History of Data Centre Development

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Abstract: Computers are used to solve different problems. For solving these problems computer software and hardware are used, but for operations of those computing facilities a Data Centre is necessary. Therefore, development of the data centre is subordinated to solvable tasks and computing resources. We are studying the history of data centres' development, taking into consideration an understanding of this. In the beginning of the computer era computers were installed in computing centres, because all computing centres have defined requirements according to whom their operation is intended for. Even though the concept of 'data centre' itself has been used since the 1990s, the characteristic features and requirement descriptions have been identified since the beginning of the very first computer operation. In this article the authors describe the historical development of data centres based on their personal experience obtained by working in the Institute of Mathematics and Computer Science, University of Latvia and comparing it with the theory of data centre development, e.g. standards, as well as other publicly available information about computer development on the internet.

Keywords: Computing facilities, Data Centre, historical development.

1. Basic Characteristics of Data Centre Facilities

1.1 Data centre definition

A data centre is a physical environment facility intended for housing computer systems and associated components. Data centres comprise the above-mentioned computer systems and staff that maintains them. The necessary physical environment facility encompasses power supplies with the possibility to ensure backup power, necessary communication equipment and redundant communication cabling systems, air conditioning, fire suppression and physical security devices for staff entrances.

Usually data centres are created for specific task classes; it is particularly referable to computing facilities. Also, the development of other components' can be influenced by the class of tasks solved in the data centre; e.g. if computation result necessity is not so critical in time, then in the centre's equipment there is no duplication of resources used for electricity supply, i.e. according to present-day standards data centre's level from Tier1 to Tier4 is chosen.

Similarly, in the concept of a data centre, often, not only the data centre's maintenance staff is included, but also the centre's personnel that ensure functional actions. Frequently, such data centres are as a component in agencies, companies, institutes or even laboratories.

Historically the development of data centres has passed in a fluent way, growing from IT (information technology) departments or a computer building research laboratories' base. It is quiet problematic to determine a precise date in history when data centre was created: it could be taken from the documents of some data centre's creation or when the first computer was disposed in it, or when it began its work.

In our historical timelines we indicate the principal time, not going deep in defining precise dates. Examples of up-to-date data centre services:

- hardware installation and maintenance,
- managed power distribution,
- backup power systems,
- data backup and archiving,
- managed load balancing,
- controlled Internet access,
- managed e-mail and messaging,
- server co-location and hosting,
- virtual servers, GRID and Cloud computing services,
- managed user authentication and authorization,
- firewalls, data security,
- etc.

1.2 Electricity supply system

Two aspects of energy use are critical for data centres. Firstly, both IT equipment and all supporting equipment are very energy consuming. Some data centres' facilities have power densities that exceed more than 100 times than in typical office use. For higher power density facilities, electricity costs are a dominant operating expense and account for over 10% of the total cost of data centre's ownership.

Secondly, it is not less important to have guaranteed energy for IT equipment and also for other equipment like cooling, or access control systems used in the data centre. Backup power systems consist of one or more uninterruptible power supplies (UPS) and/or diesel generators. To prevent single points of failure, all elements of the electrical systems, including backup systems, are typically fully duplicated, and computing facilities are connected to both power feeds. This arrangement is often marked as N+1 redundancy. Static switches are sometimes used to ensure instantaneous switchover from one supply to the other in the event of a power failure. For comparing electro-effectiveness in different data centres and also to evaluate different solutions, power usage effectiveness (PUE) is introduced. The most popular measurement of that is the proportion between total facility's power and IT equipment's power.

In addition to IT equipment the other energy consuming equipment, mainly consists of cooling systems, power delivery and other facility's infrastructure, like lighting. Data centres support equipment recalled as overhead. Often IT equipment consumes only 33% of the power in the data centre.

The most popular power components are as follows:

- generators,
- UPS,
- grounding,
- power and environmental control.

1.3. Low-voltage cable routing

Communications in data centres today are most often based on networks running Internet protocols and special protocols for computing equipment interconnection. Data centres contain a set of ports, routers and switches that transport traffic between data centres' computing equipment and the outside world. Redundancy of the Internet connection is often provided by using two or more upstream Internet service providers.

Network security elements are also usually deployed: firewalls, VPN gateways, intrusion detection systems, etc.

Data cabling is typically routed through overhead cable trays in modern data centres. But some are still recommending under raised floor cabling for security reasons and to consider the addition of cooling systems above the racks in case this enhancement is necessary. Structural cabling elements are:

- service provider cables
- backbone cables (to data centre and in-between floors)
- horizontal cables (within floors)
- zone distribution (in data centre)

1.4. Raised floors

Data centres typically have raised flooring made up of 60 cm removable square tiles. The trend is towards 80–100 cm void to cater for better and uniform air distribution. These provide a plenum for air to circulate below the floor, as part of the air conditioning system, as well as providing space for power cabling.

Raised floors have better a appearance than overhead cabling and allow higher power densities, better control of cooling, and more flexibility in location of cooling equipment. Most stand-alone computer systems are designed for cabling from below.

Overhead cable trays are less expensive than raised floor systems, cable trays can be attached to the top of racks (if they are uniform in height). Cable trays suspended from the ceiling provide more flexibility for supporting racks of various heights and for adding and removing racks.

Cable trays can be installed with several layers, for example, a cable tray system for low-voltage signals, a middle layer for power and a top layer for fibre.

1.5. Environmental control

The requisite physical environment for a data centre is rigorously controlled. Air conditioning is used to control the temperature and humidity in the data centre. The temperature in a data centre will naturally rise because electrical power used heats the air. Unless the heat is removed, the ambient temperature will rise, resulting in electronic equipment malfunction. By controlling the air temperature, the server components at the board level are kept within the manufacturer's specified temperature/humidity range. Air conditioning systems help control humidity by cooling the return space air below the dew point. In data centres there are several technologies being used to realize environmental control. The principles of data centre cooling-air delivery, movement, and heat rejection are not complex.

The under-floor area is often used to distribute cool air to the server racks. Eventually, the hot air produced by the servers recirculates back to the intakes of the CRAC units (the term 'Computer Room Air Conditioning' was introduced in 1960) that cool it and then exhaust the cool air into the raised floor plenum again.

This cold air escapes from the plenum through perforated tiles that are placed in front of server racks and then flows through the servers, which expel warm air in the back. Racks are arranged in long aisles that alternate between cold aisles and hot aisles to avoid mixing hot and cold air.

- **Computer Room Air Conditioners (CRAC).** Refrigerant-based (DX), installed within the data centre's floor and connected to outside condensing units. Moves air throughout the data centre via a fan system and delivers cool air to the servers, returns exhaust air from the room.
- **Computer Room Air Handler (CRAH).** Chilled water based, installed on the data centre's floor and connected to outside cooling plant. Moves air throughout the data centre via a fan system: delivers cool air to the servers, returns exhaust air from the room.
- **Humidifier.** Usually installed within CRAC / CRAH and replaces water loss before the air exits the A/C units. Also available in standalone units.
- **Chiller.** The data centre's chiller produces chilled water via refrigeration process. Delivers chilled water via pumps to CRAH.
- **In-Rack Cooling.** In-rack cooling products are a variant on the idea of filling the entire room with cool air and can also increase power density and cooling efficiency beyond the conventional raised-floor limit. Typically, an in-rack cooler adds an air-to-water heat exchanger at the back of a rack so that the hot air exiting the servers immediately flows over coils cooled by water, essentially short-circuiting the path between server exhaust and CRAC input. In some solutions, this additional cooling removes just part of the heat, thus lowering the load on the room's CRACs (i.e. lowering power density as seen by the CRACs), and in other solutions it completely removes all heat, effectively replacing the CRACs. The main downside of these approaches is that they all require chilled water to be brought to each rack, greatly increasing the cost of plumbing and the concerns over having water on the data centre's floor with couplings that might leak.
- **Different trends in Environmental control.** Energy-saving technology – 'green' data centres and rational cooling technologies.

Modern data centres try to use economizer cooling, where they use outside air to keep the data centre cool. Many data centres now cool all of the servers using outside air. They do not use chillers/air conditioners, which create potential energy savings.

A water side economizer uses the outside air in conjunction with a chiller system. Instead of compressors, the outside air cools the water, which is then pumped to data centre CRAHs. Water side economizers are marketed as either evaporative coolers or dry coolers.

The industry is exploring progressive cooling solutions because the current generation, discussed earlier, has proven insufficient and inflexible with increased computing requirements. (Chillers, for instance, are estimated to consume 33% of a facility's total power in current layouts).

To optimize the cooling in your data centre a good first step is an in-depth analysis of your current environment to gain a holistic understanding of your data centre's environment, increased awareness of your critical risk factors, benchmark of performance metrics, and generate a punch list of opportunities for cooling improvement.

1.6. Fire protection

Data centres feature fire protection systems, including passive and active design elements, as well as implementation of fire prevention programs in operations. Smoke detectors are usually installed to provide early warning of a developing fire by detecting particles generated by smouldering components prior to the development of flame. This allows investigation, interruption of power, and manual fire suppression using hand held fire extinguishers before the fire grows to a large size. A fire sprinkler system is often provided to control a full scale fire if it develops. Fire sprinklers require 46 cm of clearance (free of cable trays, etc.) below the sprinklers. Clean agent fire suppression gaseous systems are sometimes installed to suppress a fire earlier than the fire sprinkler system. Passive fire protection elements include the installation of fire walls around the data centre so a fire can be restricted to a portion of the facility for a limited time in the event of the failure of the active fire protection systems, such as making sure the door is not left open or if they are not installed. For critical facilities these firewalls are often insufficient to protect heat-sensitive electronic equipment, however, because conventional firewall construction is only rated for flame penetration time, not heat penetration. There are also deficiencies in the protection of vulnerable entry points into the server room, such as cable penetrations, coolant line penetrations and air ducts.

1.7. Security

Physical security also plays a large role in data centres. Physical access to the site is usually restricted to selected personnel, with controls including bollards and mantraps. Video camera surveillance and permanent security guards are almost always present if the data centre is large or contains sensitive information on any of the systems within. The use of finger print recognition mantraps is starting to be commonplace.

1.8. Data centre spaces

A data centre lies in a number of rooms: a computer room with computing facilities, a computer room for telecommunication equipment, an operation centre, entrance facilities, rooms outside computer rooms for mechanical and electrical spaces - for power generators, UPS, cooling refrigerants, structured cabling and communication entry cabling rooms etc. In data centres there are also stationed support staff offices and client service front office. The most important spaces in data centres are: computer room, computer room TR, operations centre, entrance facility.

Some of the spaces are illustrated by photos from IMCS UL.

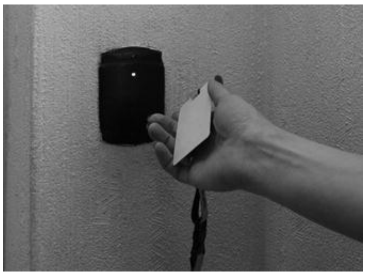
Computer room

Figure 1. Back side of racks

Figure 2. Front side of racks

Support equipment (backup power)

Entrance facility



2. Framework of Data Centres Development

Computing facilities is a kernel of data centre and other conditions were adjusted so that it secured effective operation of computing. In the table below, we will summarize a short overview about the computing development history, mainly pointing out the information available on the Internet for further independent reader investigation. Often, to display historical development timelines are used, and they have different forms:

- timelines as lists with parameters (time and description),
- timelines as tables,
- timelines with photos and videos,
- interactive timelines with specially made software,
- posters,
- wiki descriptions,
- museum descriptions.

Table 1: Historical development timelines

Timeline content	Link	Type of timeline
Computer science timeline	http://www.atariarchives.org/deli/Time_Line.php	Timeline and photo
	http://www.rci.rutgers.edu/~cfs/472_html/Intro/timeline.pdf To commemorate the 50^{th} year of modern computing and the Computer Society	Timeline and photo
	http://www.ieeeghn.org/wiki/index.php/Category:Computers_and_information_processing Category: Computers and information processing IEEE Global History Network	Description and Photo, Interactive
	http://cms.uhd.edu/Faculty/BecerraL/Mycourses/Histor	Link

	y_timelines.htm Some History Timelines In Computer Science, Mathematics And Statistics, List of links	
Industrial Technology timelines	http://www.thocp.net/timeline/timeline.htm Chronology of the History of Computing	Timeline and photo
	http://www.timetoast.com/timelines/computer-science-through-the-decades	Interactive
	http://en.wikipedia.org/wiki/History_of_technology History of technology	WIKI
	http://www.feb-patrimoine.com/histoire/english/information_technology/information_technology_3.htm Information Technology Industry TimeLine	Table
	http://www.saburchill.com/HOS/technology/008.html History of science and technology industrial revolution timeline	Table
	http://cs-exhibitions.uni-klu.ac.at/index.php?id=187 The history of (computer) storage	Timeline
	http://www.slideshare.net/wizbee/timeline-of-computer-history-8498853 Slideshare	Timeline and photo
Timeline of virtualization development	http://en.wikipedia.org/wiki/Timeline_of_virtualization_development Timeline of virtualization development	WIKI
	http://www.hds.com/go/hds-virtualization-timeline/ Storage Virtualization - Hitachi Data	Interactive
History of computing	http://en.wikipedia.org/wiki/Timeline_of_computing Timeline of computing	WIKI
	http://www.history-timelines.org.uk/events-timelines/07-computer-history-timeline.htm Computer History Timeline	Timeline and photo
	http://www.computerhistory.org/timeline/?category=cmpny Timeline of Computer History	Museum
	http://www.warbaby.com/FG_test/Timeline.html Full Timeline	Table
	http://www.tnmoc.org/timeline.aspx The National Museum of Computing	Museum
	http://www.askthecomputertech.com/computer-history-timeline.html Computer History Timeline	Timeline
	http://archives.icom.museum/vlmp/computing.html The Virtual Museum of Computing	Museum
	http://en.wikipedia.org/wiki/History_of_computer_hardware_in_Soviet_Bloc_countries History of computer hardware in Soviet Bloc countries	WIKI
The History of the Mainframe	http://web-friend.com/help/general/pc_history.html The History of Computers: From PC to mainframe	Timeline
History of software	http://en.wikipedia.org/wiki/History_of_software_engineering	WIKI

	History of software engineering	
	http://en.wikipedia.org/wiki/Category:History_of_software Category: History of software	WIKI
	http://www.inf.ethz.ch/personal/wirth/Articles/Miscellaneous/IEEE-Annals.pdf A Brief History of Software Engineering (Niklaus Wirth)	Description
	http://www.softwarehistory.org/ The Software Industry Special Interest Group at the Computer History Museum	Description
Operating systems timeline	http://en.wikipedia.org/wiki/Timeline_of_operating_systems Timeline of operating systems	WIKI
	http://www.networkdictionary.com/Software/Computer-Operating-Systems-Development-Timeline.php Computer Operating Systems Development Timeline	Timeline
	http://www.templejc.edu/dept/cis/ccollins/ITSC1305/os-timeline.html Operating System Timeline	Timeline and photo
	http://www.scribd.com/doc/36626225/Timeline-of-Operating-Systems Timeline of operating systems	Timeline
	http://wiki.jumba.com.au/wiki/List_of_Operating_Systems List of Operating Systems	WIKI
	http://trillian.randomstuff.org.uk/~stephen/history/timeline-OS.html Brief History of Computing - Operating Systems	Timeline
Programming language timeline	http://en.wikipedia.org/wiki/Timeline_of_programming_languages http://en.wikipedia.org/wiki/History_of_programming_languages Timeline of programming languages	WIKI
	http://oreilly.com/news/graphics/prog_lang_poster.pdf History of Programming Languages	Poster
	http://encyclopedia.thefreedictionary.com/Programming%20language%20timeline Timeline of programming languages	WIKI
	http://oreilly.com/news/languageposter_0504.html The History of Programming Languages	Poster
A Timeline of Database History	http://quickbase.intuit.com/articles/timeline-of-database-history A Timeline of Database History	Timeline
	http://en.wikipedia.org/wiki/User:Intgr/RDBMS_timeline RDBMS timeline	WIKI, poster
Timeline of Systematic Data and the	http://www.wolframalpha.com/docs/timeline/	Table and photo
	http://store.wolfram.com/view/misc/popup/timeline.html Timeline of Computable Knowledge Poster	Poster

Development of Computable Knowledge	http://timerime.com/en/timeline/71986/History+of+Data+Storage/ History of Data Storage	Timeline and photo
History of the Internet	http://www.webopedia.com/quick_ref/timeline.asp Brief Timeline of the Internet	Interactive
	http://www.zakon.org/robert/internet/timeline/ Hobbes' Internet Timeline 10.2	Timeline
	http://www.history-timelines.org.uk/events-timelines/11-internet-history-timeline.htm Internet History Timeline	Timeline
History of multimedia	http://www.timetoast.com/timelines/the-history-and-development-of-multimedia-a-story-of-invention-ingenuity-and-vision	Interactive
	http://www.cs.cf.ac.uk/Dave/Multimedia/node8.html History of Multimedia Systems	Timeline
History of Telecommunications	http://www.ieeeghn.org/wiki/index.php/Category:Communications IEEE Global History Network	Interactive
	http://en.wikipedia.org/wiki/History_of_telecommunication History of telecommunication	WIKI
	http://www.telcomhistory.org/timeline.shtml The Telecommunications History Group	Timeline and photo

3. Standardization for Data Centres

For ensuring computer operation we are using data centres – appropriately equipped environment. Hardware that is deposited in data centres needs wires of power supply and communications, appropriate HVAC (heating, ventilation, and air conditioning) climate conditions as well as fire safety, physical and logical security must be ensured. For all this, technological solutions were developed. Currently there are standards made up for data centres' equipping.

To ensure housing of computer systems in the data centre we are using a number of: continual research and development, their industrial production and standards among telecommunication, power usage, air conditioning, fire protection, prevention and suppression, physical premises' security systems etc. Necessary industrial solutions for data centres are used in many other economic areas. For example, ASHRAE was formed as the American Society of Heating, Refrigerating and Air-Conditioning Engineers by the merger in 1959 of The American Society of Heating and Air-Conditioning Engineers (ASHAE) founded in 1894 and The American Society of Refrigerating Engineers (ASRE) founded in 1904. The recommendations and standards worked out by those associations are taken into consideration when designing data centres, focusing on building systems, energy efficiency, indoor air quality and sustainability within the industry.

The development of data centres' provision technologies is facilitated by management of associations, research institutions and specific companies, for example:

- AFCOM (Association for Computer Operations Management), was originally established in 1980;
- The Open Data Center Alliance was formed in 2010;
- European Data Centre Association, (EUDCA), 2011;
- Data Center University (DCU) offers industry-leading education;
- etc.

The most important in data centres' standardization is the Tier level classification system. The Data Centre Tier Performance Standards are a user set of requirements used to clearly define expectations for the design and management of the data centre to meet a prescribed level of availability. The Tier Level Classification system is the foundation used by many data centres' users, consultants and design professionals in establishing a 'design-versus performance' ranking approach to today's data centre projects.

Established in 1993, the Uptime Institute is an unbiased, third-party data centre research, education, and consulting organization focused on improving data centre performance and efficiency through collaboration and innovation. The Uptime Institute serves all shareholders of the data centre industry, including enterprise and third party operation, manufacturers, providers, and engineers. This collaborative approach, completed with the Uptime Institute's capability to recognize trends on a global basis and to interface directly with owners, results in solutions and invocations freed from regional constraints for the benefit of the worldwide data centre industry.

Founded in 1993, the Institute pioneered the creation and facilitation of end-user knowledge communities to improve reliability and uninterruptible availability—uptime—in data centre facilities and Information Technology organizations.

Uptime Institute's activity began with UUUG. The establishment in 1989 of the Uninterruptible Uptime Users Group (UUUG) still left a need in the data centre community for the user's ability to disseminate information freely due to the open forum of the group meetings. Through a member-driven, collaborative learning experience, members have steadily achieved higher levels of site uptime.

Significant aspects for evaluation related to data centre performance are site selection and performance evaluation.

Table 2: Site selection and performance evaluation

Site selection	Factors	Performance evaluation	Factors
Location	Earthquake Zone Flood Plains Hurricanes or Tornadoes Proximity to Major Highways Proximity to Railway Lines Proximity to Hazardous Areas Proximity to Airports or Flight Corridors	Electrical	Utility Service Lightning Protection Power Backbone UPS Systems UPS Batteries Engine Generator Load Bank Critical Power Distribution Grounding
Infrastructure	Availability of Electrical	Mechanical	Raised Floor

	Capacity Availability of Diverse Power Feeders Utilities Expansion/Upgrades History of Outages		Cooling UPS Cooling Mechanical Plant
Water	Diverse Source Supplies Water Storage	Support Systems	Contamination Fire Detection and Protection Physical Security Alarms and Monitoring
Communications	Availability of Diverse Carriers Availability of Diverse Services Physical Security Alarms and Monitoring		
Economics	Land Construction Utilities Labour Communications		
Staffing	Accessibility Public Transportation Recreational Facilities Housing Amenities		
Security			

The Tier I data centre has non-redundant capacity components and single non-redundant distribution paths (for power and cooling distribution, without redundant components) serving the site's computer equipment. The data centre has computer room cooling and power distribution but it may or may not have a UPS or and engine generator. The data centre must be shut down for annual predictive maintenance and repair work. Corrective maintenance may require additional shutdowns. Operation errors or spontaneous failures of infrastructure components will cause a data centre disruption. As an example, a Tier I data centre may be suitable for small businesses where IT is intended for internal business processes.

The Tier II data centre has redundant capacity components, but only single non-redundant distribution paths (for power and cooling distribution, with redundant components) serving the site's computer equipment. They have UPS and engine generators but their capacity design is Need plus One (N+1), with a single power path. Maintenance of the critical power path and other parts of the site infrastructure will require a shutdown of computer processes. The benefit of this level is that any redundant capacity component can be removed from service on a planned basis without causing the data processing to be shut down. As an example, a Tier II data centre may be appropriate for internet-based companies without serious financial penalties for quality of service commitments.

The Tier III data centre is concurrently maintainable and has redundant capacity components (dual-powered equipment) and multiple independent distribution paths serving the site's computer equipment composed of multiple active power and cooling distribution paths, but only one path active, has redundant components, and is concurrently maintainable. Generally, only one distribution path serves the computer equipment at any time. This topology allows for any planned site infrastructure activity without disruption of the computer systems operation in any way. An example of a Tier III application would include companies that span multiple time zones or whose information technology resources support automated business process.

The Tier IV data centre is fault tolerant and has redundant capacity systems and multiple distribution paths simultaneously serving the site's computer equipment, including uplinks, storage, chillers, HVAC systems, servers etc. Everything is dual-powered. All IT equipment is dual powered and installed properly to be compatible with the topology of the site's architecture. Fault-tolerant functionality also provides the ability of the site infrastructure to sustain at least one worst-case unplanned failure or event with impact to the critical load. Examples of a Tier IV requirement include companies who have extremely high-availability requirements for on-going business such as E-commerce, market transactions, or financial settlement processes.

As a rule, the overall Tier Level is based on the lowest Tier ranking or weakest component. For example, a data centre may be rated Tier 3 for electrical, but Tier 2 for mechanical performance evaluation and the data centre's overall Tier rating is then 2. In practice, a data centre may have different tier ratings for different portions of the infrastructure.

Table 3: Tier Classifications according to the Uptime Institute

	Tier 1	Tier II	Tier III	Tier IV
Site availability	99.67%	99.75%	99.98%	99.99%
Downtime (hours/yr)	28.8	22.0	1.6	0.4
Operations centre	Not required	Not required	Required	Required
Redundancy for power, cooling	N	N+1	N+1	2(N+1)
Gaseous fire suppression system	Not required	Not required	FM200 or Inergen	FM200 or Inergen
Redundant backbone pathways	Not required	Not required	Required	Required
UPS power outage			72 hours	96 hours

Uptime Institute has awarded 129 certificates in 25 countries around the world.

Another example of the Tier level system is presented by Syska Hennessy Group. The higher the Tier level is, higher the total costs of data centre are. A data centre's Tier level is defined by the business needs of a concrete data centre. Below, in the table, there are examples of businesses and Tier levels applied to them.

Table 4: Businesses and Tier Levels

Applied Tier level	Business
Tier 1	Professional services, Construction & engineering, Branch office (financial)
Tier 1 or Tier 2	Point of sale, Customer Resource Management (CRM), 7x24 support centres, University data centre
Tier 1 or Tier 2 or Tier 3	Enterprise Resource Planning (ERP), Online hospitality & travel reservations
Tier2	Local real time media
Tier 2 or Tier 3	Online data vaulting and recovery, Insurance, Work-in-progress tracking (manufacturing), Global real time media, Voice over IP (VoIP), Online banking, Hospital data centre, Medical records, Global supply chain
Tier2 or Tier3 or Tier4	E-commerce
Tier3	Emergency call centre
Tier 3 or Tier4	Energy utilities, Electronic funds transfer, Global package tracking
Tier 4	Securities trading and settlement

Based on the four-Tier system of The Uptime Institute in April 2005, ANSI/TIA approved ANSI/TIA-942 Telecommunication Infrastructure Standard for Data Centers (see the list). Important purposes of TIA-942 are as follows:

- specifications for data centre pathways and spaces,
- planning of data centres, computer rooms, server rooms, and other spaces,
- defining a standard of telecommunications infrastructure for data centres,
- structured cabling system for data centres,
- recommendations on media and distance for applications over structured cabling,
- establish a standard for data centres' Tiers,
- requires infrastructure administration.

Informative annex with TIA-606-A standards compliant labelling scheme for all components. All cabinets, racks, patch panels, cables, and patch cords should be labelled. Labelling scheme extended for use in data centres. Cabinets and racks labelled by location using tile grid or row/position identifiers.

Data centre infrastructure management is the integration of information technology and facility management disciplines to centralize monitoring, management and intelligent capacity planning of a data centre's critical systems. Achieved through the implementation of specialized software, hardware and sensors, a data centre's infrastructure management enables a common, real-time monitoring and management platform for all interdependent systems across the data centre facilitys infrastructures. ISO 20000 is the world's first standard for IT service management. The standard specifies a set of inter-related management processes, and is based heavily upon the ITIL (IT Infrastructure Library) framework.

However, the standards do not give answers to all questions, e.g. the Tier level of dual site data centres and redundancy in this situation.

Table 5: Overview of Telecommunications Industry Association (TIA) standards related to data centre housing (In Europe there are others, with prefix DIN).

No.	Content
TIA 568-C.0	Generic cabling
TIA 568-C.1	Commercial Building cabling
TIA 568-C.2	Balanced Twisted Pair cabling and components
TIA 568-C.3	Optical fibre cabling components
TIA 569-B	Pathways and spaces
TIA 570-B	Residential cabling
TIA 606-A	Cabling administration
TIA 607-A	Grounding (Earthing) and bonding requirements Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises, REVISION B
TIA 758-A	Customer owned outside plant cabling (approved for publishing)
TIA 862	Building Automation Systems cabling (approved for publishing)
TIA 942	Data centres infrastructure
TIA 1005	Industrial cabling infrastructure
TIA 1152	Requirements for field test instruments
TIA 1179	Development of a new Healthcare standard (TR 42.1)
ISO/IEC NP 24764	Information technology --Generic cabling for data-centres
IEEE1100-2005 -	IEEE Recommended Practice for Powering and Grounding Electronic Equipment

The history of data centres standards development is summarized in the image below:

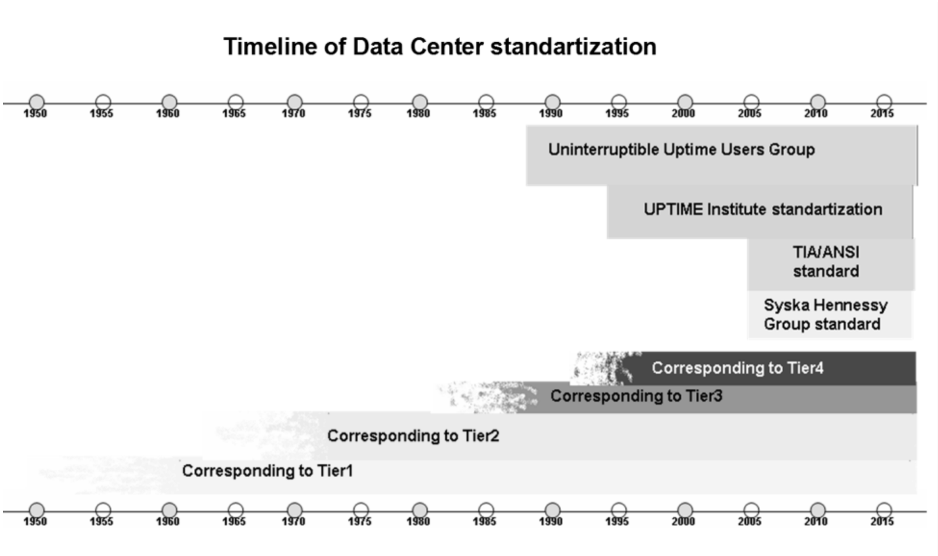


Figure 4: Timeline of Data Centre Standardization

4. Data Centres Timelines and Dots on it

4.1 The beginning of data centres

The concept of a data centre is related to industrial IT utilization. The beginning of data centre development is firmly involved with mainframe computer maintenance. The first unique mainframe computers were produced in research laboratories and also disposed there. The data centres' initial period we associate with such computer disposing and maintenance that were manufactured outside of research laboratories at least in a couple of instances. The first industrially manufactured computers and the first data centres had accumulated previous experience in mechanical data processing with different tabulators, adding machine and other devices.

Early computer systems were room-sized machines and required a lot of space. The complexity of operating and maintaining these machines also led to the practice of secluding them in dedicated rooms. Historically, assessment of data centre physical infrastructure's business value was based on two core criteria: availability and upfront cost. A data centre is a building where the primary function is to house the computer room and its support area. Four functionalities must be ensured:

- hardware disposal,
- power to maintain equipment,
- HVAC temperature controlled environment within the parameters needed,
- structured cabling in and out.

We recount examples of the first data centres formed in the following fields:

- banking sector - digital banking;

During the 1950s, researchers at the Stanford Research Institute invented the Electronic Recording Method of Accounting computer processing system (ERMA). ERMA was first demonstrated to the public in 1955, and first tested on real banking accounts in 1956. Production models (ERMA Mark II) were delivered to the Bank of America in 1959 for full-time use as the bank's accounting computer and check handling system.

In 1961 Barclays opened Britain's first computer centre for banking. The company, now called Automatic Data Processing, Inc. went public and leased its first computer in 1961, an IBM 1401.

- **Statistics**. UNIVAC I, was signed over to the United States Census Bureau on 1951.
- **Climate data processing and weather forecasting**. The Weather Bureau (USA) start in 1954- 1955 with usage of an IBM 701.
- **Medicine**. Usage of computerized citoanalyzer was started in 1954. In 1960 an IBM 650 was used to scan medical records for subtle abnormalities.
- **Civil aviation**. The first passenger reservations system offered by Sabre, installed in 1960.
- **Military field, including space**. The building of the USSR Ministry of Defence Computer Centre No1, created by A.I.Kitov in 1954. That was the first Soviet computer centre.

- Universities and research laboratories.
    - CERN's first computer was installed in 1958.
    - M.I.T. Computation Center establishing from 1956 until 1966.
    - Russian Academia of Science Computing Centre established in 1955.
    - Research Computing Center of Moscow State University was founded in 1955.
    - St.Petersburg University computer STRELA was installed in 1957.
    - In 1959 was established the Computing Center – now Institute of Mathematics and Computer Science University of Latvia (IMCS UL).

By data centre we mean the physical environment – premises and all the necessary equipment for effective operation. Data centre staff are qualified employees that ensure computer maintenance. Data centres historically have developed according to computer operation technical requirements that depend on computing facilities. As mentioned before, the data centres' initial period is connected with 1st, 2nd and 3rd generation mainframe computers. During the computers' development they became smaller and smaller, but could ensure the same computing capacities – minicomputers derived. Wherewith, by emergence of personal computers data centres' impressiveness and uniqueness entirely shrank. For personal computer usage data centres were not necessary – they could be used right there in the office. However, this IT development did not eradicate data centres entirely – other technological needs and data centres' applications derived. With the boom of personal computers started the growth of the internet and sharply in more extensive sense developed data transmission technologies, telecommunications transferring to digital technologies and a sharp merging of information and telecommunication technologies happened. Disposal of telecommunications hardware in data centres started, so they became internet nodes. Since the early 1960s, the design of data centre infrastructure has advanced through at least four clear stages:

- Tier I appeared in the early 1960s,
- Tier II in the 1970s,
- Tier III in the late 1980s and early 1990s,
- Tier IV in the mid-1990s.

These stages provide the foundation for the Four Tier Classification system defined by owners and users in association with the Uptime Institute.

4.2. Supercomputing

With great computing capacities (supercomputers) it is rationale to dispose these in data centres. Supercomputing necessity was sustained by a growing need of digital data storage amounts and computing capacities. Technological solutions and standardization developed and allowed to dispose computers and telecommunication hardware in data centres in a unified way, rack standards for hardware disposal were developed.

Data centres were always important for disposal of supercomputers and high performance computing (HPC). Supercomputers and HPC are used for highly calculation-intensive tasks such as problems including quantum physics, weather forecasting, climate research, oil and gas exploration, molecular modelling and physical simulations. Below we show growth of computing capacities in correspondence with the maximal capacity assured.

1949: 1,000 (1 KiloFlop)
1961: 100,000
1964: 1,000,000 (1 MegaFlop)
1987: 1,000,000,000 (1 GigaFlop)
1997: 1,000,000,000,000 (1 TeraFlop)

4.3. Virtualization Timeline

Communications channels historically were not powerful enough and there was no vast penetration of them, therefore personal computers-servers had to dispose in data centres as internet nodes. In that way the new service packages - colocation and hosting services were offered by data centres. In the further development of data centres services, virtualization technologies development has an important role, which currently concludes in cloud computing functionality. A short timeline of virtualization is as follows:

- 1960s: IBM introduces virtualization as a way for mainframes to share expensive memory and split mainframes into multiple virtual machines, work out timesharing and hypervisor ideas;
- 1971: IBM begins commercial production of system S/370 and adds virtual memory as a standard feature;
- 1994: Colocation services started;
- 1999: Rackspace Hosting opens their first data centre to businesses;
- 1999: VMware launches its Virtual Platform product;
- 2009: start a transition to cloud computing structures.

4.4. Racks and/or blades

There are several advantages for each solution, but every time we design anew, there are investigations we should think about and weight ...

- **RACKS**: *A 19-inch rack is a standardized frame or enclosure for mounting multiple equipment modules. Equipment* module has a front panel that is 19 inches (482.6 mm) wide, including edges or ears that protrude on each side which allow the module to be fastened to the rack frame with screws. Developers first placed complete microcomputers on cards and packaged them in standard 19-inch racks in the 1970s soon after the introduction of 8-bit microprocessors. Equipment designed to be placed in a rack is typically described as rack-mount, rack-mount instrument, a rack mounted system, a rack mount chassis, subrack, rack mountable, rack unit or U (less commonly RU). The industry standard rack cabinet is 42U tall.

- **BLADES**: A blade server is a stripped-down server computer with a modular design. A blade enclosure, which can hold multiple blade servers, provides services such as power, cooling, networking, various interconnects and management. Cooling during operation, electrical and mechanical components produce heat, which a system must dissipate to ensure the proper functioning of its components. Most blade enclosures remove heat by using fans. Networking blade servers generally include integrated or optional network interface controllers. A blade enclosure can provide individual external ports to which each network interface on a blade will connect. Alternatively, a blade enclosure can aggregate network interfaces into interconnect devices (such as switches) built into the blade enclosure or in networking blades.

4.5. A portable modular data centre

Container-based data centres go one step beyond in-rack cooling by placing the server racks into a standard shipping container and integrating heat exchange and power distribution into the container as well. Similar to full in-rack cooling, the container needs a supply of chilled water and uses coils to remove all heat from the air that flows over it. Air handling is similar to in-rack cooling and typically allows higher power densities than regular raised-floor data centres. Thus, container-based data centres provide all the functions of a typical data centre room (racks, CRACs, PDU, cabling, lighting) in a small package. Like a regular data centre room, they must be complemented by outside infrastructure such as chillers, generators, and UPS units to be fully functional. Several large hardware vendors have developed mobile solutions that can be installed and made operational in very short time.

Computing developments which have an influence for Data Centres

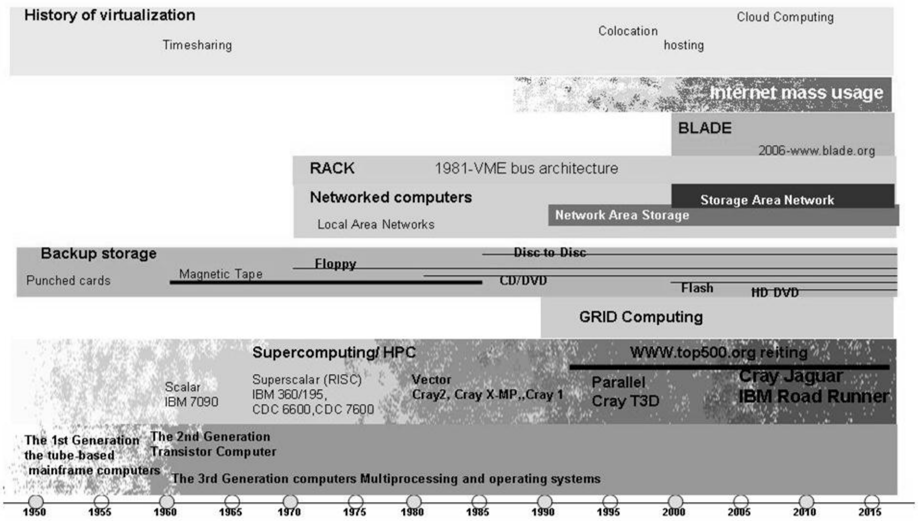


Figure 5: Development of Data Centres in relation to IT technology transformations

5. Data Centre of the Institute of Mathematics and Computer Science, University of Latvia

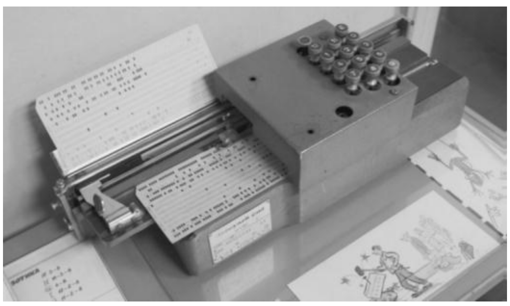
Latvia is one of the Baltic region's countries in the Northern Europe. During World War I the territory of Latvia as we know today, similarly to other areas of the Russian Empire's west, was destroyed. However, after various historical events since that time, Latvia regained its independence in 1991 for good.

The Institute of Mathematics and Computer Science, University of Latvia (IMCS UL) was established in 1959 as a computing research centre. It was the fourth computing research centre in the Soviet Union established with a goal to develop Latvian industry and public computing services for the country. From very beginning the best computing machines available in the USSR were installed and used there. Over the years the use of computing technology, relevant science field and technology itself has changed significantly. The number of people employed at the institute has varied through different times, ranging from 120-450; at present 213 employees work in IMCS UL.

Currently IMCS is the largest and the most relevant research institution in Latvia in the field of information technology, mathematics, computer science and computational linguistics. The main research fields in IMCS UL are:

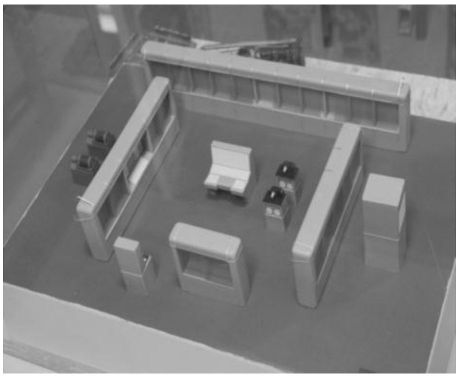
- **Computer Science**
  - Mathematical foundations of computer science
  - Complex systems modelling languages and development tools
  - Graph theory and visual information processing
  - Semantic web technologies
  - Real time systems, embedded systems
  - Computational linguistics
  - Bioinformatics
- **Mathematics**
  - Mathematical modelling for technologies and natural sciences
  - Theoretical problems of mathematical methods.

In 1984 IMCS UL established a Computing Museum. Documents and equipment in the museum reflect on computing machines of a passing age, their description and tasks which were solved with them (Balodis, Borzovs, Opmane, Skuja, Ziemele 2010)(Балодис, Опмане 2011). The Computing Museum holds 13,116 exhibits, including 504 equipment units, 287 mainframe and workstation parts, 98 computers, 44 printers, various documents and photos; and all of it is shown to approximately 500 visitors per annum.



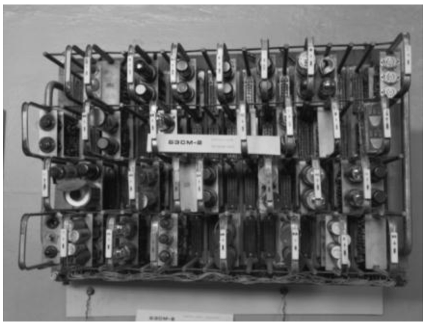
Manual punch

Below we publish some photographs showing the exhibits from the museum.



BESM 2 Model

Tape device



1/8 of ‘mother board’

Magnetic DRUM – ‘hard disk’

IMCS UL data centre’s main part – computing, has experienced technological transformations:

- from 1959 till 1970 – initial development of IMCS UL, operation on the basis of «BESM» and «MINSK» computers;
- from 1970 till 1990 – transition from «BESM» and «MINSK» computers to production of «ES EVM» and adaptation (cloning) of IBM’s mainframes;

from 1990 till nowadays –application of personal computers and internet, development of internet connectivity international node, development of GRID computing, establishing of unified computing facility as regional partner facility in European Union.

The first industrial soviet computers had many technological deficiencies:

- for effective work innovative laboratory of engineers and electricians had to be established;
- installation of first computers substantially contributed to the research growth, particularly research in the development of methods of mathematical modelling of various physical processes, research in the development of software and research in theoretical computer science;
- along with the research practical information systems for Latvian economics were developed;

- as from the seventies there was a trend for cloning, however, IMCS UL retained its initiative to carry out research for original software development.

BESM 2 Console (~1/4 part)

BK-0010 for schools – components: home colour TV, pseudo-membrane keyboard combined with processor and memory

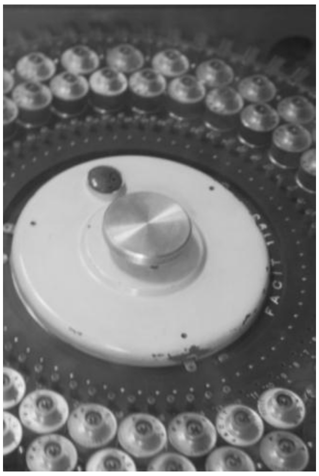


Table 6: Computers located in IMCS UL's data centre from 1959 to 1992

Exploitation time	Computers
11.04.1961–21.08.1970	BESM-2 (first generation, vacuum tubes, 5000 op/s)
29.06.1964–3.04.1972	BESM-2M
11.04.1967–06.04.1978	BESM-4 (second generation, transistors, 20 000 op/s) Computer modernization with FACIT ECM 64
03.09.1969.- 03.04.1983	GE-415 (40 000 - 90 000 op/s)
16.05.1974–31.12.1978	ES EVM -1020 (11 800 op/s)
1976–31.12.1987	ES EVM -1022 (80 000 op/s)
02.1980–31.12.1987	ES EVM -1022-02 (80 000 op/s)
12.1982–1990	ES EVM -1060-02 (100 000 op/s)
02.03.1983–06.1989	ES EVM -1055M (450 000 op/s)
25.10.1989–10.1992	ES EVM -1037 (4 000 000 op/s)
Minicomputers	
23.03.1981–06.1989	CM-4 (180 000 op/s)
24.03.1985–05.1989	IZOT-1016S
30.04.1987–1990	IZOT-1055S
07.06.1989–1990	IZOT-1080 (4 500 000 op/s)

Personal computers	
1985–1993	Acorn (BBC education class, UK)
1986–1993	ISKRA-226 , DVK, KUVT-86, BK-0010, Robotron – 1715 (Eastern Germany), Yamaha (Japan)
1989–1993	ISKRA-1030, IBM XT, AT, Mazovia, PS2

Soviet economic planners decided to use the ES EVM design (IBM clones). Prominent Soviet computer scientists had criticized these ideas and suggested instead choosing one of the Soviet indigenous designs, such as BESM or Minsk. The first works on the cloning began in 1968; production started in 1972. After Latvia regained independence, operation of ES EVM was suspended in 1992 due to costly service – electricity and a great maintenance staff.

All together transition from BESM to ES EM and mini computers did not affect the institute's research, nor the data centre's development, because ES EVM were not smaller in their volume; they were even more exacting as for data centre facility's provision.

In the existence of the data centre, there was decadence for 5 years in the end of 1980s, because mainframe computers were disassembled and other computing resources of such scale were not set up.

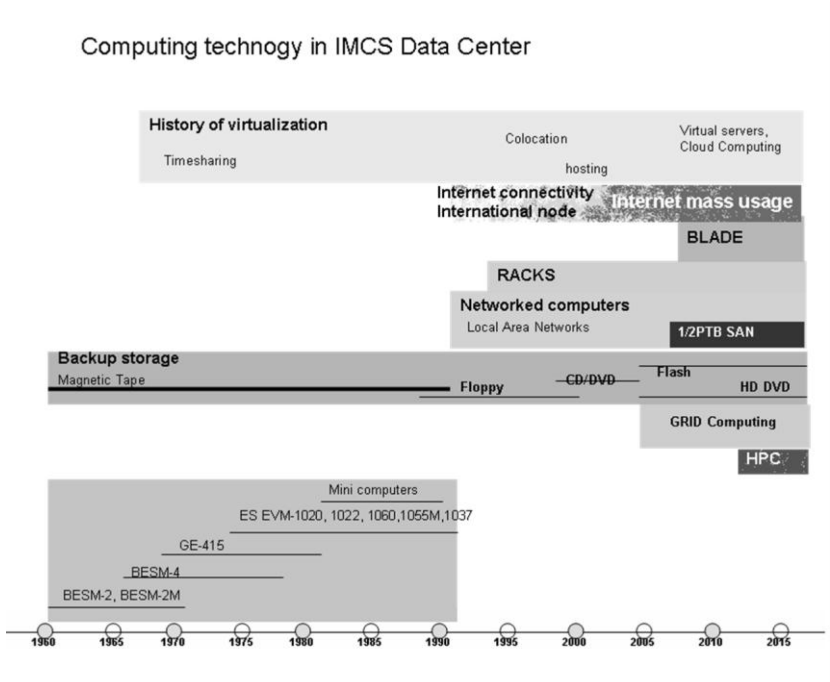


Figure 6: Computing Technology in IMCS Data Centre

Technological reform of the data centre began when Latvia regained its independence and introduction of the internet in 1992. In the data centre there was disposed and further developed an international internet node with appropriate server connection; but in the mid-1990s collocation services were offered, but in 2000 –

hosting services. This allowed to rationally use the early data centre's premises and practical knowledge of scientists. If we are talking about the data centre provisions functionality (power, HVAC, fire, security), then the best knowledge was gained with requirement ensuring of GE-415. By the beginning of the 1990s, completely new equipment and modern technologies were used, but the functional equipment of the data centre was maintained. The latest in IMCS UL was introduced the structured cabling system (only from 2006). Mentioned statements are confirmed in the picture above.

6. Conclusions

There are standards and theory about data centres in accordance with which data centres are classified. The latest generation of computing technique's maintenance requirements for environment are increasing, and as a result, every data centre in its development is tending to become the highest category data centre. To ensure such environment it is also necessary to modernize the components that form it, therefore investments in environment development are increasing. Scientific institutions do not have such resources to create the highest category data centres, although the development of data centres in them is necessary; as well as it is necessary to ensure sustainable exploitation of computing resources, it is not critical to turn-off data centre, e.g. during the time environment maintenance equipment is being changed.

Literature

1. R. Balodis, J. Borzovs, I. Opmane, A. Skuja, E. Ziemele. (2010). Research directions profile in the Computing museum of the Institute of Mathematics and Computer Science, University of Latvia (IMCS), p. 453- 461,In IFIP Advances in Information and Communication Technology Volume 350, 2011, Springer, DOI: 10.1007/978-3-642-23315-9, History of Nordic Computing 3 Third IFIP WG 9.7 Conference, HiNC 3, Stockholm, Sweden, October 18-20, 2010, Revised Selected Papers.
2. Р. Балодис, И. Опмане. Институт и три социально- технологические волны ИТ.стр. 36-40,in International Federation for Information Processing Yaroslav-the-Wise Novgorod State University A.P. Ershov Institute of Informatics Systems, Siberian Branch of the Russian Academy of Sciences Computer History Museum, CA, USA Scientific Council of the Russian Virtual Computer Museum Polytechnic Museum, Moscow SORUCOM-2011 PROCEEDINGS Second International.