

```
def _operation == "MIRROR_Y":  
    mirror_mod.use_x = False  
    mirror_mod.use_y = True  
    mirror_mod.use_z = False  
elif _operation == "MIRROR_Z":  
    mirror_mod.use_x = False  
    mirror_mod.use_y = False  
    mirror_mod.use_z = True
```

```
#selection at the end -add back the deselected mirror modifier  
mirror_ob.select= 1  
modifier_ob.select=1  
bpy.context.scene.objects.active = modifier_ob
```

Strategic Open Source in Industrial Digital Ecosystems

Leveraging the open and unleashing the power of
collaboration and digital ecosystems for industry

IN COOPERATION WITH





Introduction

Maintaining a competitive edge in the global market and leveraging technological progress, such as the potential of artificial intelligence, is putting companies under a great deal of pressure. Industrial organizations across the globe face the need to get digital capabilities and innovation on the road quickly and safely. The competitiveness and future sustainability of the manufacturing sector is particularly important for Europe: Manufacturing accounts for more than 80% of the industrial value added in the European Union and up to 90% of industrial employment [1]. The digital transformation of manufacturing has the potential for positive business impacts as well as positive effects for environment and society [2].

Yet, it is not only the competition and the technologies that are changing: Global challenges such as climate change, related to the use of raw materials, impose new conditions and demands for resilient value networks. Technologies can help to address these major challenges. However, the scope and extent of these challenges are so immense that they cannot be tackled by one individual company alone, no matter how large [3].

Throughout every step in the industrial value chain, processes need to be developed, adapted and optimized in order to harness the opportunities of a data-based platform economy and multi-company collaborative business model [4]. Next to their inherently networked nature, innovative and value-adding services do not stop at company or system boundaries. Instead, they require cross-organizational collaboration in digital ecosystems [5].

With regard to working collaboratively, there is a landscape that has been growing for decades: the open-source ecosystem. Open-source software (OSS) is attracting more and more attention, especially in the context of digital sovereignty. For example, in its coalition agreement, the German federal government refers to promoting OSS together with private and public actors in the

ecosystem in order to strengthen digital sovereignty [6 p. 67]. To utilize open and collaborative ecosystems for speed, efficiency, and security in software development, 11 companies from the automotive industry, supported by the German Association of the Automotive Industry (VDA), agreed on pre-competitive cooperation in OSS development [7].

The open source model therefore offers a wide range of possibilities, but also involves risks and requires deliberate scrutiny. However, in a report by the Open Source Business Alliance, experts also note that most medium-to-large sized companies in Germany “lack an understanding of their dependency on software in general, let alone an understanding of [open source] versus proprietary” [8]. In addition, the manufacturing sector is characterized by specific challenges associated with the use of software in long-lasting operational technologies and equipment, as well as strict security requirements. The importance of software and the dedicated management of it is increasing due to the threats in cyberspace that go along with digitalization and connecting previously isolated systems. The manufacturing sector must prepare to adapt to these threats, because that is the only way that the advantages of digitization be achieved [9].

This white paper highlights the role of OSS as a strategic tool for driving digital value creation in the manufacturing industry. It focuses on how strategic collaboration enables industrial digital ecosystems and helps address key operational and innovation challenges.

In line with this, the following sections introduce the benefits of OSS in the manufacturing sector, the opportunities that arise from a strategic approach towards OSS and its management along with the risks and pitfalls that open up when such management is lacking. In addition, the paper highlights key considerations that industrial companies should address to confidently engage in open collaboration, drive joint innovation and strengthen (digital) sovereignty. Finally, the case of the German company GEA serves as an example to demonstrate how a strategic approach to OSS in manufacturing can be implemented in an effective way.



Open-Source Software in the Past and Now

The roots of OSS lie in the idea of free sharing and distribution of software. Originally established as a software development and distribution model that emphasizes openness, transparency, and collaboration, open source sparked enthusiasm among software developers and fostered vibrant communities. This form of open collaboration, based on the principles of mutual assistance, meritocracy, and the power of many, promises user empowerment as well as high-quality software and open innovation. Over time, open-source projects of all shapes and sizes arose, embracing various technologies and community styles. Many open-source projects grew to become more and more significant, provided key building blocks for software solutions, held significant commercial potential, and were no longer developed solely by individuals under the ethos of free collaboration. Instead, the advantages of open-source projects increasingly moved into the focus of companies as a key strategic tool to create business value [10].

One example is the Catena-X initiative and the open-source Tractus-X project, as well as the Eclipse Data Space Components (EDC) framework, which enable data ecosystems in the automotive sector. As a result, a manifoldness of business models based on OSS emerged, particularly in the information technology and service industries [11]. Today, however, OSS also holds many advantages for companies from non-digital-native sectors, such as logistics, automotive, and manufacturing [12, 13]. Studies suggest that up to 96% of all codebases worldwide contain OSS [14]. The global open-source ecosystem has an estimated demand-side value of \$8.8 trillion and companies would spend 3.5 times more on software development if OSS did not exist [15]. Open source is therefore unavoidable, and organizations that work with software will most likely be confronted with open source at some point.

The key distinguishing feature of OSS is its license, which defines the rights for modifying, distributing, publishing and using the software. The license provides the necessary framework for collaboration in open-source projects. Further innovation drivers then arose from this: The open-source model covers a range of tools and processes, ranging from version control up to development platforms, that help to organize software development processes, both in open or proprietary settings. Additionally, the software industry utilized open collaboration as a strategy for new business strategies and collaboration-based models [16]. Via organizations such as the Eclipse Foundation, contemporary OSS landscape provides not only a place for communities, but also professionalized services for industrial OSS development and a legal framework for collaboration with strong governance mechanisms, for example including intellectual property rights management [17].

Open Source as Ecosystem Enabler for Industry Benefits

For industrial companies, OSS is an effective tool for embarking on the path of digital transformation and realizing innovative connected digital services. In the manufacturing sector, software encompasses not only information technology (IT) but also operational technology (OT), which is characterized by long life cycles and considerable testing and maintenance efforts, and is often still siloed from IT processes [18]. OSS in OT is often considered a burden and security risk because the source code might introduce security vulnerabilities and/or complex license obligations, and the identity or intentions of contributors are often unknown. In this context, tracking and managing the usage of open-source components has become essential and established as industry best practice. Beyond tracking the usage and following practices like dependency or vulnerability checks, the active contribution to open-source projects is becoming

increasingly relevant. The reasons for this are twofold: The first motives are security and operational effectiveness. Companies are advised that “every organization using OSS should support the OSS ecosystem” [19] by supporting key projects in order to elevate the security baseline. Furthermore, interest in open-source initiatives has been growing steadily for several years among the industrial sector for more strategic reasons: There is considerable interest in working together to address shared challenges arising from the environment, regulations, or the economic situation. OSS is increasingly viewed as an answer to the question of how to effectively collaborate and enable participation and cohesion of the many diverse actors in the industrial landscape, so that responsibility can be shared and common goals pursued [3]. The following paragraphs outline a number of opportunities that arise from using, contributing, and collaborating in open-source projects, both in relation to open source in general and to the specific situation in the manufacturing industry.

Support during the whole lifecycle and neutral baseline

A special characteristic of industrial system landscapes is the long service life of machinery and their systems, which span up to multiple decades. This means that the software used in them should be thoroughly tested for security issues and other vulnerabilities. Moreover, the software must be maintainable and developable over a substantial period, which might entail different actors in the software supply chain. A neutral format is therefore required that enables long-term access to the code and the development path and possibly the further development of individual components, features, or specializations, even if responsibilities or company structures change. Collaboration in open-source projects enables such a format and allows for vendor independence and user autonomy.

Beyond that, the low barriers to access, modification, and use of OSS can boost connectivity to enable more insights into maintenance and service demands. Strengthening and developing secure, widely available, and accessible base technology opens up opportunities for innovative networked services and for strengthening the overall digital transformation of the industry and customer confidence in digital products. The aim is not to undermine the market for proprietary products, but rather to create a commodity base on which various proprietary, value-adding products and individual business models can then be built.

Furthermore, small-and-medium enterprises often face a “digital gap” in contrast to larger, digital mature organizations, which can be overcome quickly and easily with closed solutions, but also offers a unique opportunity to find a more self-determined solution based on OSS in the long term to maintain their digital sovereignty [20].

Incompatibility and closed systems as a point of the interoperability journey

The past strategy of many automation companies tended to be very closed. This is reflected in proprietary, manufacturer-specific and exclusive technologies and protocols. Such closed systems make it difficult to open communication with other systems and achieve interoperability, for example to exchange information between different machines and components or to standardize key figures. To enable overarching functional communication, the starting point is therefore at one extreme of the spectrum between openness and closedness. In addition, individual platform lock-in strategies characterize the environment and market, making system decisions highly sensitive to power structures. Open source can offer a neutral option for solving communication challenges for specific business problems without building lock-in situations.

Standards and base technologies accelerate wide IoT adoption and value creation

When considering software in contrast to hardware, interoperability often depends not only on the specification described in a standard but is also influenced by the implementation approach. The use of shared OSS therefore enhances interoperability, as potential shortcomings or ambiguities in specifications, as well as implementation decisions, can be avoided. The importance of this is becoming increasingly apparent with the growing convergence of IT and OT systems, which is giving rise to new standards and base technologies. For effective IoT adoption and the ability to use and produce data for new service options, OT systems become more and more like IT systems and require relevant processes and practices to manage them [21]. This also necessitates a more agile and implementation-focused approach to foster standards and drive the adoption of secure base technologies.

Efficiency and knowledge sharing

Sharing source code avoids “reinventing the wheel” and redundant developments, which increases efficiency and saves resources. This is crucial for keeping pace with the dynamic nature of digital technologies, enabling a fast time-to-market for innovations and focusing on the company’s key value proposition instead of re-inventing base technologies all over again. Open collaboration formats also allow the utilization of developer resources and integration different perspectives for problem solving. Furthermore, the more a source code is actively used in operational solutions, the quality is likely to increase as each partner invests resources for testing, ensuring security, or tackling improvements. This fits in with the core idea of open source, that the more eyes looking at a code, the easier it is to identify flaws.

Ecosystem enabler and trusted collaboration format

Data and software enable cooperation and integration as a basis for shared value creation and new business models in ecosystem approaches. Simply speaking, ecosystems are a set of interacting organizations depending on each other. More concretely, ecosystems are a new structure and a form of integration beyond traditional supply chain integrations or arm's-length relationships [22]. Companies must examine the boundaries of their own organization [23] and how to deal with their digital resources in order to participate in them.

While data sharing in particular has already been recognized and promoted as a valuable tool for digital value creation in ecosystems [24], the sharing of other resources that enable digital resources is relevant as well [25]. Source code represents one aspect of this. Other shared resources might be compute resources [26] or even production capacity [27].

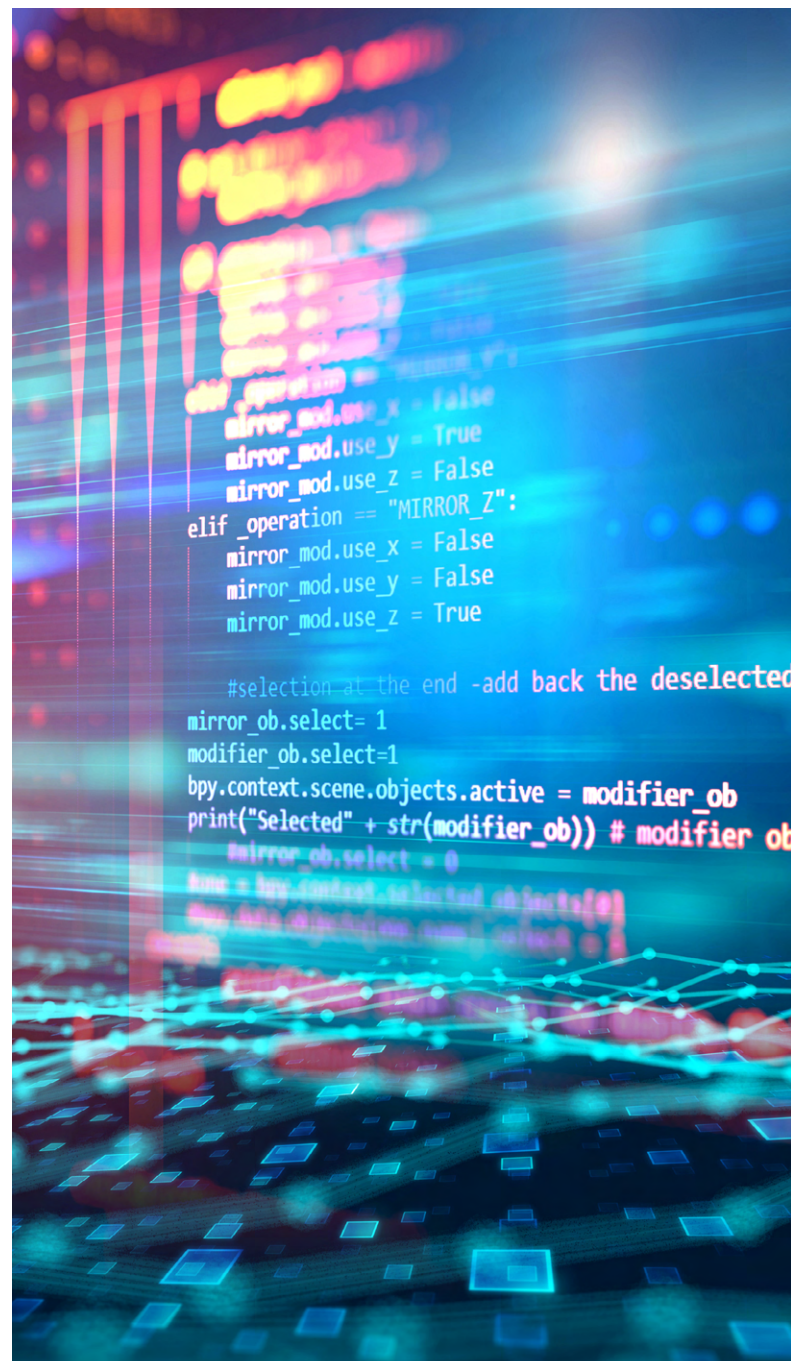
When it comes to collaborating on source code, in most cases the focus is on base technologies, building blocks such as libraries or frameworks, but in some cases also on complete applications that require a high degree of transparency or are crucial for the interoperability of data flows. The main driver for sharing the ownership of the source code are trusts and transparency requirements. Moreover, the development process rather than the outcome plays an important role: Open source provides a neutral collaboration environment to pool interests and different stakeholders under a defined governance and legal framework. As such, the contemporary open-source landscape entails not only developer communities, but also provides enterprise-oriented collaboration formats that facilitate collaborations with other organizations, non-for-profit associations and standardization bodies.

Digital transformation indicator

OSS reveals where legacy processes from the non-digital era are still being utilized in modern software development practices. Instead of "digitizing cow paths", where existing processes are merely automated and implemented in the old way, effective digitalization requires new ways of doing things and opens new opportunities. It also comes with new business opportunities and requirements, in particular with regard to interoperability between software. However, many processes are still based on the assumptions of dealing with hardware and non-digital business models. The main distinctions here are the development speed and iterative nature of many components, their roll-out and maintenance and many other aspects. Open source makes this particularly clear, as ownership and dynamics could not be more different from those of a proprietary piece of hardware. If

a company can understand and manage open-source software, many lessons learned and opportunities for change can be derived for other areas, including proprietary software and the digital suitability of processes in general. Open source can thus serve as a kind of digital checkup for processes and guidelines.¹

While the benefits of open source are widely recognized, leveraging these opportunities effectively requires a clear strategic framework.



¹ Similar to the Digital Check used for laws and regulations by the German Federal Ministry of the Interior [28].

The Need for Open Source Strategy and Management

In Germany, 69% of companies have actively decided to use OSS and 51% also actively participate in open-source developments. Yet only 32% have a strategy for their usage or development participation [29]. The effective management of OSS is closely linked to a company's value proposition within its own ecosystem and how a company manages its digital resources. Essentially, the handling of digital resources determines what data is processed and shared as well as which digital services are created and offered to customers.

A lack of an open source strategy, or a strategy that is not aligned with the overall company's goals, results in a strategic mismatch as well as operational inefficiencies and increased risks. For example, greater dependencies on software, vendors or contributors or compliance pitfalls. A strategy helps to identify and define indicators and metrics as well as operational processes and quality measures. Furthermore, the lack of open-source management increases the risk of security issues and incidents. This is also addressed by the EU Cyber Resilience Act [30].

Resource savings and preventive measures

From a financial perspective, an open source strategy is worthwhile for preventive reasons, but also for giving rise to direct and indirect cost savings and the creation of completely new business opportunities: As a first fundamental step, specifically addressing open source in IT and OT solutions mitigates the risks of breaching licenses or regulations, as appropriate processes and support systems have been established in advance. Another frequently cited advantage of open source is the obvious savings in license fees that come with most open-source licenses. However, a more nuanced view is needed here, as efforts for customization and integration still need to be considered. Furthermore, it is in the interests of both users and developers to ensure the long-term financing of open-source developments, which is likely reflected in other costs required to use the solution. Still, the use of OSS can decrease the indirect costs of the software: License negotiations and checks can be reduced by relying on commonly accepted open-source licenses. This concerns widely used base technologies, leading to lower marginal costs for repeated use. Additionally, tackling open source with concrete measures aims at improving developer efficiency due to clearly defined processes and support structures for using and contributing to open-source projects, along with the (re)use of existing implementations to avoid redundant work, covering not only development but also work and time involved in testing and security checks. Furthermore, enhanced vendor neutrality through open source reduces potential costs to switch between providers or

service partners. In addition, regarding interoperability through implementations, costs for implementing integration artifacts or removing interoperability barriers can be reduced.

Actively contributing to open-source projects, publishing an existent project, or starting a new project can lead to shared costs of continuous development and maintenance as well as even ownership. This depends greatly on the governance and management model, which is usually facilitated by open source foundations as a neutral environment with support services and structures that facilitate management of codebases with multiple stakeholders involved. An open-source collaboration with other companies can be particularly beneficial when it comes to overcoming interoperability issues or regulations. Joining forces and working on a common solution reduces the effort required by individual players. Finally, open-source projects also change markets and can create new opportunities for digital offerings or services, for example, when it comes to extensions or services for an open platform.

Collaborative value creation

A strategic approach towards OSS allows a smooth transition from a plain consumption position towards active contribution, without the risk of exposing business secrets or endangering intellectual property. Contributing back not only provides strategic benefits for building new ecosystems but is also a means of taking responsibility and caring for the community that produces and uses the source code. In this context, contributing can take many different forms, from supporting service providers up to donations and developer resources. Support for the open-source community also contributes to the ongoing maintenance and continuous improvement of the code, which in turn benefits the quality of a company's own products. In addition, positive spillover effects can be realized for other companies, which can strengthen an entire industry.

Efficient and secure software development

In addition to all strategic considerations, those who actually undertake software development are the most direct beneficiaries of a clear open source strategy: Software developers need to be empowered and have a good understanding to estimate which source code is useful for integration in industrial solutions and how to access their suitability in terms of security and quality. In addition to using OSS, developers also actively contribute to open-source projects or make projects publicly available under an open-source license. To do this, they need the right environment, best practices, and tools to confidently engage with the communities, make high-quality contributions and create a positive image of their company. Still, for building on open-source projects, software development is not enough, active community building is also essential.

Digital sovereignty risks and opportunities

Moreover, the global economic and business political situation is setting the spotlight on OSS [31] through increased demand for vendor neutrality and the desire to avoid dependence on large non-European software companies [32]. Many voices see open source as an alternative to proprietary solutions from non-European providers. In addition, open source enables many small players to work together, joining forces and collectively achieving results that are greater than the sum of their parts. Still, open source alone may not be the magic bullet. All of the major technology companies are also already embracing open source. From a global perspective, most contributions to open-source projects come from non-European companies led by Google, Microsoft, and RedHat [33]. The lack of European companies suggests that strategic potential remains untapped and there is a need to catch up in terms of open source expertise. Sovereignty is complex and is most likely not achieved solely by promoting open-source software, even if it is an important component. Yet, the vast amount of global open-source activities illustrates that open source has become a strategic tool that influences, builds and shapes markets for software and services and determines the flows of significant business value. Currently, the discussion about the role of openness is being further fueled by open generative AI [34]. Many companies are accused of "open washing", which aims to profit from the values and advantages of open source, gain customer trust or comply with regulations [35].

Throughout all the controversy and economic, legal and technical intertwining, one thing becomes clear: Openness is becoming an increasingly desirable trait and subject of interest, even if it is associated with many facets, ambiguities, abstract principles and ideal values. The global political turmoil may be a wakeup call for companies to question existing software practices and rethink sovereignty and self-determination but also calls to their own responsibility for contributing to vendor-neutral alternatives and leveraging and fostering cooperation with peers based on European values.

Ready for the Open?

If industrial companies want to take advantage of the challenges and opportunities offered by open-source software, they should consider the following aspects to ensure they are "ready for the open".

Strategic approach

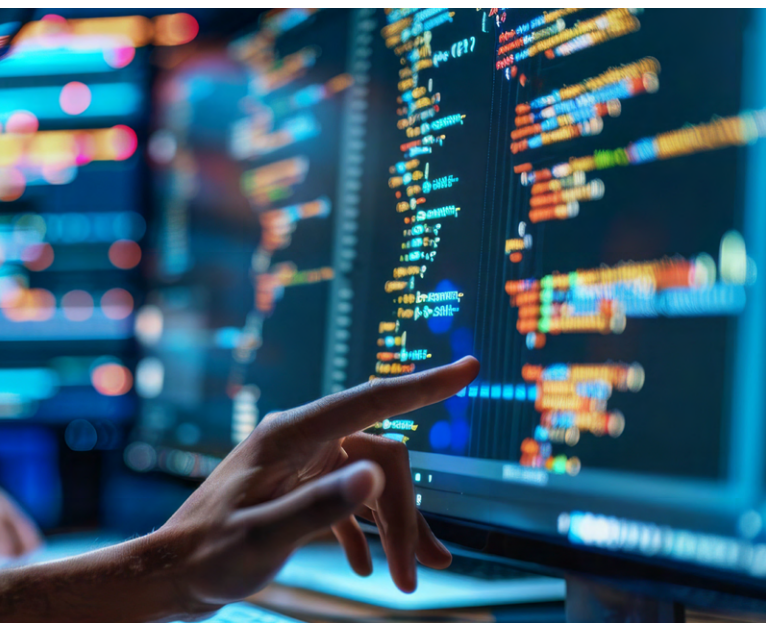
The basic prerequisite is that companies need to take a strategic approach to their open-source use and contributions and align their actions with their individual company goals. Then, industrial companies should consider the thoughtful use of open-source software, both in applications used internally and in products offered to customers. Consider who is behind the open-source project — not only with regard to preventing risks and dependencies, but also with respect to the actors driving the project need for maintenance and development. For example, the Open Source Business Alliance provided a recommendation on how public sector institutions can procure OSS in a sustainable way [36].

Get active

Now it's time to act beyond company borders as well: Identify projects of strategic relevance that would benefit from investing developer resources or build new projects and communities that serve a shared goal or solve a shared problem. Collaborating strategically and building sustainable communities requires a willingness to engage in communication and discourse and not reinvent the wheel. Effective open-source collaboration also requires clear leadership and an understanding of meritocracy [32].

Security first

While all activities should be carried out in consultation with legal experts and from a security perspective, it is just as important to recognize and promote the advantages of open source beyond licensing. Open source often requires dedicated focus and advocacy in industrial companies. For this, a sound understanding of the current software development processes and how they could potentially be improved is vital. Software developers need to be provided with an environment and resources to work with and master open-source code and collaborate — ideally in a fun way. This is another positive effect of open-source software: Working together on something, solving a shared problem and helping others gives work a sense of purpose.



The Case of GEA

GEA is one of the world's largest systems suppliers for the food, beverage and pharmaceutical sectors. Its portfolio includes machinery and plants as well as advanced process technology, components and comprehensive services. Used across diverse industries, they enhance the sustainability and efficiency of production processes globally. To seize the opportunities offered by OSS and adequately address the risks, a strategy project was carried out in which priorities were defined and specific measures were implemented. The company's slogan is "Engineering for a better world" – and OSS serves as a means to fulfill this slogan. GEA embraces OSS to enhance efficiency, sustainability, and innovation in software development. Committing to the principles of transparency, collaboration and shared knowledge, GEA utilizes OSS to avoid redundant development, quickly adapt to technological changes and maintain flexibility while reducing dependency on proprietary solutions. By actively participating in OSS communities and adhering to values such as responsibility, integrity, diversity, passion, and excellence, GEA positions itself as a supporter of the OSS ecosystem, i.e., with their Open Source Manifesto [37]. The guiding principles are shown in Figure 1.

For software engineers, this means that three core aspects guide their daily work with OSS:

- 1. Secure & High-Quality Coding:** We commit to secure coding and a code quality which is at the level of professional OSS. This is the base for inner-sourcing – sharing code across several GEA entities and teams according to OSS principles.
- 2. OSS Usage First:** Before we code something we prefer maintained high-quality OSS. We also prefer OSS before commercial software libraries.
- 3. Active OSS contribution:** GEA sponsors own OSS-projects at Eclipse foundation. GEA software developers shall contribute to those projects.

The strategic approach to OSS is closely intertwined with the overarching transformation of the industry: Software is playing an increasingly important role in mechanical and plant engineering. This is driven by the transition from automation to Industry 4.0 and further accelerated by software-defined equipment. GEA is an example of how companies can master the reliable production of software alongside the production of machines in the course of digitalization. However, it is not only on individual companies but the entire industry, especially in Germany and Europe, to take a closer look at OSS and answer relevant questions: How do we deal with OSS, how do we use OSS for the best results for our customers, and how do we participate in OSS so that we can collaborate toward the goal of secure and resilient digitalized value creation?

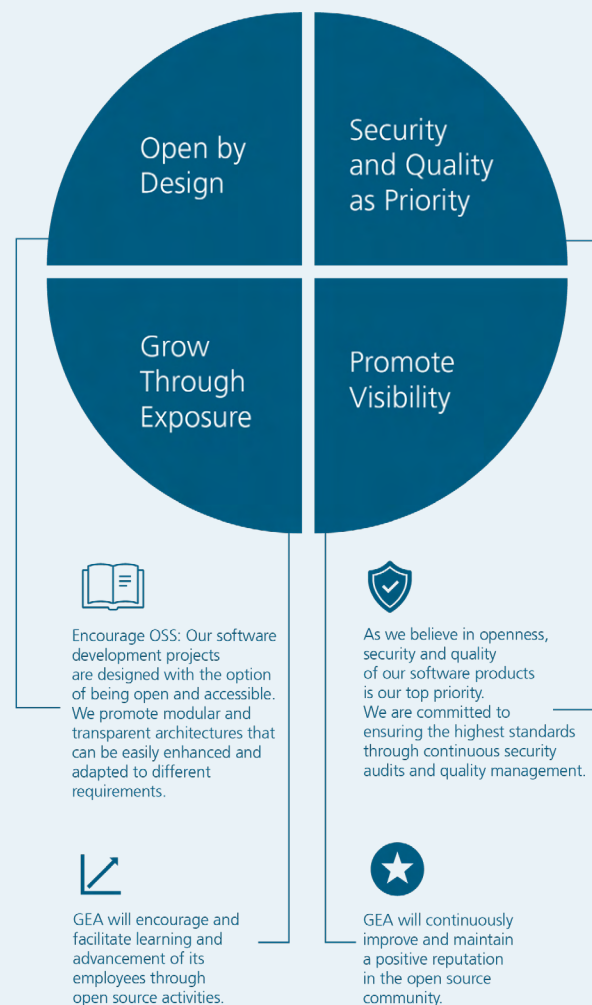


Figure 1. Company Principles

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