UDC 330.47=111 DOI: 10.5862/JE.228.10

I.V. Ilyin, O.Yu. Iliashenko, K.M. Makov, K.V. Frolov

DEVELOPIING A REFERENCE MODEL OF THE INFORMATION SYSTEM ARCHITECTURE OF HIGH-TECH ENTERPRISES

И.В. Ильин, О.Ю. Ильяшенко, К.М. Маков, К.В. Фролов

РАЗРАБОТКА РЕФЕРЕНТНОЙ МОДЕЛИ АРХИТЕКТУРЫ ИНФОРМАЦИОННОЙ СИСТЕМЫ НАУКОЕМКИХ ПРЕДПРИЯТИЙ

One of the main problems in high-tech enterprise management is the issue of integrated logistics support of production and service, which is not considered an independent methodological problem by manufacturers. The article describes the baseline architecture of the information system based on the CALS conceptual model (Continuous Acquisition and Lifecycle Support). Research into ILS tasks and reference architecture components made it possible to propose a reference architecture model of the unified ERP II system for integrated logistic support. Two main approaches to developing integrated systems were considered while constructing the information system architecture: mono platform and poly platform. Poly platform systems integration is used as a method of constructing the target architecture of a unified information system for information support life cycle product (with all the necessary improvements). A gap-analysis of the transition from the baseline to the target architecture, reflecting the main stages, is provided. The proposed reference architecture model of an information system represents a possible solution that provides support for solving not only the integrated logistics support problems but also the core tasks of the enterprise: supply chain management, resource planning, customer and supplier relationship management. A reference model of the system architecture was built with due regard to integration tools for information exchange in a single information space between all the subsystems. The proposed model is based on a single service-oriented platform and the Integration Bus which allows connecting systems of different manufacturers. Each system is discussed in detail. The key functions and tasks of each system (general and service ones) are described.

INTEGRATED LOGISTIC SUPPORT; CONTINUOUS ACQUISITION AND LIFE CYCLE SUPPORT; REFERENCE MODEL; INFORMATION SYSTEM; TARGET ARCHITECTURE.

Одной из основных проблем в управлении наукоемкими предприятиями является проблема интегрированной логистической поддержки производства и сервиса, которую производители не рассматривают как самостоятельную методологическую. В статье приводится описание базовой архитектуры информационной системы на основе концептуальной модели ИПИ (информационная поддержка жизненного цикла изделия). В результате исследования задач интегрированной логистической поддержки производства и компонентов базовой архитектуры предложена референтная модель архитектуры единой информационной системы класса ERP II. При построении архитектуры информационной системы рассмотрены основные подходы к формированию интегрированных систем — моноплатформенный и полиплатформенный. В качестве метода построения целевой архитектуры единой информационной системы непрерывной информационной поддержки жизненного цикла изделия использована интеграция (с необходимой доработкой) полиплатформенных систем. Приведен gap-анализ перехода от базовой к целевой архитектуре, отражающий основные этапы. Предложенная референтная модель архитектуры информационной системы является одним из возможных решений, обеспечивающих поддержку решения задач как интегрированной логистической поддержки производства и сервиса, так и общих задач производственного предприятия: управления цепочками поставок, планирования ресурсов, управления взаимоотношениями с клиентами и поставщиками. Построение референтной модели архитектуры системы выполнено с учетом инструментов интеграции обмена информацией в едином пространстве между всеми подсистемами. В основе предлагаемой модели лежит единая сервис-ориентированная платформа и интеграционная шина, позволяющая «бесшовно» соединять системы разных производителей. Каждая система подробно рассмотрена, описаны ее ключевые функции и решаемые задачи (общие и относящиеся к сервисному обслуживанию).

ИНТЕГРИРОВАННАЯ ЛОГИСТИЧЕСКАЯ ПОДДЕРЖКА; ИНФОРМАЦИОННАЯ ПОДДЕРЖКА ЖИЗНЕННОГО ЦИКЛА ИЗДЕЛИЯ; РЕФЕРЕНТНАЯ МОДЕЛЬ; ИНФОРМАЦИОННАЯ СИСТЕМА; ЦЕЛЕВАЯ АРХИТЕКТУРА.

Manufacturers of sophisticated scientific products are in continuous search for new ways and approaches to cement their positions in the market and to increase their marketability [1, 2]. The CALS (Continuous Acquisition and Lifecycle Support) concept is applied to provide coordinated work of all companies engaged in designing, manufacturing, distribution and operating scientific products. At the same time, no due attention is paid to the ILS industrial problem (Integrated Logistic Support). Existing foreign solutions need serious adaptation to the domestic manufacturing of sophisticated scientific products in regard to both regulatory documents and the application of information technologies to support ILS processes within the framework of an integrated information environment (IIE) [3]. In the course of IT support of ILS problem solution, most of the focus is on an PLM (Product Lifecycle Management) system which manages a product life. And every enterprise develops its own individual approach ([4—7]). It is, however, expensive, inefficient, slow, and rarely reaches expected results. IT support of ILS cannot be a system task to be assigned and solved.

This article suggests a reference architectural model of the uniform information ERP II system for integrated logistic support which helps to avoid the abovementioned shortcomings and to develop and introduce necessary architectural decisions. Such a system aims to shorten resources for scientific product preproduction and manufacturing, to improve the quality of manufacture and post-sale support of products due to the introduction of an integrated automated system based on a single digital space.

According to a systematic approach to enterprise management, the components of an enterprise architecture must be formed, reformed and developed according to their interdependency [8]. One of the most dynamic and demanded segments of information systems in production of high value-added products that requires ILS systems for effective service is information systems supporting the product life cycle which are based on integrated automated information systems [9—10]. At the same time, costs of sophisticated product maintenance exceed purchase costs [11]. Reducing product life cycle costs is one of the goals to be achieved by the introduction of the CALS concept and strategy.

Fig. 1 shows the basic architecture of the information environment of scientific companies according to the CALS conceptual model [11].

IIE forms the basis for CALS. All IIE data are stored as information objects to which a uniform system of guidelines concerning information representation, storage and interchange applies [12]. IIE information processes support the product at all its life stages.

The basic architecture includes five key inter-integrated blocks which constitute the uniform information space of a company.

Such an architecture based on the CALS conceptual model mirrors its invariant concepts which can be divided into two groups [11]: the key CALS principles and the basic CALS technologies. The latter ones are implemented by multifunctional working groups comprising experts from different fields [11]. The regulatory framework for developments consists of international and national standards [13—15] regulating various aspects of CALS technologies.

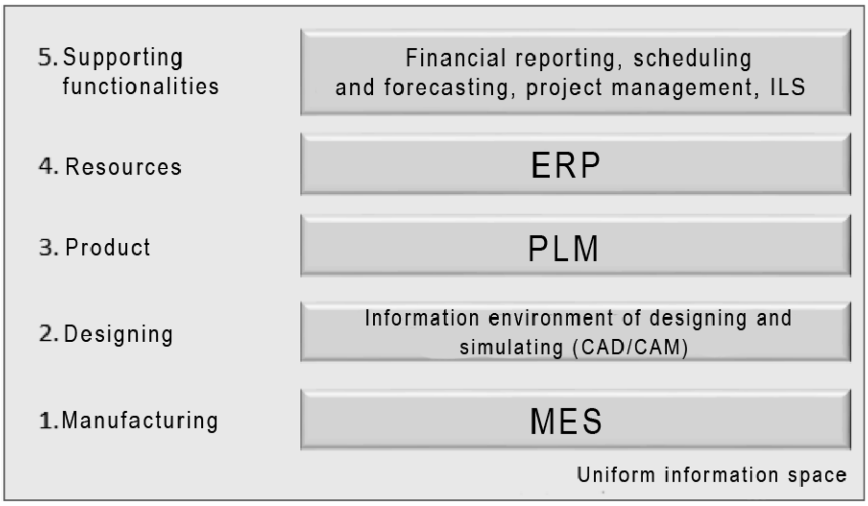

Fig. 1. Basic architecture

A complex mix of administrative processes and procedures to reduce costs at the post-production stages of the product life cycle (sometimes referred to as 'ownership costs' [16]) are united by the concept of ILS. This is one of the CALS basis invariant concepts. No information system can be associated with CALS until an ILS component is implemented in it to a certain extent. On the other hand, the process content and ILS problem composition are essentially independent of the subject area.

The analysis of normative documents ([17–21]) helped to identify the main problem related to integrated logistic support and to formulate primary tasks aimed to solve it. The ILS of a sophisticated scientific product involves the implementation of four basic processes [11]:

– product LSA (Logistic Support Analysis) at all stages of the product life cycle;

– product MRP (Maintenance and Repair Planning);

– product ISSPP (Integrated Supply Support Procedures Planning) at the design stage, later detailed in the course of the manufacturing and use of the product;

– providing personnel with Electronic Maintenance Documentation (EMD) and Electronic Repair Documentation (ERD) for the product at the design stage and in the course of manufacturing particular copies (sets) of the product.

The combined impact of the introduction of CALS technologies depends largely on the level of the integration of business processes and automated subsystems supporting them. The consolidated positive effect of employing information systems at every stage of the product life cycle can be reached by integrating business processes [22–23] applications and data within the product uniform information space.

In such a way, an integrated system of life information support for high value-added products must cover the following interacting basic components:

– exchange of information with the design departments that develop product Engineering Documentation (ED) at the level of data and processes (accepting, transferring, updating electronic ED);

– centralized / single pre-production engineering;

– management of the designing, manufacturing and application of hardware;

– pre-production engineering in assembling shops;

– management of product assembly processes with the prevalence of manual operations (including interaction with copartners, raw material and equipment suppliers);

– monitoring of the design, engineering, manufacturing processes and product operation;

– performing logistic analysis (calculating ILS efficiency indices, ILS designing, determining resource requirements, etc.);

– support of problem solving at every level of product Material and Technical Support (MTS) and product Maintenance and Servicing (MS) (schedule control, the calculation of the optimum amount of spares in store, repair team management, MS events planning, etc.);

– support of tasks for effective and integrated with the above tasks functioning of the supply chain.

When developing a reference model, it is necessary to consider that the information system must provide solutions to the following tasks:

1) in regard to logistic and financial analysis:

– strategy development, planning and control of the logistic analysis process;

– strategy development, scenario simulation of the product life cycle from a cost perspective in different currencies;

– design analysis of the product at its developing stage to formulate recommendations for the provision/improvement of reliability, maintainability, technical readiness, operational processability, and the supportability index;

– development and analysis of product Technical Maintenance System (TMS) variants to provide specified requirements related to the product life cycle, readiness and supportability;

– analysis of interaction of the product and TMS to determine the combination to ensure its supportability requirements;

– control of the product supportability index during its use and the determination of factors having a negative influence on this index;

2) in regard to maintenance and repair:

– provision of the specified level of the product readiness during its use;

– management of the maintenance and repair of sophisticated products with an allowance for their actual condition;

– maintenance and repair works period, composition and content control;

– provision of operation and resource planning for the maintenance of the whole product and its parts;

– control over work completion for all kinds of maintenance;

– requesting all services for the whole product and its parts;
– getting reference information on the period, composition, duration and intensity of works, on the performer, and necessary spares, materials, and equipment for all services;

3) in regard to operation management:
– monitoring of the technical condition and operational readiness of the equipment;
– storing of information on all the equipment in use: its structure, technical data, warranty and service contracts, operational documentation;
– maintenance and repair works scheduling, schedule and results recording;
– stepped equipment maintenance and repair manuals;
– maintaining inventory of spare parts, consumables, and other materials necessary for equipment operation;
– planning and control of material purchases for equipment operation;
– electronic equipment logging;
– circulation of electronic documents accompanying the product's use;
– taking account of the level of expertise and availability of service personnel;

4) in the development and application of Interactive Electronic Technical Manuals (IETM):
– providing users with reference material on the product design and functions;
– training personnel to perform in conformity with operating, servicing and repairing regulations;
– providing users with reference material necessary for the product operation, maintenance and repair;
– providing users with information on the product operational techniques, on necessary tools and materials, on personnel quantity and qualification;
– equipment diagnostics and troubleshooting;
– preparation and filling of automated materials and parts orders;
– maintenance scheduling and reporting;
– consumer/supplier data exchange.

Let us specify the scenario of the continuous information support of the product life cycle. There are two known approaches to forming the uniform information space of the product life: applying a set of automated systems (CAD, PDM, ERP, CAPP, MES) by the same maker (mono-platform solution); integrating subsystems by different makers (poly-platform solution) [24]. Choosing one or the other approach depends on a series of parameters: economic and time indices, operational/technological indices, indices of functionality, production process compliance, business process compliance.

Another possible scenario of establishing the continuous information support system of the product life cycle can involve integration (including necessary improvements) of poly-platform systems [12]. A mandatory requirement is the compliance of integration tools and the system as a whole with automated system requirements according to regulatory and production documents. The practicability of developing an integrated poly-platform system for the information support of the product life cycle of the high value-added product can be specified by the following factors:
– high cost and a long period of adapting foreign systems to the domestic specificity;
– availability of know-how in the field of integrating information systems and data in automated control systems;
– availability automated subsystems tailored to domestic manufacturing processes;
– availability of know-how in the world and domestic practice of business process integration, applications and data.

In view of the above, it is a model of the poly-platform integrated system of the continuous information support of the product life cycle that was chosen to develop a reference model of the information system for integrated service support.

A management information system provided the basis for the interaction of the structural components of the ILS system. Its key rule is that the information occurring at any stage of the product life cycle is stored and becomes available for all participants in accordance with their rights (levels) to information access. Fig. 2 shows the structure chart of a management information system.

The diagram shows both the manufacturer of sophisticated scientific products and the consumer. The manufacturer has the product regulatory and reference information obtained during the development, manufacturing and complex logistic analysis of the product. The consumer is provided with interactive electronic technical manuals and product reference data in electronic form. Also, the consumer makes and transfers scenarios of the product's use, provides electronic data exchange between their service and MTS systems and the manufacturer`s management information system.

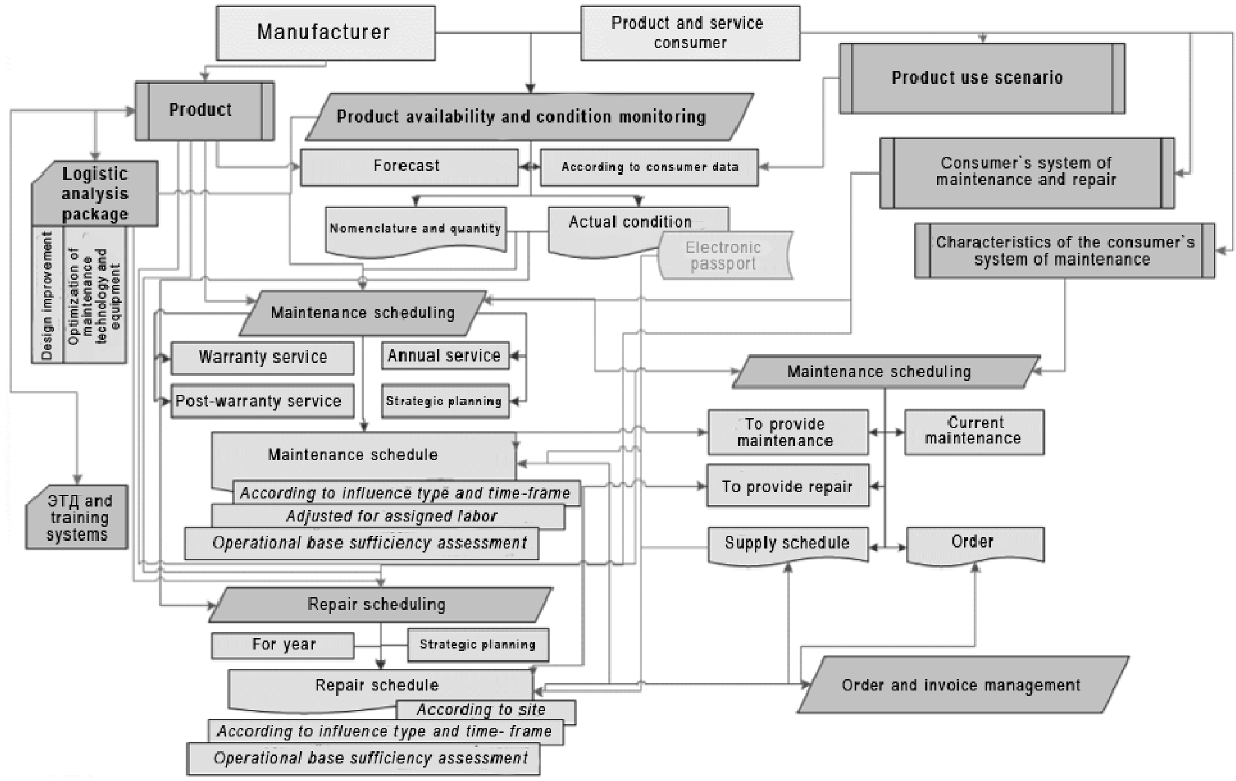

Fig. 2. Management information system

During the product's use, its operation profile is monitored by both the manufacturer (forecast data) and the consumer (actual data). These data are consolidated in the management information system and are instrumental in creating the product's electronic passport. Also, information on the current condition of the product is used by the manufacturer to adjust and to perform maintenance as well as to organize the MTS schedule to support MS events.

The scheduling of maintenance events and just-in-time purchasing of spare parts are done on the basis of MTS and ISSPP plans which consolidate actual and forecast data of the product use. The integration of automated Enterprise Resource Planning and Material Requirements Planning (ERP/MRP) information systems and systems of service management (supply, service, repair, utilization, information support, etc.) provides the pass-through optimization of material flows and resources at all stages of the product life cycle.

In response to ILS challenges and the above diagram, we propose the following reference model (target architecture) of an ILS information system (Fig. 3).

The complex of the systems presented in Fig. 3 suggests a uniform integration platform implementing the strategy of the uniform integrated system that combines technology and software.

The uniform platform allows applying the single sign-on technology which providies the user with the possibility to leave one system and enter another without reauthentication. The single sign-on technology makes it possible to reduce time spent re-entering passwords for the same account and to cut IT service costs due to a decrease in password reset requests.

An integral part of the uniform platform is the integration bus which provides an integration universal interface to systems on the integration platform if, for example, these systems are issued by different manufacturers (Oracle, SAP, 1C, Siemens, etc.). The core of the integration bus is the Integration Engine that performs typical functions of the message broker, including message conversion, routing, publication and subscription tools. The most important advantages of the integration bus are:

– flexible integration of the company's IT landscape;

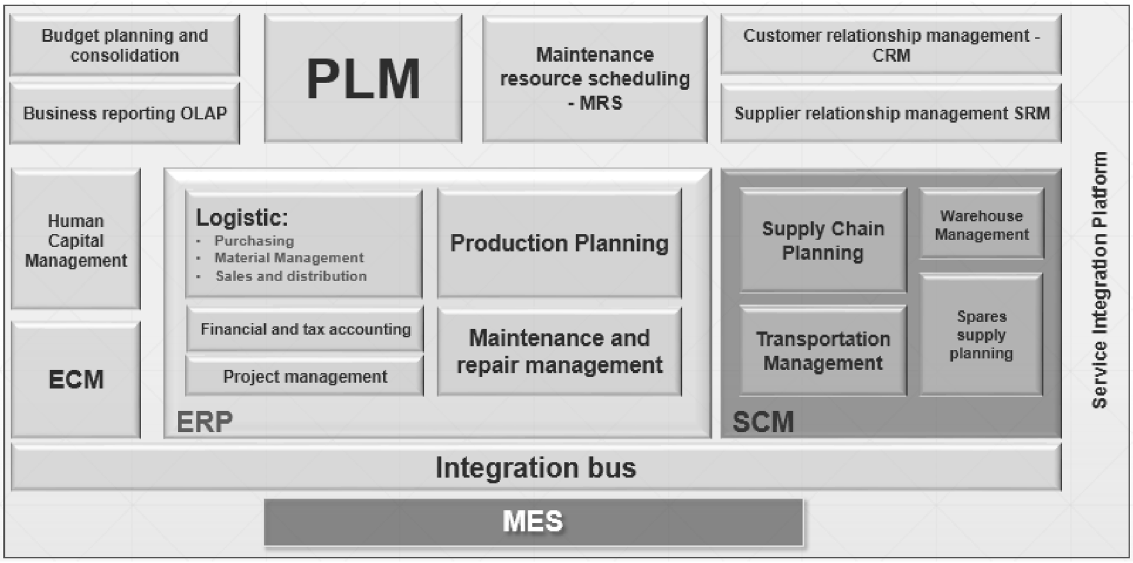

Fig. 3. Reference model (target architecture) of the integrated ILS system

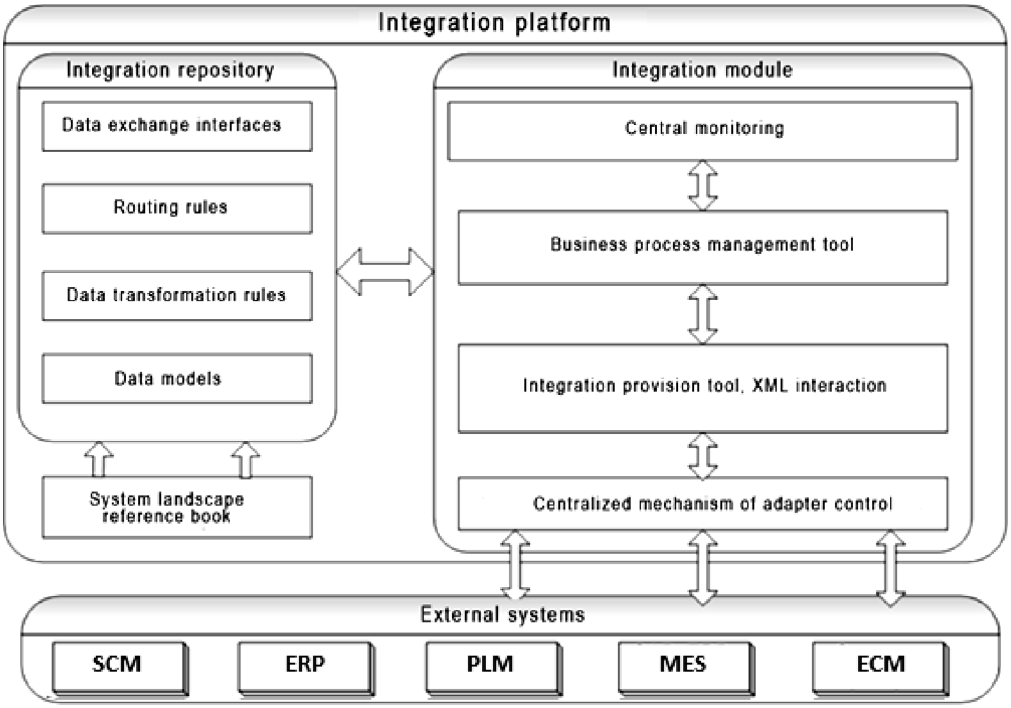

Fig. 4. Integration bus architecture

– reduction of costs associated with the introduction of new systems as a result of keeping contributions to existing systems;

– a single center of information on systems, components and intercomponent processes of the enterprise;

– centralized monitoring of intersystem processes.

The following integration principles should be applied to create an information bus architecture [25–26]: a single access point for information exchange of all systems, all interfaces of data exchange are based on the same integration platform, seamless integration, a uniform interface model (all interaction interfaces are in XML format).

The integration bus architecture shown in Fig. 4 consists of three blocks:

1) integration repository with a description of data exchange interfaces, with routing rules, data models, and their transformation;

2) integration module that performs central monitoring of data exchange and provides integration and XML interaction;

3) the third block refers to the examples of the systems involved in data exchange.

Systems to be integrated within the proposed architecture of the ILS system (Fig. 3) are divided into 4 blocks: MES (Manufacturing Execution System), ERP (Enterprise Resource Planning), SCM (Supply Chain Management), auxiliary systems beyond ERP functions.

A MES system supporting production process must be included in the uniform integrated environment, as it is one of the key suppliers of raw information about the product. MES system information is primarily used by an ERP system to solve, for example, tasks of logistic analysis, MS planning, MTS planning and support, accounting and taxation, enterprise key asset management, etc. In the proposed architecture, the ERP system mainly performs accounting and administrative functions.

Logistics control is an individual SCM system that comprises the following modules:

- warehouse logistics management;
- transport logistics management;
- supply planning;
- logistics chain planning;
- uniform information portal for all the participants of the supplying process.

The salient feature of the implementation of an SCM system within the envisioned general architecture of the ILS system is its orientation to product maintenance. Such a system aims to support service operations of sophisticated technical products, namely Service Chain Management. To ensure efficient service, an SCM system must meet the four key challenges:

- minimization of client waiting time;

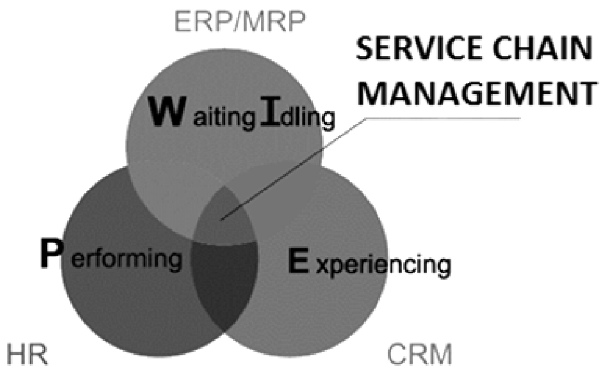

Fig. 5. Place of SCM in the system architecture

- minimization of resource idling;
- maximization of personnel efficiency and other resources;
- maximization of client satisfaction.

According to the above problems, it is possible to specify the place occupied by SCM in the IIE architecture (Fig. 5). SCM closes gaps in the functionality of the given systems, ensuring their combination in the ILS context. Human resource management systems are also stipulated in the IIS architecture.

The human resource management system in the proposed architecture provides a solution of general problems of HR management: working time recording, HR recordkeeping, HR administrating, organizational structure management, payroll accounting, etc. In order to solve ILS problems, an HCM system should be integrated with an MRS system (resource planning) which provides an extension of the basic functional to cover specific ILS problems.

The MRS (Multi Resource Scheduling) system meets the key business requirements and aids to increase the enterprise's profitability by optimizing the processes of HR planning intended for rendering service in service centers and for performance on site.

The integrated information system architecture also includes a system of customer relationship management (CRM). The current process of decision making, purchasing and operation of a scientific product in the B2B market can be conditionally divided into the following stages:

1. Customer's realizing and stating the problem that the product can help to solve.
2. Generating different solutions to the problem, including ones that imply using the product. Comparative analysis and the choice of the basic variant related to the product purchase and its specific technical implementation.
3. Analysis of different ways the product can be purchased (according to the financial, logistical, geographical and other features of the business). Choosing and purchasing the optimum alternative.
4. The product's delivery, presale preparation, commissioning, incorporation into the existing technological system, test operation.
5. Working operation, maintenance and reconditioning repair of the product during its lifetime.
6. The product improvement and modernization.
7. The product utilization.

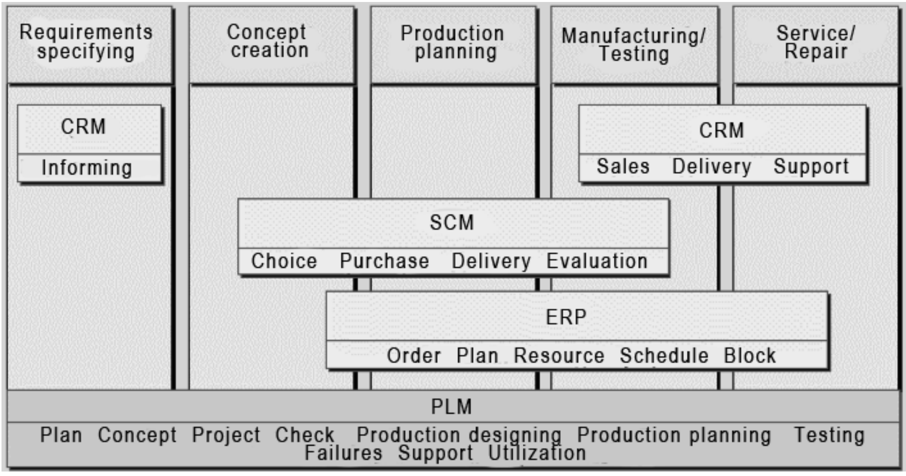

Fig. 6. Place of PLM in the uniform information environment of the enterprise

Strong and well-established relations with suppliers are essential for good maintenance service. To that end, the IIE architecture stipulates a Supplier Relationship Management (SRM) system which can work in integration with any solutions of Supply Chain Management (SCM), Product Life Management (PLM) or Enterprise Resource Planning (ERP) with no regard for the suppliers of the given systems. This can be achieved through the integration bus which incorporates the system into the common integration platform.

Operating business processes of designing, manufacturing and integrated servicing of a sophisticated scientific product in a clearly defined and mutually supportive way is impossible without a system that allows storing and managing data related to a product throughout its life cycle in a centralized manner. For this purpose, the architecture stipulates a system supporting a Product Lifecycle Management [27] strategy. A PLM system coordinates the enterprise activities, connects CRM and SCM systems, provides management of the life cycle of the product at all stages of its lifetime, from the moment of its conception till its utilization (Fig. 6).

The suggested IIE architecture model also includes a BI class system to generate and present analytical business reports that employs OLAP data processing technology.

An important stage in developing a reference model of scientific enterprise architecture is gap analysis that is instrumental in specifying the key steps and necessary changes in the target architecture. This stage discovers mismatches and consolidates business requirements, technological needs, data and application requirements.

That is obviously impossible to instantaneously replace the base architecture with the target one. This is because a simultaneous launch of all the enterprise systems in the target architecture into productive operation can involve the following risks:

– integrated information system cannot operate for technical reasons (server capacity, connection stability);
– integrated information system cannot operate for organization reasons (a level of consumer competence, significant changes in work with counteragents);
– significant extension of IIE commissioning periods due to prolonged testing (functional, integration) and training stages.

To shift to the target architecture, it is necessary to overcome the following gaps among functional structure components:

– SCM logistics;
  • organizing supply chains;
  • warehouse logistics;
  • shipping logistics;
– centralized product data management;
– management of relationships with counterparts;
  • with suppliers;
  • with customers;
– comprehensive enterprise resource planning;
– HR management;
– Electronic Document Circulation (EDC) system;
– business reporting;
– budgeting and consolidation.

In connection with this we suggest staging transition from the basic architecture to the target one.

At the first stage, it is reasonable to move from Product Data Management (PDM) to a Product Lifecycle Management (PLM) strategy which aims at more efficient support for the complete life cycle of the product by providing team developments throughout the whole product lifetime in partner networks, technologies of product development support and production process improvement as well as innovation approaches at all stages.

The second stage involves activating the SCM block that includes the functionality of supply chain management as well as warehouse and shipping logistics management. The execution of this stage allows arranging the basic logistic processes of the enterprise as a whole and in the sphere of the logistic support of maintenance service.

The third stage solves problems of information support of CRM and SRM systems, performs the migration of relevant key data (debtor and creditor basic records, etc.) from an ERP system by means of integration bus tools. The planning module is considered as an individual system (replenishment planning, scheduling for repair teams, service parts planning, transportation planning). Basic data for planning enter the system through the integration bus.

At the fourth stage, it is expedient to unfold a budgeting and consolidation system, including business reporting, because a significant extension of the composition of co-functioning information systems implies the availability of real data volume which can be a reporting base. The commissioning of a reporting system at this stage makes it possibly to accurately calculate volumes of data samples and estimate the required technical capabilities of hardware.

The final stage involves launching such auxiliary systems as HR centralized management and electronic document circulation. This allows embracing all forms and documents used by the enterprise and catering for the specifics of paperwork and sharing documents with counterparts. The introduction of an HR management system at this stage helps to reach all positions and recruitment needs, to ensure their effective planning, factoring in the business processes which were already established on the created system landscape.

The proposed reference model of information system architecture provides support for the solution to both ILS problems and general problems of a production enterprise. Also, this model represents the only way to provide integration of key systems and technologies used throughout the product life cycle and to establish control over product development and fixed asset management. The suggested information system architecture is based on a uniform service platform and an integration bus for a seamless connection of different systems. The reference system architecture model is designed with provisions made for information exchange integration tools in the uniform space among all the subsystems. The outlines of applied research on the discussed issues were reflected in the GOSTs of ILS in Russia as well as in foreign ISO standards. The subject is sure to be developed further due to the economic benefits associated with the implementation of the reference architecture model.

REFERENCES

1. **Ilyin I.V., Levina A.I.** Business architecture maturity management. *St. Petersburg State Polytechnical University Journal. Economics*, 2015, no. 2(216), pp. 109–117. (rus).
2. **Bratukhin A.G., Davydov Iu.V., Eliseev Iu.S.** IPI (Continuous Acquisition and Life Cycle Support). Moscow, MAI, 2000 (rus).
3. **Levin A.I., Sudov E.V.** The integrated logistic support of the knowledge-intensive products. Methodical material. Moscow, Research Center IPI-technology Applied logistics, 2002. 70 p. (rus).
4. P 50.1.0312001. Information technologies of life cycle product support. Terminological dictionary. P. 1. (rus)
5. GOST R 56135–2014. Life cycle management of military products. General. (rus)
6. GOST R 56136–2014. Life cycle management of military products. Terms and Definitions. (rus)
7. GOST R 56111–2014. Integrated Logistics Support for exported military products. Nomenclature of operational and technical specifications. (rus)
8. GOST R 56112–2014. Integrated Logistics Support for exported military products. General requirements for comprehensive programs providing operational and technical specifications. (rus)
9. GOST R 56113–2014. Integrated Logistics Support for exported military products. Planning logistics. The main terms. (rus)
10. GOST R 56131–2014. Integrated Logistics Support for exported military products. The order of execution of works on integrated logistics support during the life cycle of military products. (rus)
11. GOST R 56132–2014. Integrated Logistics Support for exported military products. Structure and format of the data collected during the operation of aviation equipment. (rus)
12. GOST R 56134–2014. After-sales service for exported military products. General. (rus)
13. **Ilyin I.V., Levina A.I., Antipin A.R.** Business Modeling Approaches: Architecture-Process and Design-Oriented. *Economics and Management*, 2013, no. 9(95), pp. 32–38. (rus)
14. Steve Shoaf, Innovation that moves markets. IBM Product Lifecycle Management Solutions. URL: www-3.ibm.com/solutions/plm/pub1/attachments/White Paper/plmwhitepaper.pdf (rus)
15. **Levin A.I., Sudov E.V.** Conceptual bases of management of competitive science-intensive products.

Methodical material. Moscow, RDE CALS-technologies «Applied logistics», 2005. 33 pages. (rus)

16. **Agievich V.A., Gimranov R.D., Taratukchin V.V.** An approach for modeling of enterprise architecture and it-solution architecture on the basis of a common catalog of components. *Business-informatics*, 2012, no. 4(22), pp 47—53. (rus)

17. **Becker J.** Information Models for Process Management — New Approaches to Old Challenges. *Emerging Themes in information System and Organization Studies*, 2011, part 3, pp. 145—154. (rus)

18. **Gol'din V.V., Zhuravskii V.G., Pravil'shchikov P.A.** CALS technologies and tolerant translators. *Automation and Remote Control April*, 2007, vol. 68, no. 4, pp. 710—726. (rus)

19. **Pogorelov V.G., Kulikov G.G., Fatikov V.S., Bagaeva Y.O.** Life-cycle information support of gas-turbine engine electronic technical systems on maintenance stage. *Vestnik UGATU.* 2011. vol. 15. no. 3 (43). (rus)

20. **Sammy G.** Shina, Engineering Project Management for the Global High Technology Industry, McGraw-Hill Education, 2013. 432 p.

21. **John Stark.** Product Lifecycle Management: 21st Century Paradigm for Product Realisation, Decision Engineering, — Springer; Softcover reprint of hardcover 2nd ed., 2013. 848 p.

22. **Meschalkin V.P., Moschev E.R.** Operation modes of the automated system «Pipeline» in the integrated logistic support vessels and piping industries. *Problems of mechanical engineering and automation.* 2014. no 1, pp. 64-73. (rus)

23. **Itskovich A.A., Fainburg I.A.** Integrated logistics support processes management of maintaining aircraft airworthiness. *Moscow State Technical University of Civil Aviation Journal.* 2014. no 202, pp. 28-32. (rus)

24. **Shappel D.** ESB an enterprise Service bus. St. Petersburg: BHV-Petersburg, 2008. (rus)

25. **Reshetnikov I.S., Kislecov A.P.** Standards and technology integration in production information systems. *Information technologies in design and production*, 2010, no. 2, pp. 24—30. (rus)

26. **Brom A.E., Kolobov A.A., Omelchenko I.N.** Integrated logistics support of high technology products life cycle. Ed. by Kolobov A.A. Moscow, MGTU im. N. Bauman, 2008. 296 p. (rus)

27. **Levin A I., Sudov E.V.** The development concept of CALS-technologies in industry. *RDE CALS-technologies «Applied logistics».* Moscow, 2002. 102 p. (rus)

28. **Nazarov V.V., Shabalkin D.J., Polyansky J.V.** Basic approaches and requirements for the formation of poly-platform integrated automated information system for life cycle support of aircraft on the basis of the electronic product definition. *Vestnik of Samara state aerospace University*, 2012, no. 5(36), pp. 298—305. (rus)

СПИСОК ЛИТЕРАТУРЫ

1. **Ильин И.В., Лёвина А.И.** Управление зрелостью бизнес-архитектуры предприятия // Научно-технические ведомости Санкт-Петербургского государственного политехнического университета. Экономические науки. 2015. № 2(216). С. 109—117.

2. **Братухин А.Г., Давыдов Ю.В., Елисеев Ю.С.** ИПИ (Continuous Acquisition and Life Cycle Support — непрерывная информационная поддержка ЖЦ изделия). М.: МАИ, 2000.

3. **Левин А.И., Судов Е.В.** Интегрированная логистическая поддержка наукоемких изделий^ методич. материал. М.: НИЦ ИПИ-технологий «Прикладная логистика», 2002. 70 с.

4. Р 50.1.0312001. Информационные технологии поддержки ЖЦ продукции. Терминологический словарь. Ч. 1.

5. ГОСТ Р 56135—2014. Управление жизненным циклом продукции военного назначения. Общие положения.

6. ГОСТ Р 56136—2014. Управление жизненным циклом продукции военного назначения. Термины и определения.

7. ГОСТ Р 56111—2014. Интегрированная логистическая поддержка экспортируемой продукции военного назначения. Номенклатура показателей эксплуатационно-технических характеристик.

8. ГОСТ Р 56112—2014. Интегрированная логистическая поддержка экспортируемой продукции военного назначения. Общие требования к комплексным программам обеспечения эксплуатационно-технических характеристик.

9. ГОСТ Р 56113—2014. Интегрированная логистическая поддержка экспортируемой продукции военного назначения. Планирование материально-технического обеспечения. Основные положения.

10. ГОСТ Р 56131—2014. Интегрированная логистическая поддержка экспортируемой продукции военного назначения. Порядок выполнения работ по интегрированной логистической поддержке в ходе жизненного цикла продукции военного назначения.

11. ГОСТ Р 56132—2014. Интегрированная логистическая поддержка экспортируемой продукции военного назначения. Состав и формат данных, собираемых в ходе эксплуатации авиационной техники».

12. ГОСТ Р 56134—2014. Послепродажное обслуживание экспортируемой продукции военного назначения. Общие положения.

13. **Ильин И.В., Левина А.И., Антипин А.Р.** Моделирование бизнес-архитектуры процессной проектно-ориентированного предприятия // Экономика и управление. 2013. № 9(95). С. 32—38.

14. Steve Shoaf, Innovation that moves markets. IBM Product Lifecycle Management Solutions. URL www-3.ibm.com/solutions/plm/pub1/attachments/White Paper/plmwhitepaper.pdf

15. **Левин А.И., Судов Е.В.** Концептуальные основы управления конкурентоспособностью наукоемкой продукции. Методический материал. М.: НИЦ ИПИ-технологий «Прикладная логистика», 2005. 33 с.

16. **Агиевич В.А., Гимранов Р.Д., Таратухин В.В.** Подход к моделированию корпоративной архитек-

туры и архитектуры ИТ-решений на основе единого каталога компонентов // Бизнес-информатика. 2012. № 4(22). С. 47–53.

17. **Becker J.** Information Models for Process Management – New Approaches to Old Challenges // Emerging Themes in information System and Organization Studies, 2011, part 3, pp. 145–154.

18. **Gol'din V.V., Zhuravskii V.G., Pravil'shchikov P.A.** CALS technologies and tolerant translators // Automation and Remote Control April, 2007, vol. 68, no. 4, pp. 710–726.

19. **Погорелов Г.И., Куликов Г.Г., Фатиков В.С., Багаева Ю.О.** Информационная поддержка жизненного цикла электронных систем управления ГТД на этапе эксплуатации ФГУП УНПП «Молния» // Вестник Уфимского государственного авиационного технического университета. 2011. № 3(43). Т. 15.

20. **Sammy G.** Shina, Engineering Project Management for the Global High Technology Industry, McGraw-Hill Education, 2013. 432 p.

21. **John Stark.** Product Lifecycle Management: 21st Century Paradigm for Product Realisation, Decision Engineering, – Springer; Softcover reprint of hardcover 2nd ed., 2013. 848 p.

22. **Мешалкин В.П., Мошев Е.Р.** Режимы функционирования автоматизированной системы «Трубопровод» при интегрированной логистической поддержке трубопроводов и сосудов промышленных предприятий // Проблемы машиностроения и автоматизации. 2014. № 1. С. 64–73.

23. **Ицкович А.А., Файнбург И.А.** Интегрированная логистическая поддержка управления процессами поддержания летной годности воздушных судов // Научный вестник Московского государственного технического университета гражданской авиации. 2014. № 202. С. 28–32.

24. **Шаппел Д.** ESB -Сервисная шина предприятия. СПб.: БХВ-Петербург, 2008.

25. **Решетников И.С., Козлецов А.П.** Стандарты и технологии интеграции производственных информационных систем // Информационные технологии в проектировании и производстве. 2010. № 2. С. 24–30.

26. **Бром А.Е., Колобов А.А., Омельченко И.Н.** Интегрированная логистическая поддержка жизненного цикла наукоемкой продукции: учебник (ГРИФ) / под ред. А.А. Колобова. М.: Изд-во МГТУ им. Н.Э. Баумана. 2008. 296 с.

27. **Левин А.И., Судов Е.В.** Концепция развития CALS-технологий в промышленности России // НИЦ CALS-технологий «Прикладная логистика». М., 2002. 102 с.

28. **Назаров В.В., Шабалкин Д.Ю., Полянсков Ю.В.** Основные подходы и требования к формированию полиплатформенной интегрированной автоматизированной системы информационной поддержки жизненного цикла воздушных судов на основе электронного определения изделия // Вестник Самарского государственного аэрокосмического университета. 2012. № 5(36). С. 298–305.

ILYIN Igor' V. – Peter the Great St. Petersburg Polytechnic University.
195251. Politechnicheskaya str. 29. St. Petersburg. Russia. E-mail: ivi2475@gmail.com

ИЛЬИН Игорь Васильевич – заведующий кафедрой «Информационные системы в экономике и менеджменте» Санкт-Петербургского политехнического университета Петра Великого, доктор экономических наук.
195251, ул. Политехническая, д. 29, Санкт-Петербург, Россия. E-mail: ivi2475@gmail.com

ILIASHENKO Oksana Yu. – Peter the Great St. Petersburg Polytechnic University.
195251. Politechnicheskaya str. 29. St. Petersburg. Russia. E-mail: ioy120878@gmail.com

ИЛЬЯШЕНКО Оксана Юрьевна – доцент Санкт-Петербургского политехнического университета Петра Великого, кандидат педагогических наук.
195251, ул. Политехническая, д. 29, Санкт-Петербург, Россия. E-mail: ioy120878@gmail.com

MAKOV Konstantin M. – OOO «GC KORUS Consulting».
199178. Maly av. of Vasilievsky island. 54. B. 4. St. Petersburg. Russia. E-mail: notmakov@gmail.com

МАКОВ Константин Михайлович – консультант SAP ERP, ООО «ГК КОРУС Консалтинг.
199178, Малый пр. В.О., д. 54, лит. В, корп. 4, Санкт-Петербург, Россия. E-mail: notmakov@gmail.com

FROLOV Konstantin V. – OOO «GC KORUS Consulting».
199178. Maly av. of Vasilievsky island. 54. B. 4. St. Petersburg. Russia. E-mail: KFrolov@korusconsulting.ru

ФРОЛОВ Константин Владимирович – руководитель практики SAP, ООО «ГК КОРУС Консалтинг»
199178, Малый пр. В.О., д. 54, лит. В, корп. 4, Санкт-Петербург, Россия. E-mail:KFrolov@korusconsulting.ru