Revision 6

Whitepaper Immersed Computing®

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Asperitas
IMMERSED COMPUTING®

Immersed Computing®
By Asperitas

A concept driven by sustainability, efficiency and flexibility. Using the most efficient model for operating IT, Total Liquid Cooling, and going far beyond just technology. Immersed Computing® focuses on IT optimisation and includes an optimised way of work, highly effective deployment, flexible choice of IT and drastic simplification of datacentre design. Offering great advantages on all levels of the IT platform value chain. Realising maximum results in Cloud, HPC and Edge.

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1. Background

The datacentre industry is at the peak of its growth. New datacentres are continuously being built and the challenges for datacentres are growing as fast as the industry itself. This growth is accompanied by a high demand for high density datacentres and platforms. The main cause of the increasing demand is the Internet of Things (IoT), big data and a global move to cloud based computing.

The industry is consuming about 5% of the global electricity supply and it is still growing. This has caused the focus to shift from high amounts of floor space with distributed IT environments, to high density and energy efficient centralised cloud environments.

Air based cooling becomes an ever growing challenge with the increasing demand for these high density cloud environments. Extreme wind speeds within server racks (10+ Beaufort within chassis) are required to cool high density environments and air becomes ever more problematic in these environments with vibration issues, overhead power for fan energy, zinc whiskers across IT components and power thirsty cooling installations.

The focus has been on cooling, the biggest overhead. The Power Usage Effectiveness (PUE) has been adopted as a major KPI for datacentres. The formula is simple: total energy footprint of the facility divided by the energy consumed by IT. The downside of this approach is that IT inefficiency is being rewarded, thus leaving the focus on high energy savings on cooling installations and less on possible energy reduction by increasing the energy efficiency of the IT itself.

In the past years, liquid cooling has been (re) introduced, although mostly in High Performance Computing (HPC) environments like supercomputing. The requirements in this part of the industry are such that more effective cooling allows for higher performance. Therefore, liquid was quickly adopted and today it is inconceivable that a supercomputer will be built without some form of liquid cooling.

Cloud platforms now have energy and density challenges, which are identical to HPC, although the density challenges have a different focus compared to HPC environments. Cloud platforms are designed for continuity, flexibility and resiliency. Not necessarily the highest performance. This is where liquid cooling often runs into limitations. The available technologies are often limiting in some way: complexity, cost, maintenance, cleanliness, compatibility with existing whitespaces or bound to proprietary IT.

To make liquid a viable solution for the cloud industry, a different approach was required. An approach which addresses sustainability, continuity, flexibility, Total Cost of Ownership (TCO), tidiness, cleanliness and compatibility with existing environments.

This approach is called Immersed Computing®

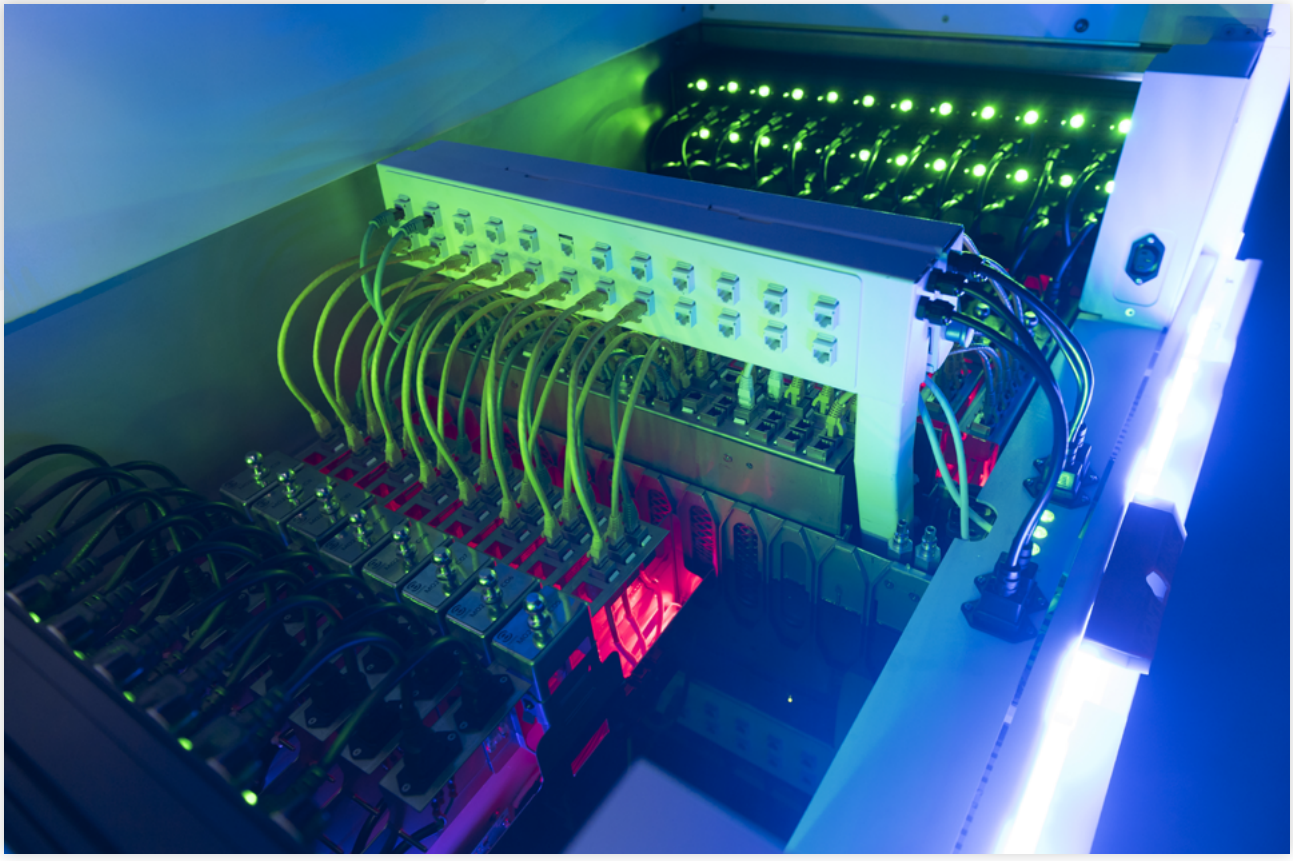

Image 1 Asperitas Immersed Computing® solution

2. Immersed Computing® explained

Immersed Computing® is a concept consisting of technological and operational aspects. It is focused on a holistic approach towards efficiency. It starts with the view that the digital platform is the central value which needs to be facilitated above anything else. The physical IT platform is therefore the most critical part of the infrastructure. By optimising the IT platform and all aspects around it, Immersed Computing® allows full optimisation of not only processing, power and cooling, but also maintenance, lifecycle and flexibility of the end-to-end operation.

2.1 Total Liquid Cooling

Total Liquid Cooling of IT, also called Immersion Cooling, is at the foundation of Immersed Computing®. It refers to the complete immersion of electronic components in a dielectric liquid. By doing so, all the heat generated by the IT is captured in the liquid. Suitable dielectric liquids can absorb approximately 1500 times more heat energy than air with the same volumes and temperatures.

Total Liquid Cooling is not new. It has been an accepted method of conditioning electronics for more than half a century. In the late sixties, the first patents for oil immersion systems were already granted. These were abandoned after some time due to the lack of focus on energy efficiency. Air based systems were already abundant and 19” racks already were accepted standards. The use of Total Liquid Cooling has only remained common practice in niche markets where other factors became problematic like deep sea research (pressure vessels) or high voltage installations.

Suitable dielectric liquids today are hydrocarbons and fluorocarbons. With the core values of Immersed Computing® in mind, Asperitas is mainly working with medicinal quality synthetic oils as a primary cooling medium. This is due to the wide availability throughout the world, the low cost and the minimised safety concerns involved. Medicinal synthetic oils are manufactured by multiple manufacturers and brands may sometimes be mixed or interchanged, depending on manufacturer statements. Fluorocarbons, although quite suitable for Immersed Computing®, usually relate to a cost which is at least 30 times higher. This makes it less interesting for an "open bath" approach. The synthetic oils used by Asperitas are similar products as Vaseline, although with a higher purity and much lower viscosity.

Traditional single phase liquid circulation requires infrastructures with pumps and piping for circulating dielectric liquids from a basin, through a facility, to a cooling tower and back into the immersion basin. This same circulation pushes the dielectric liquids through the IT chassis and over the micro-electronics, thus removing their generated heat.

Passive circulation of the dielectric liquid is where Immersed Computing® is unique and ground-breaking. Asperitas eliminates any infrastructure for the dielectric liquid. Instead, the liquid is circulated by natural means and does not leave the immersion system. The liquid circulates by the heat generated by the IT and water-cooled "Convection Drives®". This means that the primary circulation is completely driven by the thermal expansion of the liquid and gravity. The only requirement for heat rejection is any common liquid coolant infrastructure.

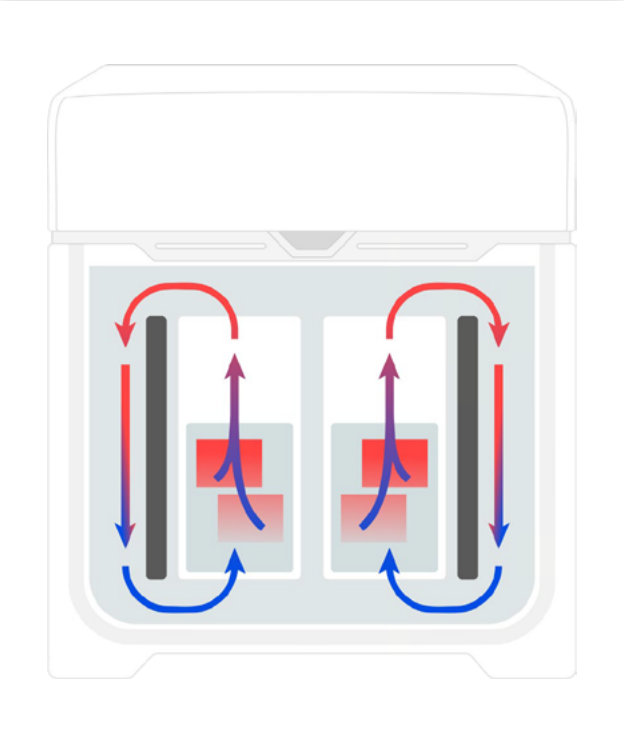

Image 2 Natural Convection

The ensured high quality of the liquid in Immersed Computing® is facilitated by the purity of the used liquids, the lack of moving parts and the fact that everything in touch with the liquids has been thoroughly tested and certified before commissioning. No air is ever mixed into the liquid in the system and the lid is closed by default, since a closed lid improves the effectiveness of the thermodynamic process. This prevents oxygen from reacting with the liquid. The thermal stability of the liquid is also guaranteed by liquid quality and extensive safety mechanisms which are integrated in Immersed Computing® solutions.

A double hull and cold shell protect the environment of the system from any liquid or thermal leakage. The double hull is insulated and provides an optimal safeguard against any form of leakage. The only place for the heat to go is into the water circuit. This means that the result of Immersed Computing® is coolant with the same amount of thermal energy as the IT electrical consumption. Simply put, 22 kW IT equals 22 kW heat captured in the liquid, which is rejected with water at minimised losses.

Any type of server can be inserted into the system, although it does not maintain the traditional server shapes as we know them in air-cooled racks. After all, traditional servers are not designed to allow liquid to flow through the chassis by itself. Immersed Computing® servers consist of IT components like mainboards with components attached, power supplies and storage. Specialised Asperitas Universal Cassettes or AUCs are used for Asperitas systems. All information on the AUCs is publicly available for hardware designers and manufacturers.

The Asperitas certification process addresses any reliability concerns by optimising server designs and rigorously testing each design in collaboration with the IT manufacturers. This process includes full component compatibility research and qualification, establishing thermal boundaries and limitations and full design documentation which is supported and used by manufacturers and integrators to allow volume delivery and support. All server designs are aimed at the highest temperature tolerances.

2.2 Enclosed and self contained

The focus is on compute, as IT is at the basis of every platform or datacentre. All other aspects of a server, rack, cooling or even power system only facilitate the IT. Immersed Computing® allows for a shift in focus from Cooling to Compute. The self-contained approach allows for a much deeper level of integration than any other rack- or liquid solution. Everything required to facilitate and manage IT like power and data connectivity is integrated and fully manageable with Immersed Computing®.

Integrated power distribution is used for powering all IT in the system. The power distribution system can be redundant and fully managed and must be applied in such a way that cable management is simplified and nothing needs to be routed outside the immersion system;

Integrated universal switching allows for the distribution of Ethernet connectivity throughout the system. Universal Switching Cassettes allow for any brand of switch to be immersed, and the network connections are distributed to each server with minimised and intuitive cable management;

The integrated cable management approach allows for standardised and optimised serviceable cabling and logical cable management without bundles or over lengths. Only backbone/uplink cabling comes out of the system.

2.3 Flexibility

Flexibility is key for Immersed Computing®. Platforms must be easily expandable and should grow with the environment. To address the current challenges in the industry, systems must be easy to deploy and the platforms should not be limited to proprietary IT, a fixed shape or size or predefined IT specifications.

Immersed Computing® is plug and play. Due to the self-contained approach, a single system requires only power, access to a water loop and data connectivity to operate. This can all be supported in up-to 2N configurations which enables full deployment and commissioning in any type of datacentre environment within a few hours.

Future proofing and climate independence. Immersed Computing® platforms are prepared for high cooling temperatures which makes any platform climate independent (global chiller-less deployments) and the accompanied optimised high return temperature tolerance enables reusable energy. This enables new deployment strategies for platform and datacentre planning.

Modularity is achieved with the self-contained immersion systems with a scalable footprint. A single water loop can be shared across multiple systems and modules can be placed back-to-back and side-to-side. Since there is no air required for the system to operate, large rows of interconnected systems can be placed in relatively small spaces.

The scalability of Immersed Computing® allows for very fast deployment of datacentre locations because there is hardly any infrastructure required. Power systems are minimised with less overhead, cooling infrastructure is minimised and IT is optimised for high utilisation.

The open IT approach allows for any type of IT to be used with Immersed Computing®, regardless of brands. Limiting factors are related to the use of liquid. Material compatibility is addressed by the certification process which also ensures an optimised design for liquid.

An end-to-end ecosystem of partners enables Asperitas in the development of any technology within immersion. Asperitas enables the development of liquid optimised technologies by building strategic collaborations with server, chip and component manufacturers around the world. By sharing knowledge within this ecosystem, any immersion challenge is addressed and solved.

2.4 Way of work

The most critical factor with Immersed Computing® is the mind-set and way of work. This does not only cover the design or certification process. Implementing Immersed Computing® means working with liquids. Asperitas has been focused on creating a solution where working with liquid is safe, clean and easy.

Understanding liquid itself is an important first step. By adopting liquids, certain aspects of a data-centre operation and way of work will need to change. Most obviously, liquid behaves differently than air. The interaction with any device inside liquid is therefore also different. Anything which is immersed will be wet when it is extracted and this may be the case during servicing or after replacements. Anything taken from the liquid, when properly worked with, may leak when removed. Although dielectric liquids seem similar to water (colour, odour, viscosity etc.), they behave differently.

Preventing leakage is the first step in the design or deployment of any system and the way of work. The system itself is already focused at no-spill. This leaves the way of work. People servicing IT must be prepared to deal with liquids, to adjust the work process, to have proper supplies and take the time required for liquids to drain. Immersed Computing® includes all the tools required to deal with regular and irregular maintenance.

Cleaning the smallest spills must be a routine. Depending on the liquid type, leakage may not evaporate, but can remain on a surface unless properly cleaned. A small drop is not a big deal, but lack of containment or clean-up of multiple small spills over time does become an issue. Each drop should therefore be wiped immediately.

Supplies and consumables which are specialised for the type of liquid used are required for maintenance and clean operations. Water can easily be cleared with a towel or sponge and residue will simply evaporate, but any hydrocarbon will not be absorbed by the same materials, nor will it evaporate easily. Widely available, but specialised supplies need to be available wherever people are working on Immersed Computing® platforms. Asperitas includes all absorbent materials required for normal maintenance and any level of spill management.

Maintenance on electronic components requires removal of the IT from the liquid. Since all the IT is placed in a vertical position, it becomes impractical to manually lift a server from a module. This is addressed with a specialised, (semi-)automatic hoisting mechanism. The Asperitas Service Trolley is specialised for hoisting, servicing and transporting IT, cleaning up spills and servicing liquid.

Training of service staff on the properties and operation of dielectric liquids and the use of essential supplies is of utmost importance. It is quite simple and lessons are easily handed over, but the basic knowledge should be there.

3. Benefits

Immersed Computing® provides benefits for many layers within the IT value chain, from the physical geographical location to the end user of a platform. Each type of environment is different so it helps to create more insight in the layers underneath a dense platform.

3.1 Energy efficiency

Immersed Computing® offers the highest energy efficiency of IT environments. This is caused by two main factors and several side effects.

1U server energy reduction A single 1U fan consumes about 12 watts at full power. A fan assembly usually consists of 2 fans. 1U servers often require at least four of these assemblies across the width of the chassis and additional fans for the power supplies. This adds up to about 120 watts. With low powered servers, this is up to 45% of the energy footprint.

The lack fans reduces 6-45% of it energy.

Any air-cooled IT equipment requires air circulation. In servers this consumes between 6% and 45% of the total energy footprint. 1U servers with average CPU power with good utilisation (i.e. 80W per CPU) often end up with the highest fan overhead. Larger servers (2-5U) have larger fans which consume less energy, but these servers take up a lot more space in a rack which makes the rack less effective. This fan overhead and space limitation is completely eliminated with Total Liquid Cooling.

The high heat capacity of liquid allows IT to operate within higher temperatures compared to air. This means that running IT in higher environmental temperatures, still allows the IT components to operate well below the maximum component temperature tolerances. Immersed Computing® platforms are aimed towards 40+°C cooling temperatures, so there are normally no chiller units required and energy overhead is reduced to a minimum.

Energy reuse is greatly optimised as all IT energy is captured in the form of heat inside water. After all, the enclosed system is liquid cooled and there is no other way for the heat to go besides the facility (water-based) coolant which runs through the Convection Drives®. Warm water can easily be transported or even stored for energy reuse scenarios.

The lack of pumps ensures the highest efficiency in liquid cooling. Mechanically circulated immersion systems require significant overhead energy for pumps and control systems. The saving of Immersed Computing® systems due to the natural circulation which regulates itself is enabling the highest efficiency cooling.

3.2 Datacentre build

The cheapest datacentre is the one you don't need to build.

Reduced floorspace is one of the obvious benefits of Immersed Computing®. Compared to an average air-cooled cloud datacentre, Immersed Computing® can facilitate 5-10 times as much density.

Air-cooled rack

An air-cooled rack can commonly support about 5kW of IT power, and takes the space of 2 floor tiles. In order to get sufficient air through the rack, 1 or 2 floor tiles are needed in front and in the rear of the rack, also to allow space for servicing. The total footprint of the rack now becomes 600x2400/3600 mm.

This results in a power density of **1,5-2kW per m^2**

Immersed Computing®

An Immersed Computing® platform which supports 32 kW IT power with a footprint of 600x1200 mm, needs no airflow. With a service area of 600x1200 mm for each module.

This results in a power density of **more than 22 kW/m^2**

No raised floors and isle separation schemes are required. Since there is no air involved with Immersed Computing®, there are no air flows to separate. Although raised floors are fully supported and even convenient for routing of facility cooling circuits, they are not a requirement for Immersed Computing®.

The physical location of the datacentre becomes less challenging with Immersed Computing®. Since there is hardly any environmental impact like noise, datacentres can be built in urban areas. This opens up possibilities to get closer to the edge of the network to allow further growth of Internet of Things and delivery of content to end users with minimised impact on the core network.

3.3 Datacentre facilities

Overhead facilities can be downsized or existing capacity can allow for more IT.

The minimised cooling requirements for Immersed Computing® result in smaller and heavily simplified cooling installations. However, if these are already present, there is more capacity for more IT power. In reusable heat scenarios, warm water can simply be used and cooled by a heat user which can eliminate coolers all together.

Minimised power requirements have a significant impact on the utilisation of the facility power envelope. The cooling power budget can be used for IT or emergency no-break systems can be reduced. No-break systems are expensive and depending on the type of datacentre, these need to be sized to allow all IT to function during power outages, as well as the cooling installations to facilitate the IT. The power systems can be downsized or, when already present, facilitate more IT.

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3.4 Datacentre operations

Immersed Computing® offers significant benefits towards business continuity and maintenance costs.

Business continuity is improved as total immersion of IT protects the IT itself much better than traditional air environments, because:

- No oxygen gets in touch with the actual components which prevents oxidation. The liquid creates a protective barrier since oxidation requires oxygen and water. The liquid keeps both away from the IT. This drastically reduces any physical degradation of the IT components over time;
- Moisture does not mix well with dielectric liquids. Since there are no moving parts and all liquid movement is maintained by natural means, any accidental water accumulation (unlikely spills or condensation) will just stay underneath hydrocarbon-based environments, or on the surface of fluorocarbons. Residual moisture can easily be taken out by a liquid polishing system which is part of the service trolley;
- Thermal Shock is greatly reduced due to the high heat capacity of liquid. Where air cooled systems have enormous temperature fluctuations within the chassis when utilisation fluctuates, the immersed environment only has minor fluctuations. This greatly reduces stress by thermal expansion on micro-electronics.
- Reduced component failures are the result of these effects. These in turn reduce component costs and workload for service staff.

Normal maintenance costs are greatly reduced. Since total immersion eliminates the root cause of most electronic component failures, the most important situation to address is regular maintenance, upgrades and renewals. Reduced and simplified overhead installations for power and cooling also result in reduced potential for failure and maintenance.

3.5 IT hardware

IT hardware should be optimised for Total Liquid Cooling to ensure the maximum beneficial effect. This means that servers will be able to perform much better than traditional air-cooled servers. The loading of a single immersed server can be sized to replace three or more air-cooled servers. This results in an enormous consolidation where less IT is required to provide with the same amount of digital capacity.

3.6 Software cost

Fewer OS and CPU licences are required due to the use of optimised IT hardware. Because of the smaller number of physical servers, fewer operating system licenses are required. The same can be said about applications which adopt a per CPU licensing structure. Often database servers and virtualisation systems benefit from fewer CPUs from a licensing perspective. Since licensing cost often outweigh the hardware cost, this may in some cases be the highest financial saving in the entire value chain.

Image 3 Immersed Computing® facility

3.7 Environments with greatest benefits

All IT operators can benefit from investing in Immersed Computing®. Immersed Computing® not only positively impacts sustainability, but also many CAPEX and OPEX factors, dramatically reducing TCO. However, the more links a company controls in the value chain, the more financially attractive the business case for adopting Immersed Computing®. Especially for greenfield deployments.

IT owner/operators will achieve the best results, especially with HPC requirements in single tenant environments.

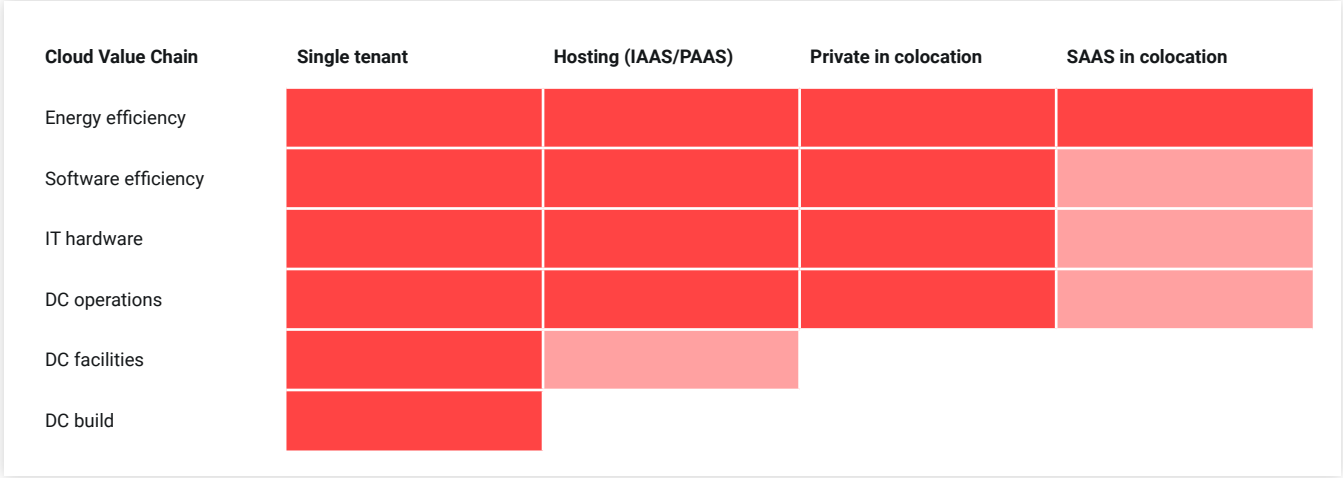


Image 4 Immersed Computing® for different types of IT owners/operators

High performance computing Immersed Computing® solves density requirements and allows for liquid cooling on a much larger scale than usual;

Private datacentres Private / hybrid cloud operators who own the entire value chain experience the same benefits as cloud operators;

Cloud optimised or HPC colo datacentres Colocation datacentres which focus on facilitating HPC of high density cloud providers can facilitate the growth of compute platforms by offering Immersed Computing® as a dedicated housing environment;

Edge computing The limited infrastructure requirements of Immersed Computing®, as well as the remote management capabilities enable micro/mobile edge deployments in urban areas;

Mobile solutions The plug and play solutions and minimal infrastructure requirements make applications possible in remote geographical areas where availability of energy supply and cooling is problematic.

4. Asperitas solutions

Asperitas has developed the solutions to fully integrate IT platforms within Immersed Computing®. It is based on immersion technology with a modular system, the AIC24, supplemented with the tooling required for operating IT. The most important elements of the tooling are the service trolley and the maintenance supplies for working with immersed IT. Asperitas provides training which addresses the new elements around operating and maintaining Immersed Computing® as effectively as possible.

AIC24

The AIC is a fully integrated, self-contained, plug and play, modular unit. The standard AIC24 has a footprint of 600x1200 mm and can contain up to 48 servers, 288 GPUs or any other combination of IT components.

Image 5 AIC24

Image 6 Service trolley

Tooling

All the tooling required for the maintenance with wet IT is developed by Asperitas, including ESD leak trays, spill kits, liquid supplies and more.

Service trolley

The ESD protected service trolley has been developed and optimised for Immersed Computing® with the AIC24 modules. It addresses all maintenance: hoisting cassettes, servicing and transporting IT, cleaning up spills and polishing liquid.

Training

The following training is available at the Asperitas Technology Centre:

- Operating AIC24 and the service trolley;
- Designing IT for Immersed Computing®;
- Risk management with Immersed Computing®.

5. Best practices

Best practices in datacentre planning, processes and IT and platform design, help get the maximum results out of Immersed Computing®.*

5.1 Datacentre planning

Considering high cooling temperatures when choosing the geographical location. Reusing the energy used in a datacentre becomes viable with Immersed Computing® because the heat is already captured in the facility liquid circuit, which allows easily transportable heat. This heat can be used in a completely different industry to replace energy used to heat something (heat grid, industrial process, swimming pools etc.). A datacentre built in the proximity of such an industry can achieve the maximum reuse of energy.

Using the best technology for the best purpose is made easy with Immersed Computing®. Its flexibility enables a hybrid approach to any IT platform environment where the best of all worlds can be applied. The simplicity and scalability of Immersed Computing® allows it to be applied in harmony with any other (existing) environment.

Optimising temperatures for water loops is made possible by aligning different liquid-cooled technologies appropriately. By implementing temperature chaining, which involves setting up different technologies in series, an air-cooled datacentre can build up the temperature in the water loop. Water-cooled HVAC systems require the lowest temperatures, then a specific liquid IT environment like rear door cooling, followed by an Immersed Computing® environment after which a Direct Liquid Cooled environment adds the last energy to the loop. This gives high temperature differences on a cooling infrastructure which makes the cooling process more efficient, because a higher percentage of energy can be rejected without compression cooling. (Please also refer to “The datacentre of The Future” whitepaper by Asperitas.

* In addition to: European Code of Conduct for Data Centres - Best practice guidelines OCP Immersion Requirements

Designated liquid maintenance areas ensure clean and safe (large scale) maintenance of liquid-cooled IT. A maintenance room for liquid is easily set up. Such a room is similar to common IT maintenance areas (ESD protected), but with a few fundamental differences like sufficient tooling for liquid management: Leak trays, consumables (cloths and gloves), ESD lab coats and a drain.

Image 7 ESD protected maintenance area

5.2 Liquid processes

There are specific safety protocols for liquid systems like spill management or fire safety. The overall safety is not affected negatively, but awareness of different ways of work is required. Awareness of potential disasters is usually within the basic mode of operation of any datacentre organisation.

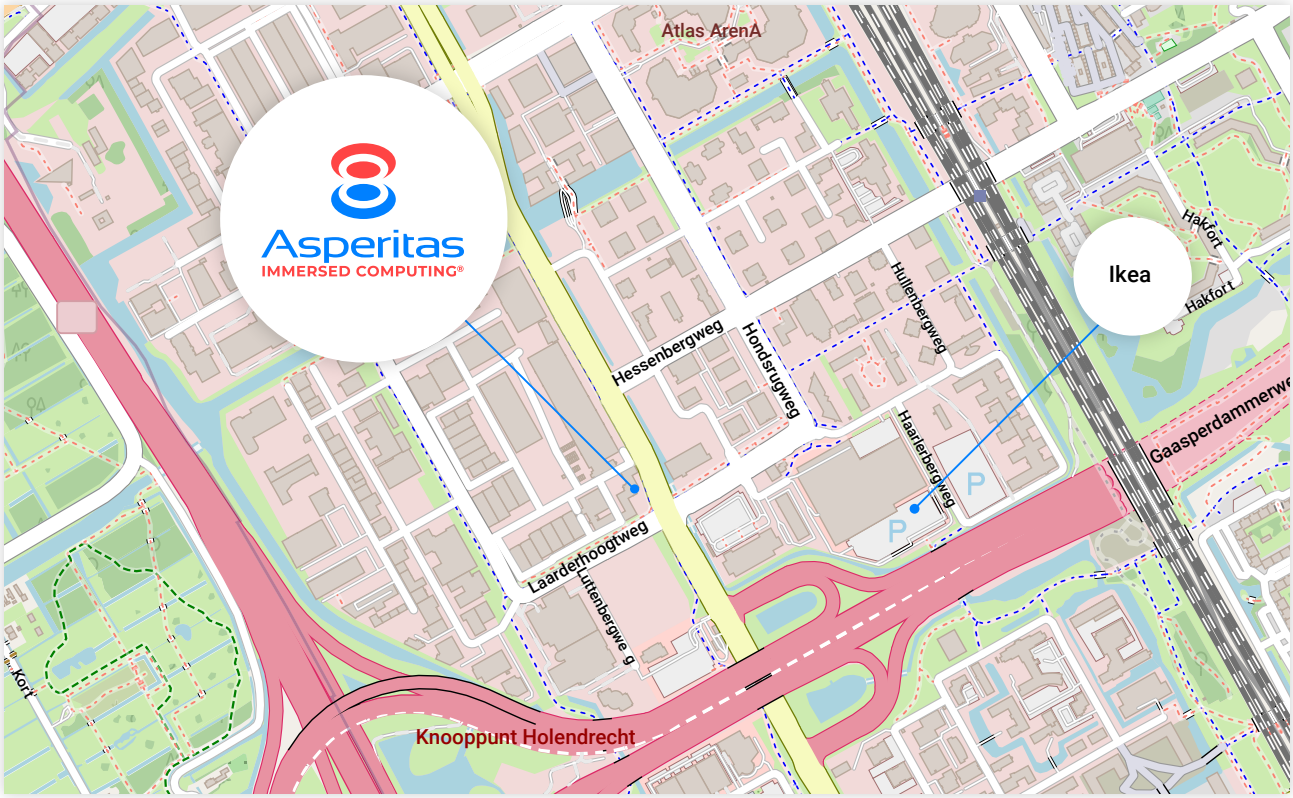
Documented procedures and inventory of dielectric liquids are part of the safety protocols. All dielectric liquids are chemicals, therefore each type of liquid comes with a Material Safety Data Sheet (MSDS) and a Technical Data Sheet (TDS). The MSDS contains all necessary safety related information like classification and recommended safety procedures including fire management. The TDS contains all technical data like ingredients viscosity, density, pour- and flashpoint. These documents should be available to anyone with unsupervised access to a facility where liquid is used and easily and quickly reachable for emergency services.

6. Asperitas company

Asperitas is a clean-tech company focused on greening the datacentre industry by introducing Immersed Computing®.

Since 2014 Asperitas has developed Immersed Computing® as a unique approach to the IT industry. Building on existing IT platforms technologies by integrating liquid immersion cooling, power and network components, improved cooling physics and a strong focus on design and engineering for usability, Asperitas has come up with multiple integrated IT platform solutions which can be effectively utilised in most, if not all situations.

The Asperitas development partners include Intel, SuperMicro, Boston, Shell, Schleifenbauer Aqualectra and Brink Industrial. Asperitas is leading the industry through OCP and ASHRAE. Asperitas is furthermore recognised and supported by the Netherlands Enterprise Agency as a Cleantech company.



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