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# Engineering Collaboration in Product Development of Modular Products

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**Abstract.** Innovative enterprises seek to develop and produce smart products by the intelligent coordination of engineering processes across different enterprises and domains. A global automotive supplier is a leader in the development, manufacture and sale of hydraulic and pneumatic components for passenger cars and trucks. Modular design is necessary to gain high performance at limited costs of product platforms. It imposes a comprehensive approach for engineering communication with numerous customers worldwide. Providing that the engineered data is delivered to the recipient in the right format, quality and time is substantial in the collaboration between the supplier and its customer. The supplier has tackled the challenge by establishing a focal point of data exchange and translation (including a knowledge protection), which includes also modular product structures. The OpenDESC.com service, utilized by the company as the focal point of data exchange and translation, is capable of sending and receiving data to all partners, ensuring the independence from the standards and tools their partners use. This paper shows the requirements, challenges and solutions in the engineering collaboration on modular products.

**Keywords.** Engineering Collaboration, Modular Product Development, CAD Data Exchange Service Center

## Introduction

The automotive industry has been one of the main drivers in economic prosperity during the past century. With a yearly production of almost 80 million passenger cars and 12 million trucks, it is a key economic factor in the leading industrial nations. The market competition is fought out between a handful of Original Equipment Manufacturers (OEM) which compete each other with continuous product innovations adopting new technologies such as electrical propulsion and autonomous driving [1]. Starting from optionless mass production such as Ford T car, the OEMs offer more and more a huge variety of different vehicle variants combined with configurations. This plethora of variants and options is propagated into subassemblies and auxilary devices like clutches, fans and pumps. To handle this complexity and variety, significant efforts in product concepts and supplier partnerships are undertaken [2].

Modularization basically aims to extend the offering at limited costs [3]. Because of the development effort and time required for developing a new engine or gearbox, it is the intention to adapt the same engine into a maximal number of different car models. The same concept is also used for development of modules and components which are developed and produced by the suppliers. Hence, a concept of a maximum of reusable

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basic parts (e.g. core engine) in combination with different car bodies and regulation related mounting parts was established. Suppliers have the possibility to build their own product platforms to facilitate such modularization [4]. Additionally, the interface between the engine and the gearbox has been standardized allowing a flexible combination of engines and gearboxes and potentially hybrid modules. In this way, a cascade of modules emerges, what requires an appropriate concept of agile collaboration between OEM and supplier [5].

The aim of collaborative engineering, an emerging human-centred discipline, is to enable engineers and engineering companies to work more effectively with all stakeholders in achieving rational agreements and performing collaborative actions across various cultural, disciplinary, geographic, and temporal boundaries. Because products have become more complex, competitiveness has harnessed efforts in companies worldwide and sustainability issues have raised concerns in society, collaboration is increasingly needed from inception throughout the disposal of a product [6]. Furthermore, suppliers have often been identified in recalls related to design failures. Alliances between most of OEMs become now a permanent feature of business.

The German automotive manufacturers association (VDA) has conducted the fundamental work to define and classify the typical collaboration models and basical processes [7]. As a result, there are 6 supplier types defined according to the established criteria: production-technical integration, process integration, functional integration, and geometrical (spatial) integration of the whole product (car). Taking the fact into account that a supplier serves many customers in an extended enterprise concept, each of them having their own, various processes and infrastructures, there emerges a strong need for a comprehensive integration approach based primarily on standards and providing the relationships to all the customers [7]. Based on the ever higher share of partner and supplier content in typical global product development, the potential risks of insufficient engineering collaboration are self-evident (Figure 1).

In this context, there are differences between three frequently confused terms: coordination, cooperation and collaboration. Coordination refers to activities performed by different individuals in order to make them compatible with a common purpose or result; cooperation refers to engaging in work on monitoring and evaluation, learning from each other and sharing experiences; and collaboration refers to using information to create something new, seeking divergent insights and spontaneity, jointly developing proposals, sharing information, planning joint workshops, and raising funds together among other activities [6]. In our case, collaboration thrives on differences and dissent and must be supported by suitable processes, methods and tools [8].

However, due to the different collaboration environment (processes, methods and applications) deployed at the automotive OEMs, a unified solution is not a real option at this time. In particular, automotive suppliers that develop system components for a number of different OEMs or tier-1 suppliers, face the challenge of ensuring that they make CAD data available in the format required by their customers with a high level of reliability and, if data translation is involved, that they take the system configuration of the respective customer into consideration [9].

A successful supplier integration includes both the exchange of CAD data and protection of intellectual property for product modules. The paper is structured as follows: Section 1 gives overview about the platform development of the automotive components; Section 2 presents our approach for data exchange and translation proven in an industrial application; Section 3 expresses some concluding thoughts.

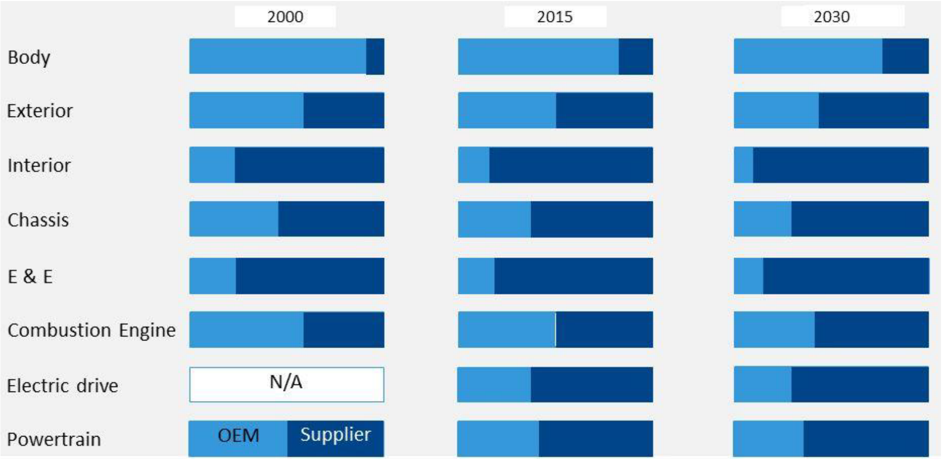


**Figure 1.** Increase of share of suppliers in value added, derived from [7].

## 1. Platform development

For the methodical development of modular systems suitable supporting methods and tools are required. Modularity is achieved by partitioning information into visible design rules and hidden design parameters. The visible design rules ("visible information") are basic decisions that affect subsequent design decisions. Ideally, the visible design rules are established early in a design process and communicated broadly to those involved [10].

Considering the criteria for the modular design such as the functional orientation, requirements management or a corresponding target derivative, the guide to the modular design and final evaluation are phases in a development process that should be adapted accordingly. Like other processes in the product development, modular design requires support by dedicated workflows in CAD and PDM systems. As will be described later, this is a pre-requisite for a successful data exchange.

Customization comprises the ability and strategy that aims towards design and manufacture of tailored products for an individual customer [11]. Depending on where the actual customization starts, four different business models can be identified: Engineer-to-order, Modify-to-order, Configure-to-order and Select variant. A higher degree of customization is often required for system suppliers and modularization must be supplemented by parametric models and design methods.

Whenever possible, appropriate conditions can be created first, for example, by adjusting requirement specifications. Modular design is suited to most but not to meet all the requirements. A careful trade-off between conflicting requirements must be accomplished [12], taking the product differentiation and the product diversification into account. In particular, by means of platform development the desired external variety (differentiation) has to be realized with a lowest possible internal diversity [13]. For the identification of possible approaches to selecting the appropriate differentiations, systematic support is necessary. The function-oriented approach already contributes an important part. Numerous principles are available for the technical realization [14].

Advanced guidelines for the identification and determination of potential differentiation characteristics are given by various sources [15][16]. The selection of principles must be carried out in close coordination with the respective corporate strategies and taking into account various aspects, for example, ratio cost/benefits, ease of assembly procedure, design, cultural differences and even more [17]. System performance and effectiveness need to be evaluated based on typical configurations based by design decomposition [18].

From the business point of view, modularization has three purposes: to make complexity manageable, to enable parallel work, and to accommodate future uncertainty [10]. So, it is possible that a component cannot be included in the platform as a result of certain cost constraints: for example, if the total cost of a component is comparatively low, and consequently providing only small scale advantages by using a carry-over part in several platforms. Such decisions are occasionally heavily dependent on the desired aspect of the modular platform development such as quantity of common interfaces, quantity of modules and variants, and depth of the product structure.

To fully benefit from the advantages of modular product architecture, the desired impact when designing a product platform must be estimated. Depending on what effects are required primarily by developing a modular system, the design of the system changes. Companies also need to develop an ability to cope with difference in requirements from different customers and changes during the development of a customized product [11]. In the platform development of seats, besides of variation control, the aspect to increase flexibility could be in focus to meet the customer needs of more individualization. Otherwise, the primary goal to be achieved by developing products with less settled customer perception, for example, fan or cluchmaster, the number of variants and the complexity level should be reduced. Since both components differ according to the customer impact, the concepts of the product platforms are different.

The new concept Design Platform was introduced to manage fluctuating requirements, supporting methods for efficient customization and needs for improved support [11]. The need to increase re-use and to gradually build up a source of articles, components, methods, guidelines, etc., based on previous projects while technology can bring new solutions, was identified by the companies as essential.

Systematic development, modelling, structuring and upgrading of modular products will improve the agility after the entire supply chain is streamlined to product platforms. In such a way, development of solutions for different customers' demands can be provided, even if their requirements fluctuate. Various directions of impact itself can influence each other. An isolated view is, therefore, usually not possible. In addition, the potential of differentiation or standardization changes depending on the level of the considered product structure.

## 2. Use Case Industrial Application

Our industrial example is provided by a global supplier with headquarter in Far East, which provides aggregates and components for hydraulics and pneumatics in the engine, transmission, and chassis systems like steering and position control. With staff of more than 11.000 worldwide, it is a leading manufacturer of such products, which are used not only in the passenger cars, but also in commercial vehicles, agriculture machines and special vehicles. In all situations where great force is required in a small space in the vehicle, hydraulics is superior to each electric system. In our case, most components are built in a modular way which has to be preserved in the collaboration and data exchange with OEMs and within the joint ventures as well.

### 2.1. More electronics and software

Like many other functional aggregates and sub-systems in the vehicle, hydraulics and pneumatics are also increasingly equipped with electronics and control software to enhance their efficiency and to always tap their performance only when necessary. This not only increases the complexity, but also the variety of product types, without the engineers having more time for the development of the products. To make the variance manageable, the company uses standardized product platforms for some time now for both, the passenger cars, as well as the truck sector that covers about 80 to 90 percent of the customer requirements, thereby reducing the engineering effort and production costs as well. Overall there are more than 30 such platforms at this time, which can have much longer life cycles than the customer-specific characteristics of a singular aggregate.

Many automotive suppliers develop their products using the CAD system of their customers, in order to facilitate the seamless data exchange without the data translation. Such segmentation indeed allows higher agility in the customer process, but imposes high complexity and higher expenses in the internal processes, in particular at the begin and the end of a development project. However, this impedes the standardization of assemblies and components across products. Our customer, however, pursues a one-system strategy with translation in customer process when necessary. The platform strategy requires that the OEM products are designed in a single CAD system because the components could otherwise only be reused internally with considerable effort. Therefore, designers in all the product engineering locations all work with the CAD system Creo Elements/Pro, which is used worldwide on a total of more than 300 workplaces. This distinguishes them from engineers at many competitors companies that use the respective CAD systems and system configurations of their customers which are forced to manage a high internal complexity which occurs on segmentation of the CAD landscape and the downstream processes.

Of course, the one-system strategy conflicts with the need to deliver the CAD models and drawings in the respective customer formats so that OEMs can use it for digital mock-up studies, thermal and flow analysis and further simulations [19]. Therefore, the company has been using the conversion service OpenDESC.com. Consolidating the European subsidiaries a decade ago, their CAD department faced the question of whether to realize their own data exchange and translation hub or to outsource the entire customer data exchange process [20]. The cost of the acquisition of licenses, the maintenance of the OEM specific environments, employee training and other costs have been estimated higher by several times than the use of OpenDESC.com. This has justified the initial decision for outsourcing which meanwhile has been confirmed several times already.

Key characteristics of the exchange process include the translation of the modular model structure and protection of intellectual property by removing the components which comprise the know-how, but are not relevant for CAD collaboration [21]. In the exchange of assemblies based on modular design, there are basically two approaches. The first one is converting the invariant portion of the model which comprises the modules at the beginning of the project and, after that, exchanging only the variable components as parametric feature models. This has the advantage of a lower exchange volume but requires a PDM exchange, as otherwise the data may be inintentionally overwritten.

The second possibility concerns the exchange of full packages containing the invariant as well as the variable components. Here, the invariant and the variable components must be marked differently. An intelligent converter (e.g., CADfeature) can translate a mixed model (parametric + BREP) accordingly. Though causing the higher data exchange volume, this possibility is stronger and easier to handle. Furthermore, this approach allows to mix the full parametric feature and BREP models, when necessary (Figure 2). This saves the costs and improves transprency. Furthermore, one of the well-known problems of data exchange – is the persistent naming problem can be resolve on this way. While creating an internal geometric model in a CAD system, there are several ways to generate the CAD model entities [20]. However, during the data exchange process, the distinct modeling entity can be differently represented and it usually can cause unexpected errors.

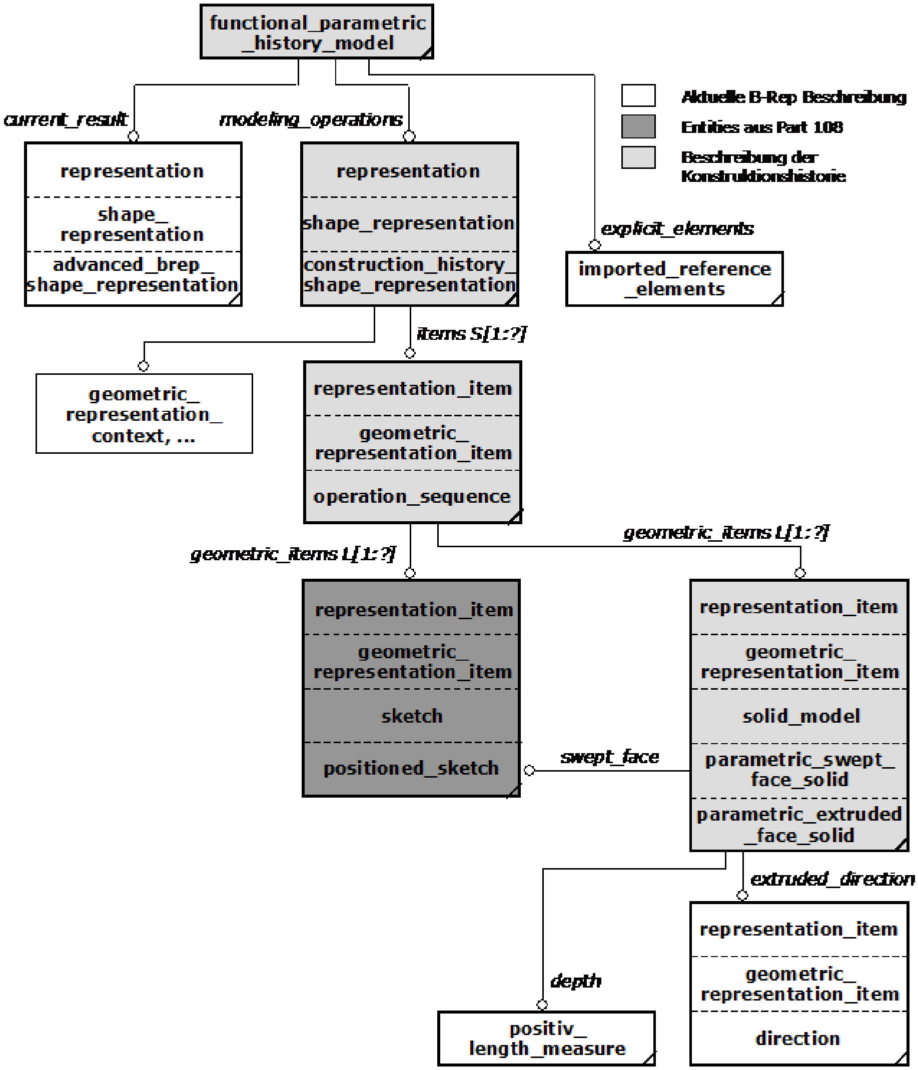


**Figure 2.** Description of the engineering design history in the STEP file [20].

### 2.2. Automation of data exchange

OpenDESC.com is a holistic service for enterprise-wide data communication, which includes both the conversion and the secured transfer of the converted data to the partner. Via an intuitive service portal, users can provide their CAD data, as well as other product-related documents, automatically for the exchange and import the data and documents provided for them into their backend systems. Before the transfer, the CAD data can be converted into the format required by the receiver taking into account the OEM-specific requirements. The context diagram of OpenDESC.com is shown in Figure 3.

Crucial for the decision in favor of OpenDESC.com was not only the long-standing expertise of PROSTEP in the field of data conversion, but also match the high security requirements e.g. the ability to encrypt the data on the portal during the exchange to the customer. The issue of data security was a major aspect of the benchmark which was conducted by support of the former parent company [21]. The assessment upon ISO27001 standard is also beneficial. Further modern collaboration approaches are under continuous evaluation, but not realized due to their obvious weaknesses in the productive use [22][23].

The automation of the data exchange is important for the supplier because the company decided several years ago that drawings should only be transmitted via secured data connections [24]. Therefore, in addition to the OEMs, for which the CAD data is provided in the native or sometimes in neutral formats, many suppliers of the company are also integrated in the partner network, to which the data is forwarded on request without conversion. This no longer involves only CAD models and drawings, but sensitive product data of all kinds, for example, specification sheets or contracts of purchase. In the comprehensive solution service data base around 1,000 relationships for the data exchange are now deposited.

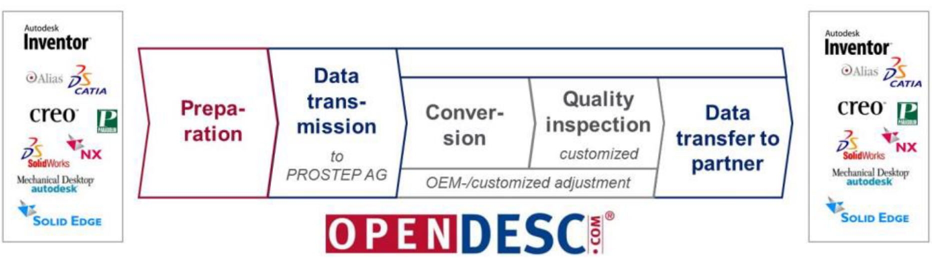


**Figure 3.** CAD exchange and translation in www.opendesc.com.

### 2.3. Customer specific conversion

The project engineers use this conversion service only for communication with the clients. First, the mounting space provided by the OEMs in different formats, can be translated via OpenDESC.com into the Creo format. They often get a lot more data than they actually need for their work (e.g. the front module as the mounting space for a fan), what can cause difficulties if the data volume exceeds a certain limit. In such cases several approaches to reduce the data volume have been applied. Secondly, the models and drawings of the hydraulic and pneumatic products are converted via the conversion service into the respective customer format when sending to the OEM, wherein the design history is lost, of course. In fact, that makes no difference, because the company intentionally simplifies their models before sending to protect their know-how. In case of platforms, the translator CADfeature from Elysium is able to translate form features, if desired [20] (Figure 4).

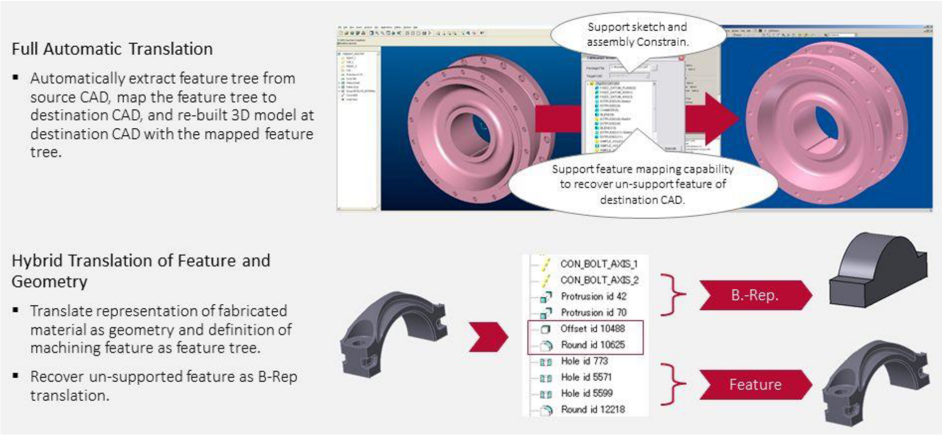


**Figure 4.** Translation of BREP and form features with CADfeature [20].

From the perspective of the users the conversion process is very easy. They only need to select the files to be sent, the recipient and the desired format in the window of the exchange portal - all other operations run automatically without their assistance. Within 48 hours the models and drawings are translated into the target format, taking into account the start models and other specifications of the relevant OEMs. Based on pre-defined addresses in the Odette File Transfer Protocol (OFTP) connection, the converted files are then forwarded directly to the customer or - depending on the OEM - even uploaded directly into their PLM system. The engineers, therefore, do not need to worry about the data exchange, but rather will be informed that the data has been delivered to the customer.

The requirements for data quality have increased significantly in recent years by progressing digitalization. Customers not only want to receive the native models and drawings, but want to embed more and more metadata in the CAD models to quite waive the drawing completely by way. At some point drawings aren't needed anymore, because all information is related and inserted into the 3D model. Consequently, that will make intellectual property protection even more difficult. Apart of a comprehensive concept of intellectual property management, an appropriate CAD data export filter must be used for such a scenario [21][24].

### *2.4. Evaluation and practical experience*

The data exchange and conversion service is not yet connected and embedded in the PDM system, so that the user must check the data out of the PDM backbone SAP PLM before the exchange and conversion. This can cause errors in data handling. The plan is, however, to start the process directly from the PDM system and also monitor the data exchange here, at some point. This requirement has not the highest priority, but first of all the SAP PLM has to be rolled out globally and the CAD system landscape has to be unified.

It is assumed that with the introduction of a strategic CAD system throughout the division, the volume of data to be converted will increase significantly. Currently, between 250 and 300 conversion jobs with a data volume of a total of five to six gigabyte are handled each year over OpenDESC - of which more than half for data export. CATIA V5, Siemens NX and PTC Creo are the most exported data formats at the different system configurations of the customers. The costs for the service don't differ too much from year to year. For that amount of money, the company would not be able to provide and to maintain different customer systems, and to pay two experts for data translation. However, the use of the translation service provides not only cost advantages. At least as important is to ensure that the customer receives the data in the desired quality, because the CAD capability contributes directly to the supplier evaluation by the OEMs and, therefore, impacts the future orders. Since the company is using OpenDESC.com, there was always a good score in the evaluation on the part of customers.

## 3. Conclusions and Outlook

The relationship OEM – supplier is substantial for proper function in the automotive industry and, therefore, subject of continuous improvement. Mutual dependence requires significant efforts and expenses to build and maintain such connection and collaboration. Internal and external collaboration and communication is increasing and has to be optimally supported with PLM systems. Never to forget that such a dynamic collaborative environment is subject of continuous change not only in turbulent times but also by updates on a regular basis. Suppliers who work together with different OEMs and tier-1 suppliers have to constantly cope with new requirements relating to exchange partners, data formats, system environments to be supported, quality and security requirements, etc.

The recent trend of technologies of modular design in the automotive industry is to use, combine and integrate different technologies such as advanced CAD systems, product configurators, agent based systems and PDM systems. However, this makes interfaces more complex and fault-prone. Development of intelligent PLM architectures as well as the development of intelligent modular products (i.e. intelligent system: model-tool-product), which can communicate and cooperate, demands the design of more intelligent organizations of designs processes for product variety, for product configuration, and for mass customization [25]. If mixed models are desired, the features which must be translated as a form feature can be selected by the appropriate tools.

In regard to customer communication, such complex business requirements can be easily resolved by collaboration with a competent service provider which acts as a data hub in the global automotive network. This reduces considerable administrative overhead in terms of time and money, which can, on occasion, have a negative impact on quality and adherence to deadlines. It not only cuts costs but also facilitates making the exchange processes uniform and ensures a higher level of reliability and traceability. In case of change at the customer' site, this approach allows to work again in the same environment by using a stable, predefined interface in the customer process.

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