projects. These needed to be addressed in order to ensure a healthy open source community.

After almost two years working with industry stakeholders to focus on building a better, collaborative solution, the Academy of Motion Pictures Arts & Sciences and the Linux Foundation launched the Academy Software Foundation (ASWF) in 2018. Initially created as a home for OSS developers in the motion picture and broader media industries to share resources and collaborate, the Foundation has become much more: It's become a hub for innovation and a supportive, dynamic community for engineers and developers working to create shared tools for the entertainment industry.

SPIDER-MAN™: ACROSS THE SPIDER-VERSE; courtesy of Sony Pictures Imageworks

The ASWF follows a typical Linux Foundation open governance structure. Each technical project operates independently and has its own decision-making model based on a "do-ocracy"; the people doing the work make the decisions. Anyone can contribute and participate in the projects, regardless of whether they are a member of the Foundation. In a technical open source project, the critical value is that each contribution is weighed on the merit of that contribution adding value to the project. Whether it's a simple bug fix, a security patch, or a new feature, the best technical solution that solves the business need will find a community that values those contributions. With no one company controlling decision-making, open governance enables transparent, value-driven discussion.

"The Foundation quickly got to the point where now we wonder, 'How did we ever survive before? How did we get this stuff done that speaks to the central role the organization plays in our day-to-day operation?' We're only a couple years in, but it feels like the Foundation has been there forever because it's so critical."

— Larry Gritz, Sony Pictures Imageworks

ASWF Projects

The Foundation is currently composed of 14 projects. These projects have been critical to the creation of major motion pictures enjoyed by people around the world. Most recently, ASWF projects have been used on films and shows *including Guardians of the Galaxy Vol. 3, Loki, Elemental, Spider-Man: Across the Spider-Verse, Nimona, Oppenheimer, The Last of Us, The Creator, and Mission Impossible: Dead Reckoning Part 1.*

- **OpenVDB:** a C++ library for manipulating sparse dynamic volumes used by visual effects studios to create realistic volumetric images such as water/liquid simulations and environmental effects such as clouds and ice. Contributed by DreamWorks Animation, the project has won several Academy Scientific and Technical Awards.

- **OpenColorIO:** an industry standard for consistent color management across VFX and animation pipelines. Contributed by Sony Pictures Imageworks, it has been used on hundreds of feature film productions and touches nearly every pixel of every visual effects frame in most major motion pictures.

- **OpenEXR:** a standard HDR image file format for high-quality image processing and storage. Developed by Industrial Light & Magic in 1999, it was the first release of a major open source project by a studio and won an Academy Scientific and Technical Award.

- **OpenCue:** an open source render management system used to break down complex jobs into individual tasks. Developed by Google Cloud and Sony Pictures Imageworks, it is based on Sony's internal queuing system, Cue3, which has been developed and used in production at Sony over the past 15 years.

- **OpenTimelineIO:** an open source API and interchange format that facilitates the communication of editorial data and timeline information in rich and flexible workflows—filling a critical but often-overlooked gap in film production pipelines. Contributed by Pixar Animation Studios.

- **Open Shading Language:** a small but rich language for programmable shading in advanced renderers and other applications, ideal for describing materials, lights, displacement, and pattern generation. Developed by Sony Pictures Imageworks, it's the de facto standard shading language for VFX and animated features and is an Academy Scientific and Technical Award winner.

- **OpenImageIO:** a ubiquitous library for VFX applications and pipelines to perform scripted manipulation of digital image files, with particular focus on scalability and functionality for professional VFX and animation feature film workflows. Developed at Sony Pictures Imageworks, it's one of the VFX industry's earliest open source projects.

- **Digital Production Example Library:** a library of digital assets (3D scenes, digital cinema footage, etc.) that demonstrates the scale and complexity of modern feature film production, including computer graphics, visual effects, and animation. These assets are available free of charge to researchers and developers of both open source and commercial projects to test, demonstrate, and inspire ideas.

- **Open Review Initiative:** an umbrella project working to build a unified open source toolset for playback, review, and approval of motion picture and related professional media. Hosted projects include xSTUDIO, developed by DNEG, and Open RV, developed by Autodesk, as well as a video-encoding guidelines repository.

- **OpenAssetIO:** an open source interoperability standard between tools and asset management systems that reduces the integration effort and maintenance overhead of content creation pipelines. Contributed by Foundry.

- **OpenFX:** a popular open source plugin standard that allows interoperability between image-processing tools in the VFX industry. By creating an interoperable ecosystem of plugins, it has become

- the reference standard for visual effects and video-processing software creators. OpenFX was contributed by the non-profit Open Effects Association, which had previously managed the project.

- **MaterialX:** an open standard for representing rich material and look-development content in computer graphics, enabling its platform-independent description and exchange across applications and renderers. Developed by Lucasfilm, it has been incorporated into widely used applications and standards. MaterialX also includes OpenPBR, a new sub-project developed by Autodesk and Adobe to provide creatives with a more artist-friendly bridge between software applications.

- **Rawtoaces:** a software package that converts digital camera RAW files to container files containing image data encoded according to the Academy Color Encoding Specification.

- **Rez:** an open source, cross-platform package manager that creates standalone configured environments for third-party and proprietary digital content creation software. Initially developed at Dr. D Studios, Rez is widely used in the pipeline community and solves countless package management problems for visual effects and animation production developers.

Community Engagement

The Foundation's flagship event, Open Source Days, is the leading event dedicated to OSS for visual effects, animation, and digital content creation. In-person and virtual registration doubled in 2023, with visual effects/animation studios, software vendors, and other professionals presenting on emerging open source projects, best practices, and the latest trends in open source for the motion picture industry. In addition, the ASWF introduced a new Virtual Town Hall Series leading up to the Open Source Days main program. Over the course of several weeks, Foundation projects including MaterialX, OpenColorIO, OpenAssetIO, Open RV, xStudio, OpenTimelineIO, and OpenEXR shared milestones, highlights, and future roadmaps and answered questions from the community.

To encourage more contribution and developer engagement, the Foundation launched a new virtual Dev Days event, a global 48-hour code-a-thon. Developers of all experience levels were encouraged to spend eight hours over a 48-hour period learning about a project, interacting with project leadership, and writing code. Participating companies included Autodesk, Sony Pictures Imageworks, Lucasfilm, DreamWorks Animation, Wētā FX, and Walt Disney Animation Studios.

Diversity & Inclusion

The year 2023 marked the third annual Summer Learning Program, led by the Foundation's Diversity & Inclusion Working Group. The program provides practical skills and mentorship to underrepresented students and young people looking to explore technical careers in the animation and VFX industries. The focus for 2023 was the LGBTQIA+ community. Twenty participants were provided free access to online learning and matched with an industry professional from studios including Industrial Light & Magic, Pixar Animation Studios, Netflix, and Activision Blizzard for one-on-one mentoring.

Alliance for OpenUSD

Pixar's Universal Scene Description (USD) technology, initially introduced in 2013, signaled a paradigm shift in the 3D ecosystem. USD laid the groundwork for enhanced creativity and collaboration through the efficient interchange of 3D assets and scenes. In 2016, Pixar made USD open source, sparking widespread industry interest and adoption.

The Alliance for OpenUSD (AOUSD), founded in 2023 by industry-leading organizations Pixar, Adobe, Apple, Autodesk, and NVIDIA, is a collaborative effort to standardize and enrich the interoperability and functionality of 3D graphics across various platforms and industries. At the heart of AOUSD's mission lies a commitment to fostering collaboration and innovation through open standards governance. AOUSD enables a vibrant ecosystem of interoperable 3D tools and workflows through its working groups.

AOUSD Working Groups

- **Core Specification:** This group precisely defines OpenUSD standards to ensure seamless interoperability across diverse software platforms and devices.

- **Materials:** In collaboration with the ASWF, this group concentrates on standardizing material definitions within OpenUSD.

- **Geometry:** Expanding on the foundational standards, this group drafts detailed specifications for USD-based geometries.

- **Marketing:** This group focuses on promoting the value of OpenUSD and positioning AOUSD as a leader in open standards for 3D content creation.

AOUSD and the Khronos Group are initiating efforts to align OpenUSD with Khronos' glTF standard, ensuring seamless integration and interoperability for advanced 3D scene composition. This collaboration aims to synchronize the roadmaps of both standards, enhancing the tooling pipelines and broadening the scope of 3D content creation across various platforms.

AOUSD also works with the ASWF to support various working groups that advance the use of OpenUSD in film and game production. One key initiative involves integrating OpenUSD with the ASWF's MaterialX project, which enhances the motion picture community's capabilities in visual effects. Additionally, the ASWF's working groups focus on specific aspects of USD,

such as advancing PhysCam and PhysLight in the cameras group, developing the Book of USD in the games group, and investigating glTF/USD interoperability in the assets group. The USD on the web initiative also found an early home at the ASWF, serving as the primary forum for Autodesk's WebAssembly port. This collaboration empowers the motion picture community to develop and deploy cutting-edge visual solutions, advancing the industry's capabilities in visual effects and beyond.

Open 3D Foundation

Real-time 3D technology is catapulting innovation to new heights in industries spanning gaming, robotics, motion pictures, virtual/augmented reality, AI/ML, digital twin, manufacturing, automotive, healthcare, architecture, and more. The projection for the visualization and 3D rendering software market is $8 billion by 2027. Real-time 3D engines have grown from the realm of game developers to become the foundation for delivering these experiences.

Hosted by the Linux Foundation, the Open 3D Foundation (O3DF) is home to a thriving community of artists, content creators, developers, and technology leaders focused on building and fostering Open 3D Engine (O3DE), the modular, fully featured, high-fidelity, real-time, open source 3D engine.

Now in its third year, the community has sustained its momentum, with over 2 million lines of code changed. Pull request creators include Lionbridge, AWS, Robotec. ai, and Huawei.

OD3F is committed to organic community-led growth and is committed to the following path:

- **Prioritizing Stability:** minimizing crashes and bugs within O3DE to ensure a smoother user experience

- **Thoughtful Development:** avoiding disruptive changes without proper deprecation plans

- **Enhanced Feature Development:** exploring the implementation of webGPU, Blender integration, Houdini integration, and USD pipeline integration

- **Boosting Visibility:** increasing the visibility of O3DE and other open source tools and engines, ensuring that they receive the recognition they deserve

Gaming

O3DE has its origins in game development and provides an open source game engine alternative to the industry, breaking free of entrenched commercial licenses and unnecessary, cumbersome features.

The Multiplayer Sample Game introduced with the O3DE 23.05 release provides client and dedicated server reference implementations of common game elements at play to help game developers jumpstart new projects. It also delivers key examples of integrations with O3DE systems, such as terrain, lighting, audio, scripting, and VFX. It utilizes the Atom Renderer's advanced features to achieve its visual goals, including global illumination, cascade shadows, emissive surfaces, bounce lighting,

temporal anti-aliasing, and hybrid reflections (screen space and ray tracing).

In an exciting collaboration with the next generation of developers, O3DF introduced Project Eureka with the Rochester Institute of Technology. Through this initiative, O3DF is underwriting a team of students to build a commercial game using O3DE while enabling the students to build their portfolios and learn from industry experts. Project Eureka is the first of its kind and will grow the library of O3DE assets for use by other aspiring creators; identify O3DE feature gaps from these student developers in real time; build a

pipeline of talent for internships, mentorships, and employment; and foster O3DE adoption among the next generation of developers, artists, and content creators.

In a further demonstration of O3DE's growing adoption, Carbonated Inc. announced in March 2024 that their game "Mad World", developed using O3DE, will be shipping on iOS and Android devices later in 2024. This is expected to be the first commercially released mobile game utilizing O3DE.

Robotics

As real-time 3D engines tackle applications well beyond game development, O3DE has seen increased adoption in the robotics industry due to the engine's modularity and core functions across content creation, physics, and sensor simulations.

Robotec.ai, a software leader that empowers the development of simulation platforms for robotics applications, teamed up with O3DF to create two plugins (known as Gems in O3DE) to extend the engine's capabilities for robotics simulations. The O3DE ROS 2 Gem integrates O3DE with the robot operating system (ROS) and contains a number of components to build robotic simulations. These include sensors, controllers of different types of drives for mobile robots and joint systems, manipulator arms, dynamic spawning of robots, and other utilities and tooling. The O3DE RGL Gem provides GPU-accelerated Lidar simulation for 30x faster performance.

"O3DE has what I consider to be the best kind of ROS integration, in the sense that we write ROS2 code in the simulator. So, we can use all the packages directly without any bridges, which impacts performance and enables us to communicate directly to the ROS ecosystem and record data efficiently."

— Adam Adam Dąbrowski, VP of Robotics and Simulations, Robotec.ai

O3DE's consistent and transparent licensing terms ensure that developers are never blindsided by unexpected charges. User-driven development means that features are based on user needs, not vendor monetization goals. An open codebase is fully transparent, fostering a welcoming environment for developers transitioning between game development tools. O3DF also strives to highlight diversity within the O3DE community, including profile interviews with game developers, game designers, authors, and programmers.

O3DE software releases continue to focus on performance, stability, and usability enhancements. Moving forward, O3DE is looking to develop a modern, high-fidelity renderer and a modular architecture, facilitating easy integration of third-party tools and simplifying feature additions. O3DF looks forward to working closer with the ASWF and AOUSD in the future.

Conclusion

While all of these vertical industries have unique open source projects and communities, they also share a common thread. All of them realized that open collaboration presents opportunities to reduce costs and time to market, increase quality, and open new areas of competition. The ability to achieve these results on a collective basis pushes innovation forward across respective industries. Critical issues such as cybersecurity and AI are pushing this collaboration even faster.

Top companies across many industry verticals figured out years ago that they needed to be in the top quartile in software innovation if they were to survive and thrive in the future. Accordingly, they studied and learned from the world's top software development companies and discovered that the software leaders had been openly collaborating for a decade or more, building software plumbing and infrastructure. They were licensing these assets they developed in open source so that they would be openly available to anyone. On reflection, many came to understand that their individual ownership of intellectual property for parts of their software stack that customers didn't care about was limiting them in terms of business opportunity and expensive in terms of development and maintenance. To accelerate adoption, openly working together on common plumbing could present more opportunities for business growth.

The case studies of successful patterns were right in front of them. They discovered that projects such as Linux, Apache web server, and Eclipse all enabled software innovators and users to build much more rapidly the higher-value software that their customers were demanding. The open source model of collaboration on the foundational software made these companies faster innovators and was followed with lower individual investments, as the development costs were shared across the organizations working in the project community.

Then the realization hits: Instead of working for years on a standard that everyone could go off and invest in implementing their own way, these open source projects are openly building a shared industry implementation that effectively becomes a neutral, de facto standard on which everyone can build competitive offerings and solutions.

What happened next is nothing short of amazing to have watched as these industries transformed how they build infrastructure for their industry, from individual competitive firms building everything for themselves to communities of competitive firms collaborating in the open.

1   https://ourworldindata.org/grapher/global-fossil-fuel-consumption

2   https://ourworldindata.org/emissions-by-sector

The Linux Foundation promotes, protects and standardizes Linux by providing unified resources and services needed for open source to successfully compete with closed platforms.

To learn more about The Linux Foundation or our other initiatives please visit us at **www.linuxfoundation.org**

Sponsored By: