1 Introduction
Currently, at most operational enterprises, the so-called “focal” nature of informatization takes place. Independent, disparate databases and specialized information systems (IS) are created in different departments and services of unified enterprises that are related to the same object of operation, management or design - a pipeline system (PLS) [1]. To the such systems, widely used in enterprises, it is possible to classify: accounting and management of material resources, finances, personnel; commercial accounting; billing; geoinformation; computer-aided design systems; telemetry (often from several different developers); certification; electronic hydraulic models; registration and management of applications, connections, repairs, etc. Each of the systems has its own data storage and transmission format, is used and supported by different services of the enterprise for making decisions at different temporary and territorial levels of technological processes control. In this case, it is observed: 1) duplication of information in different databases (DB) and IS; 2) its inconsistency or inconsistency; 3) the need for parallel support of the same data in different systems; 4) difficulties of using information and functionality from one IS in others; 5) the complexity of the collection and preparation of data for the design and adaptation of development schemes, development of basic and repair modes, etc.; 6) the availability of information in any IS and at the same time the impossibility of its use for managing technological processes in the enterprise.

The problems of “focal” informatization can be overcome by creating a unified digital space (UDS) of the enterprise, providing the possibility of prompt access of all services and specialists to any information available at the enterprise. Thus, the creation of such a space should be one of the primary goals in the field of informatization of operating enterprises.

Problems of «focal» informatization and the lack of necessary information in the management of an enterprise are the main barriers to modern concepts of intelligent control of PLS, involving the automation of analysis and decision-making management processes based on the involvement of electronic models that require information from different sources and information systems. The universal solution of the presented problems is the creation of a common digital space of the enterprise, which solves many of the existing problems at the enterprise and brings the technological management of PLS to the next level.

2 Review of available approaches
The formation of a unified information or, as is more often indicated at the present time, digital spaces has a rather long history. The first works relate to 1958, when military engineer Anatoly Kitov proposed the creation of a unified state multilevel network of computer centers in the USSR to manage the country's economy [2]. This idea was seriously interested by Academician Viktor Glushkov, who finalized it and in 1964 presented a model of a three-tier nationwide automated system (NAS). But this project was not implemented [3].

These days significant step towards the development of digital space is the resolution of the Government of the Russian Federation No. 1632-p (08.28.2017) on the approval of the program “Digital Economy of the Russian Federation”. Also in 2017, along with the emergence of the «Industry 4» concept in Russia, a project of the UDS of industry called “4.0RU” was launched. Along with the development of the digital economy and the digital space of the industry, there is an active discussion of the concepts of “digital energy”, “smart” or “digital city” [4-5]. In these projects close integration and intensive data exchange between all engineering networks, urban services, suppliers and resource consumers is proposed [6].

Attempts to create UDS of enterprises have been undertaken for several years, and the need for its organization has been actively discussed in the literature, both by specialists in the field of Information technology (IT) [7-9] and by specialists from operational enterprises [10,11]. But, at the same time, the task of the UDS creating is often identified with the automation of workflow in order to optimize the production and economic activity of enterprises (business processes automation). So, in the two largest operational enterprises of Russia «Mosvodokanal», «Vodokanal of St. Petersburg», a unified information system of enterprise activity based on the Oracle E-Business Suite (OEBS) technology [12] is used. It is a full-featured complex of integrated ERP business applications of the II class. In other enterprises, “SAP”, “Microsoft Dynamics”, “1C ERP”, “Galaktika”, “Parus” and others are widely used to create a digital signature. A brief description of the listed programs is presented in [1,13]. All mentioned and other available on the market software belong to the Automated Control System (ACS): ERP (Enterprise Resource Planning) or MRP (Manufacturing Requirement Planning) categories and does not meet all the requirements for a UDS, because it is primarily aimed on business processes optimizing, automation. Consequently, it can be said that, despite the declared policy of digitalization, enterprises continue to evolve according to the usual scheme of individual processes automation in the form of well known “automation pyramid” [14,15] (fig.1). In general structure of
Production management, several hierarchical levels are distinguished. Management automation at each of them is implemented using appropriate management systems and software [16]. It is not adapted for solving the problems of technological processes management of the pipeline networks functioning. Software of the lower levels of the hierarchy belongs to the category of Computer-Aided Process Control Systems (CAPCS) and has a limited set of functions (collection, transmission, storage, and processing of data). This set of functions is insufficient for the transition to the concept of intelligent control, this software is not adapted for UDS creation.

![Diagram of Enterprise Automation Pyramid]

**Figure 1.** The pyramid of enterprise automation.

The traditional approach to creating an UDS is to install some unified information platform, for example, “IBM InfoSphere MDM Server” [17]. All data available in the enterprise are transferred to this platform, then these data are normalized and all interested services are given access to the necessary data. This approach seems reasonable from the point of view of correct data organization, but it requires the replacement of a significant part of previously installed, purchased and mastered software, and some unique software cannot be effectively integrated into this platform. Therefore, the problem of integration of different information systems still remains.

### 3 The main provisions of the UDS concept

As opposed to the standard approach to the construction of ACSs (“top-down”, Fig. 1.), which presupposes the centralization of information within a single IS, the authors propose an approach based on the principle of integrating information resources from the bottom to the top and in horizontal direction in order to provide access to these distributed resources to all applications and users, both inside and outside the enterprise. This approach seems to be more flexible, although it requires both lump-sum
costs for matching data from different sources, as well as fixed charges, for maintaining this correspondence in the future. At the same time, information support of decision-making processes on the management of technological processes of operation of PLS is a cornerstone of the approach. As a platform for the integration of various ISs, potentially, the information-computing environment (ICE) "ANGARA" [18-21], developed at ESI SB RAS, can be used. ICE “ANGARA” is designed to automate the creation, support and end-to-end use of PLSs electronic models of various types and complexity when solving applied analytical problems within a unified graphical user interface.

This approach is designed to ensure: 1) the completeness of information about the object of operation by integrating various information resources (cartographic, schematic-parametric, passport, operational, contractual, etc.); 2) the validity of information - by eliminating of data duplication or inconsistency, either through the principle of "a single data entry point", or by differentiating access rights for data input and editing; 3) availability - by providing on-line access, both to specialists of the enterprise, and outside users to the information in network; 4) end-to-end support of settlement and analytical tasks of different territorial and temporary management levels (reconstruction, development, design, dispatch control, etc.) on a unified information basis; 5) the flexibility of the development and application of the UDS - by ensuring the possibility of new IS integrating, updating or replacing existing ones.

The transition of operational enterprises to such a concept will create prerequisites for: elimination of information barriers within the enterprise between different services; transition to new principles and technologies of intellectual control, which will increase the controllability and consistency of decisions making and, in fine, increase the efficiency and quality of consumers supplying; information integration of various organizations and enterprises located on the same territory (city administration, supervisory and regulatory authorities, online resources for subscribers); functional intersystem integration of various systems for the coordination of operating modes of adjacent systems.

4 Approval of the UDS concept in real conditions
Approval of the proposed concept was carried out at the municipal enterprise "Vodokanal" of Irkutsk city. This enterprise supplies the population (600 thousand people) and industrial enterprises of the city with cold water and pumps and cleans the effluent. The basis of the enterprise’s IS is the «1C ERP» system in which all accounting and financial reporting, data on clients and the resources consumed by them, contracts with customers, etc. are maintained. Measured process parameters (pressure, flow rate) are transmitted and stored in various SCADA systems (“ClearSCADA” Schneider Electric and others.), accounting and control of energy resources (consumed electrical power by pumping stations) is carried out in the «Alpha Center» system, design and coordination of consumers connection schemes is carried out in the «AutoCad» format. Data on the city plan is stored in the geographic information system «2GIS», which is monthly updated by the developer. For the tasks of planning, calculating and controlling the hydraulic regimes of water supply and sewage systems, the enterprise uses the “ANGARA-WS” software and computing systems [22] and “ANGARA-SS”.

The ICE “ANGARA” (Fig. 2) acts as a core in UDS, because it has an open architecture (both in data and in functions) and allows you to store data on any modern DBMS. MS SQL Server was chosen as the DBMS because it was available in the enterprise. At the first stage, the opportunity to import geoinformation from the monthly updated “2GIS” system to the ICE “ANGARA” (in the form of the vector format “SHAPE”), was realized. As a result, users are able to see the piping network schemas on a updated city plan. Obtaining the necessary data from SCADA-systems is carried out according to the OPC protocol generally accepted in such systems. The obtained data can be displayed on the network diagram in the appropriate place, as well as used in other tasks, for example, for: hydraulic calculations; water consumption forecasting; balancing of supply volumes, water consumption and wastewater reception. Data on the power consumption of pumping stations are obtained from the “Alfa Center” system using the MEC-104 protocol. The greatest complexity was caused by integration with the “1C ERP” system. In this case, bilateral interaction was implemented through the SOAP protocol, which required the creation of some procedures that provide the necessary data, both on the side of “1C ERP” and in the ICE “ANGARA”. There were difficulties with determining the correspondence of records in different databases. For example, if the list of consumers in the ICE “ANGARA” is about 11,000 entries, then the similar table in “1C ERP” contains over 44,000 entries, since in the first case a consumer is a building with its own connection to the water supply network, and in the second - a list of legal entities and individuals.
consuming water in this building and having relevant agreements with the water supply company. Data exchange between “ANGARA” and other IS can be carried out in three different ways: 1) upon the user's request, the ICE requests the necessary data in the other systems and displays data in its forms; 2) ICE collects measurement data according to a predetermined schedule and stores them in its database in an aggregated form; 3) IS send new or changed data to the “ANGARA” database. Setting up the method and time interval of interaction of systems is carried out by enterprise specialists, without the participation of the IS developers. The above ISs make up the first (lower) level - primary information resources (Fig. 2), each of them has its own data storage format (Oracle DBMS is in red, MS SQL Server is blue).

**Figure 2.** UDS scheme implemented in "Vodokanal" enterprise.

The second level is made up of information and computing resources - a number of specialized software that use the ICE “ANGARA” database for solving calculation and analytical tasks (hydraulic calculation, analysis of water supply and consumption balances, forecasting water supply and energy consumption of pumping stations, log of claims and damage, etc.) . The data in the “ANGARA” database is stored in a form that significantly reduces the operating time of these software (tens or hundreds of times), compared with the option of requesting data directly from the primary IS.

The third level consists of external and internal consumers of information. Domestic consumers include divisions and services of the enterprise (dispatching service, technical operation department, planning
and technical department, water supply shop, sewage shop, electrical department, chief engineer services, capital construction department, etc.). City services include: city administration, committee on housing and communal policy, service on tariffs, etc. External information consumers are clients of the city’s water supply system, homeowners’ association. Co-operating enterprises operate other engineering networks of the city (electricity, gas, heat, etc.).

5 Conclusion

The requirements for the UDS arising from the analysis of the existing problems of informational support for operational enterprises and trends in the intelligent automation of PLS are formulated. Analysis of existing approaches to the UDS showed that the traditional approach does not pay enough attention to the processes of the decision-making automation for the control of the operation object (pipeline network). It becomes relevant with the intelligent automation of PLS. A new concept of UDS is proposed. This concept focused on overcoming the existing problems of informational support for operating enterprises. Also it provides the possibility of integrating for various urban engineering systems on a unified information basis. It is shown that the implementation of the UDS concept can be based on the ICE “ANGARA”, as evidenced by the approval in “Vodokanal” enterprise of Irkutsk.

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