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<h2>Publishable Final Activity Report</h2>	
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Project coordinator organization name:	HOLOGRAFIKA
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Summary of the project and objectives

Looking at the major trends in the display technologies and television (B/W, Colour, HD) it is evident that the next step is the 3D. Even though the numerous developments in display technologies recently, even though the lot of improvements in the image quality, resolution, colour, contrast, etc., the view still looks artificial. The difference is the missing third dimension. Viewers should see a 3D image on the screen, as they would see in reality. There was a boom in using and manipulating 3D data in IT systems; still the weakest chain in the information flow remained the displaying that has not yet been solved properly up to now. 3D displays should provide the same level of functionality and freedom that current 2D displays offer while exceeding their capabilities. Systems that cause any optical discomfort or restrain the viewer will not be broadly accepted on the long term. The proposed system was based on well-proved hologram geometry principles and represents a high-end approach in the 3D displaying. Not limited by roadblocks in the principle and with the continuous technology development it has the potential to reach even the hologram quality displaying. When hanging on the wall, future displays should look like a real window, undistinguishable, except the technology working behind.

While the transition from black&white to color represents a factor of 3x increase in the information content, true 3D displaying requires orders of magnitudes, at least 100x boost in the display capabilities and thus it will be the most significant move, almost a paradigm shift, in the display technologies and the related environment for the coming years.

The objective of HOLOVISION project was to develop a next generation holographic 3D display that overcomes the limitations of the current 3D displays, reconstructing natural 3D images to number of viewers in a reasonable field of view, with walk-around possibility without any restrictions or glasses. Moreover to answer today's expectations with regard of resolution, brightness, contrast, highest possible fidelity-fidelity, good depth resolution and size.

The project had an ambitious workplan with challenging technical deliverables, all-newly engineered components, systems, with a prototype to demonstrate the capabilities of this technology to be among the potential displaying solutions for the future 3DTV.



In line with the targeted objectives the world first **100 Mpixel 3D display** was developed in the frame of the project.

The display is based on a modular optical system and a hologram screen. The spatially distributed arrangement is enhanced with novel temporal multiplexing.

The idea was to build a no-compromise display that is based on the latest available technologies and components, like LCOS microdisplays with fast switching speed in single panel configuration, specific geometry high brightness LED-array illumination modules of six colours providing the highest possible colour-fidelity, a dedicated optical system, a redesigned 4:3 35" hologram screen. Due to the hologram geometry principles, where 2D is a special subset of 3D, the display is fully compatible with 2D displays, able to show 2D images without the necessity of any switchover. In 2D terms the image resolution is 1350x1024 and no change in the native resolution when 3D content is on the screen.

The display provides a *large field of view (FOV)*, where viewers do not have to be positioned. They will experience perfect 3D view with continuous horizontal motion parallax in the whole FOV from the proximity of the screen to far distances widening over 60 degrees. The field of view is a very characteristic parameter of 3D displays, because wider view requires more data and at many systems it is limited by optical reasons.

In general, the very basic law is, that for a true 3D image orders of magnitudes higher number of pixels are needed than used for 2D. This amount of pixels or pixel/sec rate should be provided by the 3D display, otherwise the image will be compromised. It is possible to generate 3D images by systems controlling large number of pixels simultaneously, theoretically it is also possible to reach this rate by higher speed devices, however we do not have the proper fast devices today.

In the HOLOVISION project a new principle was realized: the combination of the two approaches. The parallel, spatially distributed system, the known modular arrangement is combined with novel temporal feature, enabling to optimise the system to fully exploit the capability of components and technologies used. The use of high-speed digital imager, by using reconfigurable geometry at the illumination with specially designed optics and a control generating intermediate views accordingly, it is possible to introduce virtual positions in the optical modules, where light beams are emitted from, thus to go up with the angular resolution and *increase the field of depth (FOD)* of the display.

An important objective was the project the control system, especially the rendering hardware. High speed control electronics, backed by a render cluster with proper 3D

software solutions and GPU based rendering and compression algorithms provide the real-time dynamic feature allowing the integration the 3D display to variety of IT systems.

By these features it is possible to realise different operational modes at the HOLOVISION display. The display will be able to switch between a *high-depth mode* using less grey/colour scale steps, operating in a *super colour-fidelity mode*, or even in a *high-brightness fine grey-scale achromatic mode* limited only by the throughput of the available imager panels in the future.

Even with the limitations the display hardware is capable for more, to exploit various operational modes for different 3D image contents and a possible intelligent operational mode control for image quality enhancement offers possibilities that are even beyond the today available computing technologies, but definitely is among the most exiting challenges that can fuel further development projects and activities.

Further to the prototypes and components developed in the project, the results, experiences with the applied technologies are already in use and exploited in other EU projects. The development of the optical modules was an important step, serving as basic building blocks, that will be used in different category Holografika products.

The optical module is basically a high-resolution compact LED projector. It has the chance to be productized to be the first HD LED pocket/companion projector on the market, especially since the projection market is moving towards the pocket/companion/nano projector categories in the coming years.

The project work plan included continuous end-user involvement in the system definition, validation and demonstration activities. *Test material* was compiled to study *human factors* in the 3D displaying. As one of the potential applications, a *terrain visualisation prototype* was developed, which supports collaborative decision making for 3D environments. The appreciation and understanding of the terrain data was compared with alternative visualisation using conventional and stereoscopic displays.

Further to this, there are potential professional application areas that require high accuracy and resolution, like oil&gas exploration, where large chaotic 3D dataset are visualized in collaborative scenarios that need the resolution, high-end CAD applications, scientific visualization can benefit and several niche market segments, where extreme needs are for demanding displaying solutions.

3D displays cannot be considered anymore as just toys or novelties. The 3D data is widely used and there is an obvious need for 3D displays. The major obstacle of being accepted up to now is the fact that most of them were simply not good enough for real applications. The technology is here and the 3D is evidently the next step in the displaying. The project proved that it is possible to build 100Mpixel desktop displays and it will be a significant benchmark on the way towards future Gigapixel displays.



The HOLOVISION display with the Render Cluster

The project was led by Holografika, a Hungarian technology company active in the 3D display field, Videoton (HU) and Stockeyale (IR), as technology partners, were responsible for the LCOS driving and LED components respectively, while BAE Systems' (UK) and Insyte (UK) provided their expertise in evaluating the human factors at 3D displaying and the application development.

Participants' list

Participant role*	Participant no.	Participant name	Participant short name	Country	Date enter project	Date exit project
CO	1	HOLOGRAFI KA Kft.	HOL	H	M1	M42
CR	3	STOCKERYALE (IRL) LTD	STY	IRL	M1	M42
CR	4	BAE SYSTEMS (OPERATIONS) LIMITED	BAE	UK	M1	M42
CR	5	Insyte	INS	UK	M3	M42
CR	6	VIDEOTON	VID	H	M2	M42

*CO = Coordinator
CR = Contractor

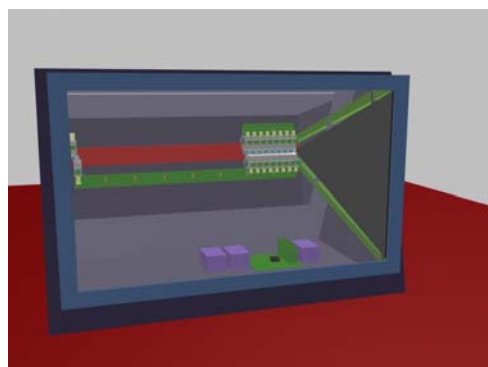
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Summary of the project activities and the achieved results

The HOLOVISION project started in November 2004. After having set up the project management structure, the Consortia commenced to perform the project plan.

The first half of the project year was the conceptual phase, the basic principles of the Holographic display were identified to meet the initial user requirements. Therefore, from the beginning emphasis was laid on end-user involvement. An extensive evaluation process was carried out on the state of the art, as well. The preliminary conceptual planning was already set off in parallel with the system specification to iteratively check any potential roadblocks for the later development stages. The actual development has begun from the second 6 month, parallel in each of the workpackages.



One of the major components of the Holographic 3D display is obviously the **optical system**. The optical design was phased according to the main tasks in the workplan. After having modelled the optical system the geometrical configuration of the desired key elements were defined. As of the next phase the development of the special imaging and illumination optics started. The optical design was performed with the help of optical designer CAD software. Being a very complex optical system, the modelling of the system, the design and the optimization of the optics, the thermal analysis of the lenses, etc., were very computation intensive tasks. The other key element in the optical system is the screen. Several screen samples were tested and measurements were carried out to find the most adequate one for the HOLOVISION display.

The other main development area of the HOLOVISION display was the special **illumination module**. As of the LED-based illuminator first an Alpha prototype was developed. Several LED chips were examined and tested to select the most effective chips that can fulfil the desired optical requirements of those available on the market. The LED substrate prototyping and the design of the necessary driver electronics has also started already from the beginning in accordance with the conceptual plan.



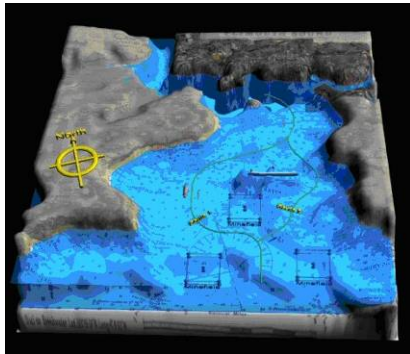
After the basis of the system architecture was specified a comprehensive survey was performed to identify proper **microdisplay** component. As for leading-edge solutions, it was a critical task to find the suitable panel that fulfilled all the targeted resolution, speed etc. parameters. There were not too many options for such demanding requirements, some of the options were just paper designs, some with excellent technical features were only in the prototype phase, thus several suppliers were contacted until the final imager could be selected, causing delay in the flow of the project.



After having the decision the **microdisplay driver module** development has started. An FPGA based LCOS evaluation board has been designed and manufactured that enabled to carry out initial display tests and measurements. In the HOLOVISION display a large number of pixels, in the range of **100 million**, have to be managed, which means a massive bandwidth requirement that has to be fuelled. For practical reasons the DVI channel were selected as a base that provides a relatively broad bandwidth for data transfers.

The preliminary **mechanical design** was started on the basis of the optical layouts and dimensions. Mechanical CAD software was used to model the system and also to optimise

the final physical measures of the display. This required a continuous co-operation with optical design, since the optical arrangements, tolerances determine the mechanical layout and size.



Apart from the actual display development the development of a **visual application** started in this period, as well. A first prototype of the terrain visualising application has been prepared, which is based on OpenGL and was conceived to provide a fully configurable solution. The application is controllable not only via the standard computer peripherals as keyboard or mouse, but also with special game-pad devices to provide the user maximum freedom in terms of handling and controlling the application.

Further to the technical developments strong emphasis was laid on **preliminary validation and dissemination** activities. Continuous end-user involvement was required to ensure iterative development process. Partners of the consortium attended several exhibitions and conferences and organized workshops to present the planned technology of the HOLOVISION display. A questionnaire has been designed and administered by BAE Systems to potential users at different internal workshops to gather user feedbacks and requirements for existing 3D displays in general and specifically for the future HOLOVISION technology. Beyond that the planned technology was also presented at different international exhibitions such as *European Research and Innovation Exhibition 2005* in Paris and *C+D 2005 - International Defence Forum*, Budapest. To further disseminate the first achievements and results of the HOLOVISION project the Consortium has set up a public website that provides also general information on the project.

The development and implementation continued in the 2nd year providing some practical results. Beside the development work the technology was disseminated to potential end-users and technology adaptors. Their feedbacks were gathered and forwarded to the developers to ensure an iterative process.

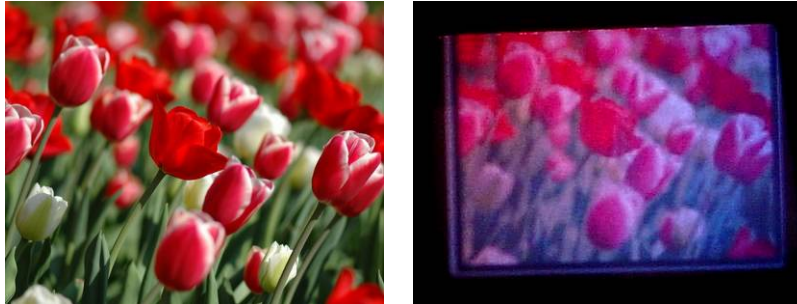
The **optical system** was one of the most challenging development tasks in the project. After facing a number of difficulties the design of the optics has reached the final phase and was ready for manufacturing to clear technology steps, tolerances, constraints with manufacturers that might require modifications that could even make questionable the realization of that solution. Being a complex design task, a number of different approaches and solutions were considered during the development.

The development of the **LED illumination module** continued with the BETA prototype design and process of manufacture. The BETA design included specific upgrades to the Alpha following a very productive evaluation process. The modifications included LED chip performance upgrade, in line with LED developments in the marketplace, some developments to the substrate geometry, primary optical element design and manufacture and electronics driver developments.

Continuing the trend, this development stage was evaluated prior to the design and release of the Final illumination module.

The electronic design of the optical units has progressed too. The LCOS microdisplay components have been purchased; a new **microdisplay driver board** have been developed, manufactured, assembled and tested. Holografika, Videoton and StockerYale, working closely together, carried out successful integration tests. The positive test results showed that the completed prototype LCOS driver board is working well together with the

Alpha prototype LED illumination module, no major changes are required for the final design, only minor upgrades. The photos here are showing the very first test images, both the original and the one captured from the microdisplay.



A strong co-operation was required between the optical, electrical and mechanical design staff, since the optical, electronic circuit requirements determined the mechanical constraints for every component and vice versa. The **mechanical design** should follow the outcome of the optical and electronics design process, the electrical and optical components of the optical modules were modeled into mechanical CAD software. Having modeled the optical units, the design of the full mechanical system of the HOLOVISION display has started. On the other hand mechanical constrains, physical dimensions of components limited the principal integration of optical modules, thus various mechanical designs were set up, to find ways of with the least compromises to minimize visible artifacts.

Along with the actual display development, an **OpenGL based visual application** has been developed. The application allowed user configurable 3D test patterns and menus as well as terrain to be visualised, it offers control for drive and flythrough navigation along with test pattern, and menu display interactions.



As such, it provides a configurable testbed for holographic displays by providing

a) Real-Time out of the window scenes (based on an airport database complete with interior hanger components for “close in visualisation”)

b) Dedicated test pattern support and on-line control

c) On line control for visualisation parameters such as lighting effects, clip planes.

d) On screen user interaction and information displays via a 3D menuing system.



The application developed by Insysy has been passed to Holografika and has undergone successful initial integration.

In parallel with the technical development process, **validation and preliminary dissemination** tasks were continuously carried out.

Holografika has submitted a publication of the concept on the Electronic Imaging 2006, attended a number of conferences of which the most important were the following: the SID-MEC 3D symposium in March 2006, Eurographics 2006, ViZSIG conference and LTN - London Technology Network together with BAE Systems.

During 2008 BAE Systems attended the UK Displays and lighting conference in Leicester, UK. As well as describing the status of HOLOVISION to members of other EU FP6&7 projects (e.g. MUTED) an opportunity was taken to report the state of 3D and supporting technologies back to the HOLOVISION partners. Copies of papers obtained at the event have been distributed. BAE Systems has made a provisional agreement with South West region of the UK Ergonomics Society to present the findings from the HOLOVISION project in September 2008. Since this is beyond the end-date of the project, BAE Systems will fund this.

During this period, BAE Systems has continued to provide demonstrations of the technology on an earlier generation 26" 3D display from Holografika. A further 9 demonstrations were given to a total 58 people. Particularly significant was the UK government advisor Prof Damian McDonnell an LCD expert who was very complimentary of the display, HMI specialist from Jaguar cars, and representatives of Digital Arts a Californian spin-off company from Multi-Gen Paradigm who specializes in interaction devices for 3D displays. The latter were also very complimentary of the images produced on the Holovizio display.

In the third project year, after facing a number of difficulties, the design of the **optics** has been completed. As the result of the tolerancing process we arrived to a system that was ready to be manufactured. We were in an extensive search for manufacturers for both glass and plastic components followed by price negotiations.

The Beta **LED illumination module** design was developed into a product through this stage of the project. Through careful consideration to the design review of the Alpha prototypes and results from testing the Beta prototype was formed to fit electrically, mechanically and optically to the system.

Some of the challenges were to fit the necessary drive electronics in a narrow mechanical envelope in the Illumination module, which was achieved in close collaboration between STY and HOL and also to increase the efficiency of the LED illumination board. This was also achieved in close collaboration of HOL and STY and through an investigation of current market trend in LED device technology and the addition of the primary optics.

The **microdisplay driver board** was finalized, manufactured, assembled and tested.

Various **holographic screen** samples with different characteristics have been mastered and tested. The results of these tests led to the definition of the final screen. The holographic screen has been chosen so that it provides homogeneous vertical scattering over the screen and helps hiding minor gaps between the optical modules. The cover glass has been chosen to increase contrast and protect from disturbing specular reflection.

During the year an interim review was scheduled. Having the subsystems, components completed, the first optical modules, which are basically the basic building blocks of the system, were assembled and the operation demonstrated. Beside the special optically optimized and unique control features, necessary for the 3D image generation, the modules are capable for autonomous operation, as well. These optical modules are size wise the smallest and can be considered in their category the first SXGA/HD ready, compact 6 color LED based pocket projectors.



On the left: the final LCOS and LED based optical module, the world's smallest SXGA 6 color pocket projector.

The problems identified during the assembly of prototype **optical modules** have been all solved. The injection molded lenses planned for the final modules had extremely high manufacturing costs at the volumes needed, so that the optical system had to be redesigned with spherical glass lenses. Although the redesigned optical system uses more elements, the total price of the optical system was much lower this way. The added benefit of using glass lenses is that they are much less sensitive to heat changes, however some more distortions arisen, we normally compensate. The redesigned optical system became shorter and narrower, which enabled the creation of even shorter projectors. Optimization of the illumination system also resulted in 50% increase in brightness and enabled to decrease the number of LED chips, resulting in less heat production and in lowering system costs.

Based on experiences of the projector prototype, the **illumination system**, both LED array and driver circuit have been redesigned. The LED driver was separated to two boards to reduce size and to separate low and high current circuitry, eliminating noise.

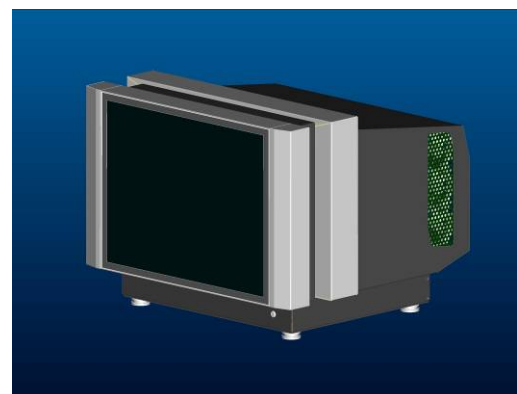
Optimization of the optical system allowed for size reduction, which also affected the LCOS and LED driver boards. Thermal connection between LED array and related mechanical components has been increased. Improved cooling and increased maximum LED current provided by the LED driver resulted in a brightness that exceeded original expectations and the extreme fast pulse response significantly improved the image quality by better bit-plane separation. Both the width and height of the projector modules have been decreased to the minimum. The 6 color LED panel has been chosen for the final optical modules, implementing 4 operation modes: Normal, Hi-Depth, Hi-Color and Hi-Bright.

The prototype modules have been optimized for cost-effective manufacturing and accommodation to the final mechanical design. To compensate for the significant delays accumulated by subcontractors and component distributors, the original testing procedure to the projectors was organized to allow for distributed work of smaller teams.

Final optical and mechanical parts were assembled in dust free lab, then LCOS microdisplays, LED arrays were carefully adjusted to their optimal position. The experiences from the assembly of the modules can already be used in small series production, including the changing quality of components from certain suppliers.

For the integration of the modules the **frame of the display** has been manufactured. To keep schedule some risks were involved, since certain manufacturing steps had to be done parallel without having the other final parts completed or fully measured / tested.

After all the components have been completed, the assembly of the final HOLOVISION display has been started. Power supplies, main controller and all projectors have been built into the frame. After that, mirrors and other screen components have been glued and painted.



The latest hardware components have been tested as potential building blocks for the **rendering cluster**. After choosing and integrating the latest mainboards and slim GPUs, the rendering cluster could be made very compact, of only 9 rendering nodes instead of the planned 18.

The racks consist of two 20U sized commercial rack mounts, and custom designed PC cases that allow for better air ventilation than typical cases. The rack mounts have been slightly modified in terms of carrying capacity, cabling cuts and increased airflow.

The Main Controller board has been developed, controlling power of the projection modules, bridging communications between PC and projectors, provides emergency shutdown and simple On/Off functionality. Through this connection, various settings of the projectors can be manipulated, like LED control, DVI configuration and temperature.

The Vegetative Controller Software has been implemented, which allows various controlling, maintenance, calibration, status retrieval, as well as mode changing features via a simple API that hides the low-level serial communication from the user.

The cluster operating system has been upgraded to a Fedora Core 8 Linux-based system, which allows for easy integration of new hardware devices thank to updated kernel and software modules.

The OpenGL wrapper followed the change to handle 8 projectors per node. A new version featuring multithreaded execution has been developed, allowing simultaneous usage of GPU and network, improving rendering speed significantly.

A new file format for storing calibration data has been specified, which overcomes the limitations of the old file format, resulting in better image quality, especially on the sides of the image.

Apart from this, several benchmarks have been commenced to identify the bottlenecks of the current implementation, and also to know how the number of nodes / screen size / etc affects rendering speed, so that we can predict the rendering speed of future clusters.

Along with the actual display development, the **OpenGL based visual application** has been continuously developed. In the last period Insyte have developed the application further by adding 3 new test patterns (hedgehog, plus two stereogram images to test alignment and depth perception, changing the colour of menu items to make them more visible and adjusting the position of menu items to the center of the screens.

The widespread dissemination activities targeted multiple market segments e.g. oil/gas exploration, automotive design in order to gain user feedback and study potential applicability/exploitation of the technology developed in the project.

A further 11 **demonstrations** given to predominantly external to BAES organisations to a total of 73 people.

A poster was presented at the London Technology Network event to >100 experts in a meeting on 3D displays.

Further development of 3D test material has taken place and these have been produced as 3D test models within Insyte's application.

Holografika joined 3DHome Consortium established by Insight Media as founding member.

The development work faced extreme challenges in the final phase, the project deadlines at the end became very tight, but the Consortia could complete the project tasks and deliverables. It developed a remarkable 3D display that might be a benchmark for future display technology development and will provoke several applications along with further R&D activities.

Publishable results

Other than the actual display that could be sold on the market HOLOVISION has reached to generate distinct exploitable knowledge. The knowledge elements are summarized in below table.

<i>Exploitable knowledge</i>	<i>Exploitable product(s) or measure(s)</i>	<i>Sector(s) of application</i>	<i>Timetable for commercial use</i>	<i>Patents or other IPR protection</i>	<i>Owner & other Partner(s) involved</i>
1., Enhanced HoloVizio™ technology	Multi-operation-mode holographic 3D display	- Medical - Automotive design - Scientific visualization	2009	Patents for the basic principle are already existing or pending	HOL
2., HoloVizio platform based on unified building blocks	Different category HoloVizio displays	Many	2008	-	HOL
3., New technology for increasing angular resolution thanks to enhanced projection technology	Multi-operation-mode holographic 3D display working in high-depth mode	-Terrain modeling -Scientific visualization	2009	-	HOL
4., New technology for increasing colour reproduction thanks to 6 colour based illumination	Multi-operation-mode holographic 3D display working in high-colour mode	-Automotive design -Scientific visualization	2009	-	HOL
5., High resolution LED illuminated pocket-projection unit	High resolution projector to be used as a component	Projector manufacturers	2009	-	HOL
6., Compact high graphical power rendering hardware	Creative application of leading technology latest PC mainboards and graphics boards.	3D rendering market	2008	-	HOL
7., Enhanced Distributed OpenGL rendering library based on multithread operation	Techniques for driving large scale high pixel number displays	Large scale / high speed visualization	Used for further research / exploitable from 2008	-	HOL
8., LightField rendering SDK	Techniques for the creation of	High-quality still image /	Used for further		HOL

	3D lightfield data based on various source formats / layouts.	video creation for 3D displays.	research / exploitable from 2008		
11., End user response to true 3D image	Human behaviour and workflow improvement possibilities while working with natural 3D imagery	CAD Design Homeland security Scientific visualisation	2008	-	BAE
12., End user response to true 3D animation	Understanding the improvement possibilities while working with natural 3D animations	CAD Design Homeland security Scientific visualisation	2008	-	BAE
13., Assessment of HOLOVISION display for training applications	Enhanced training communication methods through the usage of 3D applications	Military and other training	2008	-	Insyte