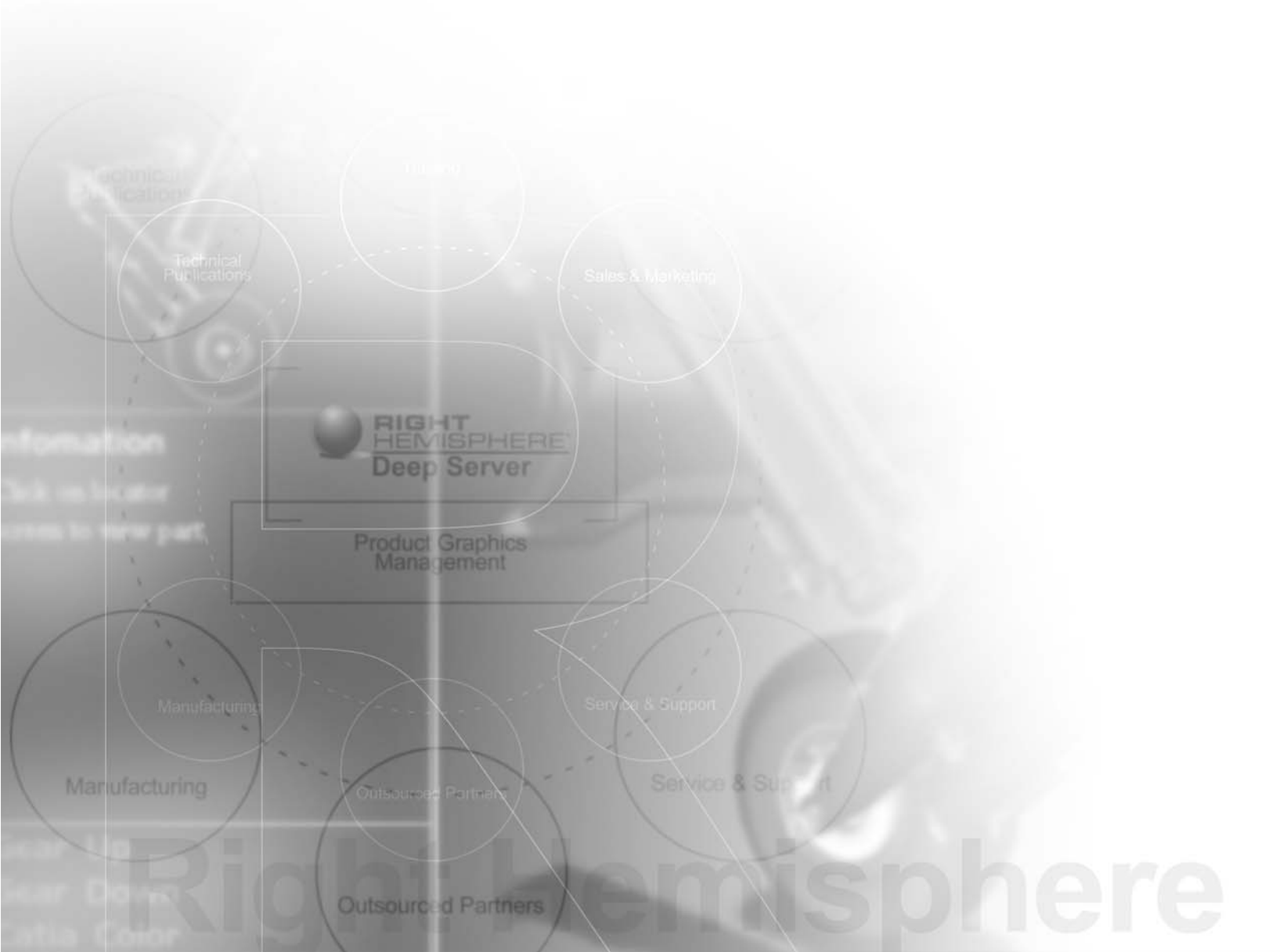
Right Hemisphere
Product Graphics Management for Interactive 3D Training White Paper



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Summary

Recent studies have shown that students remember up to 90% of what they do versus only 10% of what they read. Interactive 2D and 3D training content simulates doing. And interactive training in the form of interactive electronic technical manuals (IETMs), computer based training (CBTs), instructor led training (ILTs), simulations, and virtual reality is a lower cost alternative to actual product mockups, physical simulations, and other non-electronic "learning by doing" approaches.

For these reasons, interactive training has become mission critical in aerospace, defense, automotive, and other industries. But achieving this level of reality for complex products and systems, across a varied landscape of CAD, publishing and learning applications, using a variety of subject matter experts and courseware authors, in accordance with diverse educational methods is a significant challenge.

This paper describes these challenges and new interactive training approaches such as IETMs, CBTs, SCORM, and more. This paper introduces Product Graphics Management as a key enabler for 3D interactive training with focus on integrating, automating, and managing 3D learning content objects. Further, this paper describes how Right Hemisphere's Product Graphics Management software has been applied to the JSF program. Finally, this paper identifies future developments in interactive 3D along with potential benefits.

" Because we had to build our training courses as the Comanche helicopter was being built, we needed immediate access to the 3D files as they were being created by engineers - or we would have to rebuild each drawing ourselves in another application.

With the courseware expertise of Aera, the software technology of Right Hemisphere and our own infrastructure, we're now able to produce 3D images in minutes, instead of the weeks it would have taken to recreate each image."

Paul Robinson,
Maintenance IMI Project Manager of the Boeing - Sikorsky Comanche First Team.

The Business Challenge: Augment Training Effectiveness and Efficiencies for Increasingly Complex Systems

When the US Government originally commissioned the next generation attack helicopter, the Comanche, for the US Army, defense contractors Boeing and Sikorsky were faced with a new challenge - namely, that of building the necessary maintenance training courseware concurrently with the design and construction of the helicopter. Suddenly, the old model of waiting for the first physical prototype of the helicopter to be built before beginning to create the corresponding courseware was thrown out the window.

The Boeing and Sikorsky team in conjunction with their courseware developer, Aera Corporation, needed to find a new solution to cope with the pace of change that would occur during the design cycles of the project. The traditional content creation process and associated workflows for creating a training asset in the form of a 2D illustration or 3D model would not work. Accommodating design changes in the time available using traditional workflows would have been both cost-prohibitive and extremely time-consumptive. The Comanche training team discovered that the only way for them to maintain development pace with design creation was to directly access the engineering data itself.

In searching for a solution, the Comanche training team discovered a new paradigm, pioneered by Right Hemisphere, a software company based in California, for computer-aided design (CAD) data reuse that would not only enable access to the design data itself, but also provide a complete, cost-effective workflow for conversion and repurposing of that data into a variety of learning objects including 2D illustrations, 3D graphical models, and 3D interactive scenes. Because these learning objects could then be rapidly integrated into courseware, the Comanche team could collapse traditional content creation workflows into an efficient production pipeline, automate the content production process, and largely eliminate a number of manual authoring of 2D and 3D learning objects.

With the ability to create training content prior to completion of construction of the aircraft, a paradigm shift occurred in the field of military and aerospace operational and maintenance training. This seismic shift is being powered by new enterprise software known as Product Graphics Management (PGM). Product Graphics Management software dramatically accelerate time to market, increases revenue via more compelling interactive training courseware, and reduces interactive training costs by:

- Streamlining publishing of interactive training courseware including IETMs, CBTs, simulations and virtual reality
- Creating more effective, differentiated interactive training
- Leveraging existing CAD and training investments

With the cost of creating 3D content lowered from hundreds of dollars per part to a few pennies, the Comanche team was able to dramatically increase the amount of interactive 3D content in their courseware. The original Comanche project specification called for 18% of the courseware to use 3D content. Using Right Hemisphere's Product Graphics Management software, the project team successfully increased this to over 80% for the same budget. The training developers knew instinctively, as they were given free reign for the first time to build truly media-rich interactive courseware, that it would result in more compelling and effective training for helicopter maintenance procedures and that training content development would never be the same again.

While the Comanche project was eventually cancelled by the US Army in the early part of 2004, this training content production and publishing revolution has continued. Sikorksy recently made the strategic decision to shift the Right Hemisphere PGM software to its next major helicopter training contract - the BlackHawk, and leverage the benefits they experienced in the Comanche project for their new training development.

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By unlocking CAD data for 3D visualization and simulation training solutions, Product Graphics Management platforms promise to streamline the production of interactive courseware and deliver more flexibility to course designers, instructors and students. For manufacturers, operators and training providers, these emergent publishing platforms have major implications for the future of training content provision and how, in the near future, the industries' maintenance teams and individual technicians will learn and work. Further, they offer a means to clearly demonstrate that cutting training costs while raising training quality need not be mutually exclusive.

"Assuming a fleet of 50 aircraft with utilization of 8.3 hours per day, component turn time of 30 days, and protection level based upon criticality, we calculated our rotable inventory requirements based on our removal rate experience. Using these nominal values, the required inventory is approximately $42 million. A 1% improvement in removal rate decreases the capital outlay by $300,000. Does that pay for some training?"

Guy Borowsky,
Vice President of Maintenance for AirTran Airways

From IETMs to Virtual Reality Training Systems and Beyond

Interactive media is quickly emerging as a critical component of modern military and aerospace systems training practice. To best understand the needs of modern graphical content creation workflows and publishing solutions, we first need to quickly review the breadth of applications that today's training teams use and create.

IETMs - Interactive Electronic Technical Manuals

In 1996 the Commanding Officer of the USS ANZIO described IETMs as an "information multiplier", with which, 'junior personnel can perform complex technical tasks with nearly the same effectiveness as senior technicians'. IETMs were originally introduced to replace the paper documentation mountain which covered; theory of operation, detailed circuit analysis, fault isolation procedures, remove and replace procedures, illustrated parts lists, corrective maintenance, preventive maintenance, test procedures, removal and replacement instructions, tables, figures, and more.

Today, typically based on standard World Wide Web related technologies, IETMs offer: word/phrase search capabilities, internal cross-reference links, hyperlinks to external related source information and the use of 2D isometric graphics hyperlinked to related documents and diagrams. Search time and human performance in operations is generally estimated to improve by at least 20% when IETMs have been used to support maintenance teams.

The combined role of reference documentation source and decision support aid has resulted in IETMs becoming a central component of systems maintenance and operations training practice. IETMs are increasingly being co-adopted for use in training and current practices include:

- The instructor uses the IETM as a source to make Computer Based Training or to structure syllabi
- The instructor uses material from or references the IETM during instructor led lessons
- The trainee uses the IETM for self-study, during practice assignments and by using the IETM on-the-job

Interactive electronic technical manuals are quickly evolving into interactive electronic training manuals. This evolutionary transition means that next generation IETMs will provide a common tool to access operational and maintenance training courseware, in addition to maintenance and operational procedure information, throughout a product's lifecycle. While the vast majority of IETMs today use static 2D graphical representations for illustrating parts and removal and replaces procedures, there is a steady and certain move in adopting interactive 3D displays. One interactive 3D view, that can be rotated, panned and zoomed, can replace as many as 20 isometric drawings. Moreover, 3D displays have been shown to be more effective in communicating essential structural and spatial information than 2D line art.

From 2D to 3D Representations

During the Joint Strike Fighter F-35 Concept Development Phase, Boeing's investigations indicated that trainees tested three months after learning a given task - were significantly more effective at that maintenance task if they refreshed their skills using interactive 3D models rather than, if they used more traditional isometric line art illustrations. Such studies combined with the declining costs and increasing performance of 3D enabled personal computers are leading to a growth in the use of interactive 3D media in training and support applications. Figure 1 below, shows the experience retention between 2D and 3D media.

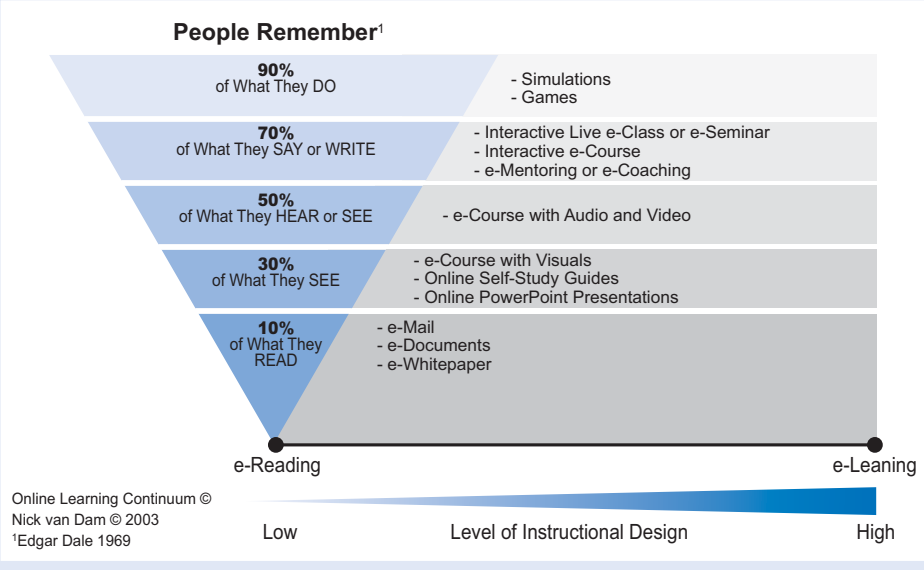

Figure 1. Online Learning Continuum illustrating efficacy of simulation for learning

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Interactive 3D learning objects, when grounded in ergonomic interface design processes, provide trainers with a means to ensure:

- Effective communication and comprehension of complex systems or processes
- Effective skills transference between teaching materials and actual systems

Maintenance training in modern military and aerospace industries increasingly focuses on learning procedures that combine effective diagnostic skills with remove and replace skills. Such maintenance relies on the technician having a clear understanding of how a system functions and rapid access to materials in the form of IETMs which let them refresh their mental model of a given task. A mental model is the term used by cognitive scientists to describe how we internalise a concept or a process, in essence, how we think something works. Ineffective training or unclear training materials can produce inappropriate mental models - leaving trainees with either misunderstandings or a lack of clarity of how a system functions. Studies such as Boeing's Joint Strike Fighter (JSF) evaluations have shown that interactive 3D learning objects can help trainees build the best appropriate mental model for a given task.

Learning based only on 2D graphical representations for many maintenance and operational tasks requires the trainee to make a mental abstraction of the task processes involved. Such abstractions can lead to confusion, misinterpretation or a reduction in the ability to readily transfer skills learnt during training into real world situations. For operators and trainers, this can lead to higher unit replacements and longer maintenance times in the field or longer training times for instructors and trainees. Interactive 3D training has been demonstrated to deliver faster student learning by enabling trainees to create accurate mental models of complex systems and components.

Features, Benefits and Results of using Interactive 3D for Training

Key Features	Benefits	Results
Realistic & visually intuitive representations	Rapidly build accurate transferable mental models	Faster, more effective student learning and improved operational efficiency
Available on demand (unlike physical trainers)	Flexible learning	A greater number of students can easily access training information on their schedules and when they need it
Highly interactive	Learn by doing and simulation	Delivers greater exposure to maintenance, support and operation situations
Modular 3D content design	Reuse 3D content across training programs	Use same content in training centres and in modular components for use in on - site and just in time based learning

Table 1. Summary of features, benefits and results of employing interactive 3D media presentations in training material.

The experience of US army training teams, who regularly employ 3D simulation-based learning, indicates that interactive 3D learning materials can be a highly cost-effective component of training courses. Specifically, the US army teams have found that:

- Interactive 3D training systems decrease the requirement for physical, hands-on mock-ups and actual tactical vehicles for institutional training
- They enable scheduled training tasks to go ahead when tactical vehicles are not available
- When integrated with learning management software, interactive 3D learning content enables instructors to effectively train classes with a higher student to instructor ratio while still providing safe, self-paced learning environments
- Simulated 3D training environments empower instructors to use training scenarios, which often cannot be replicated on mock-ups or tactical vehicles due to safety and expense issues

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Two examples of successful 3D training developments and their benefits		
Example	**Description**	**Success**
Tornado Maintenance School, RAF Markham, UK	Replacement of physical training mock-up of Tornado fighter aircraft - with interactive 3D desktop Computer Based Training (CBT) application	- Cost 1.5 million as opposed to 14 million for a physical trainer - A 40 percent improvement in the uptake of training issues - Course duration reduced from 14 weeks to 9 weeks - Students exposed to 25 times more avionics maintenance training experiences
363rd Training Squadron's Aircraft Armament Apprentice School at Sheppard Air Force Base, USA	Insufficient funds to purchase a complete F15-E for training led to development of an interactive 3D virtual reality immersive training application	- $425,000 as opposed to several million dollars for a real F15-E - 40 hour 'weapons safe for inspection' training course - required to ensure weapon systems are disarmed before maintenance, reduced to 4 hours - Greater number of students now safely managed by one trainer

Table 2. Two examples of successful 3D training programs.

In the past, design assets were not necessarily in a suitable form to easily convert to 3D content and the recreation of CAD assets required highly intensive manual methods; displaying high quality interactive 3D applications required the use of specialist graphics cards or computers and custom complex 3D graphics application code.

Thanks to the global computer games industry, modern standard PC's using technologies from NVIDIA, Intel and ATI now deliver 3D graphics capabilities that outstrip the specialist supercomputers used only a few years ago. Standard business application platforms such as MS Office™ , Web browsers and document standarts such as Adobe PDF provide a means for embedding and widely distributing 3D content using tools such as Right Hemisphere's Deep Publish.

Removing barriers to 3D adoption	
Content Exists - Workstation Design	**80% of CAD now in 3D**
Hardware Platform - CPUs/GPUs	**NVIDIA, Intel, ATI**
Application Platform - MS Office - Browser - XML Standarts - PDF	**Microsoft, Adobe & Others**
3D Authoring Tools	**Deep Creator, Virtools, Viewpoint, Anark, Eon Reality & Others**

Table 3. Enabling technologies are removing barriers to 3D adoption.

A new generation of 3D application authoring tools such as Deep Creator, Viewpoint, Virtools, Anark and EON reality have emerged and replaced the need to write bespoke code in C+ with almost point and click level interactive 3D authiring tools. Tomorrow's technicians are growing up using interactive 3D for entertainment in the form of X-BOX™ and PlayStation™ and are deeply familiar with interactive 3D based media. All these factors combine to remove the barriers to widespread adoption of 3D based training materials.

Now the only remaining barrier is the cost and time involved in producing 3D content.

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Computer Based 3D Training

Practical hands-on training at training center maintenance simulators are only one aspect of maintenance and operational training provision in the military and aerospace markets. As economic pressure drives operators to seek lower costs, modular on-site training becomes increasingly attractive.

Operators, military or civilian, increasingly need their in-field technicians to learn, upgrade and refresh very specific skill sets while still in their work environment. While it is economically unfeasible to ship physical mock-up systems between facilities, virtual 3D task trainers can be delivered directly into standard PC's as part of everyday training.

This enables the benefits of using interactive 3D training to be readily transferable to modular learning content delivered on-site for work-related training.

"The major disadvantage of all present training methods is the fact that the trainer and trainee need to be physically at the same location for the entire duration of the training. Also, on-job training requires accessibility to the relevant aircraft type to complete the training objectives... A synthetic device that allows people to gain some hands-on practice at their own location could not only shorten training demands on real aircraft, but substantially cut training accommodation costs."

Des Gaynor,
FLS Aerospace

Learning Management Systems and SCORM

A Learning Management System (LMS) is typically a Web server-based software application system that enables organizations to track a student's access to and progress with Web-based training content.

A Learning Content Management System (LCMS) enables trainers to manage the learning content that gets delivered through a LMS. There is increasing market convergence between Learning Management Systems and Learning Content Management Systems and some of the most common features are summarized in Table 4 below:

Common Features of Learning Content Management Systems	
Administrative functions	Management of course creation and subscription Learner registration Course / module assignment Course sequencing Performance reporting for individuals and groups (e.g. results of tests, modules, time spent with study material and module completion status).
Learning Management	SCORM Runtime API User Performance Records Trainee/Learner Task/Unit performance tracking.
Course Content Import/ Export	An LCMS is a framework for delivering training content. Normally, course content is imported in the form of learning modules, courses or individual learning objects from specialist suppliers or training teams.
Student Presentation Interface	A personalized user interface generated for end users based on their subscribed courses, related events, stated learning objectives and user preferences.

Table 4. Common Features of Learning Content Management Systems

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Because of the need to move a course from one Web-based Learning Management System (LMS / CMS / LCMS) to another, run or reuse course content across different systems (multiple proprietary vendor tools) and create searchable learning content or media repositories across different environments, the Sharable Content Object Reference Model (SCORM™) was created by the U.S. Department of Defense ADL (Advanced Distributed Learning) Initiative.

The SCORM standard defines a Web-based learning "Content Aggregation Model" and "Run-time Environment" for learning objects. At its simplest, it is a model that references a set of interrelated technical specifications and guidelines designed to meet the DOD's high-level requirements for Web-based learning content. The SCORM runtime environment Application Programming Interface ("API") provides a standardized means for task training modules delivered over the Web to track trainee performance and record this in the LMS's database system. SCORM™ and Learning Management Systems enable organizations to reduce staff time away from stations while maintaining effectiveness through managed, on-site learning.

"18 advanced technical training courses covering a wide range of specialties, to include accounting, air traffic control, aircraft maintenance, medical and security forces, were converted for online delivery. 7,800 students have enrolled in the last 12 months, reducing days away from station by 101,400."

Dr. Paul W. Mayberry, Deputy Undersecretary of Defence for Readiness

The Challenge Facing Training Content Teams

As we have seen - modern military and aerospace training markets use a diverse number of interactive media platforms to deliver training related content - from IETMs through 3D enabled desktop Computer Based Training, Virtual Reality systems and Web-based training courses. The challenge facing training teams is how to generate training content for these diverse platforms while retaining synchronization of data and ensuring the exact same representations are used throughout all their training platforms. Further complicating this is the need to reduce time to market, create training material in parallel with engineering and design and technical documentation, and support new developments such as on-demand course creation. Like the Comanche team - many training providers are reviewing their current content creation workflows and finding them incapable of economically scaling to meet these increasing new requirements.

A traditional workflow for creating technical illustrations such as a parts diagram used in IETMs and training documentation, involves the export of 2D raster or vector images from the CAD package.

These images are generated using a hidden line removal (HLR) rendering option within a CAD system. The files are then manually edited in a specialist editor such as IsoDraw or Corel Designer™, to remove the many extraneous lines that are not required, and possibly, to add some clarity and exactness. Once the illustration is complete, additional data may be manually imported from other sources and interlinked with hotspots, hyperlinks, animation and more. Some illustration products such as ITEDO's IsoProcess™ can import CAD data directly and thus simplify the first two stages of development and remove the need for a CAD seat to create the image. However, every technical illustration used in an IETM or training content must be created in this manner, and such manual editing is extremely time and resource intensive.

3D CAD data carries information for manufacturing, testing and mechanical simulation. Much of this is not needed for real-time 3D training simulations. When media producers do not have the necessary tools or experience to extract and repurpose CAD data for their needs, they will often resort to modelling "replicas" in applications such as 3ds Max™ or Maya™.

When creating 'replicas' there is always a danger that an important element maybe overlooked and that no clear audit trail is available to show how the created 'replica' 3D model is related to the original design. Further, when the design changes - the replica representation will need to be recreated again.

Even when CAD data can be converted, there are often additional actions which the simulation team needs to do, such as perform polygon reduction to make the model suitable for real-time viewing, manage all files for a given project, apply additional material properties, author interactivity and more. Often, each of these actions requires a separate tool, an import and output between different graphical formats and diverse software packages and additional manual processes.

As with 2D technical illustrations, using traditional production workflows, every model used in training content must be created in this manner and as a result the process is highly time and resource intensive. When faced with resource intensive processes and workflows and increasing requirements for electronic documents, 3D interactive simulations, Web-delivered content and more, many training teams come to the same conclusions that the Comanche team did - that their traditional workflow processes are incapable of scaling to meet these new requirements and that a cost-effective, streamlined alternative is required.

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An Overview of Product Graphics Management

Product Graphics Management (PGM) is a new category of enterprise software that integrates, automates, and manages product graphics across the extended enterprise. PGM integrates product graphics across CAD/PDM and Publishing applications. PGM leverages CAD models as a source for lightweight graphical models and derivative graphics. PGM then integrates these graphics into Enterprise Content Management (ECM), Digital Content Creation (DCC), and Dynamic Enterprise Publishing (DEP) applications for multi-channel publishing to customers, employees, distributors, and suppliers.

PGM automates 2D and 3D graphics publishing processes using scalable graphics technology and best practice solutions to automate manual activities, integrate already automated ones, and provide better visibility and control at every step.

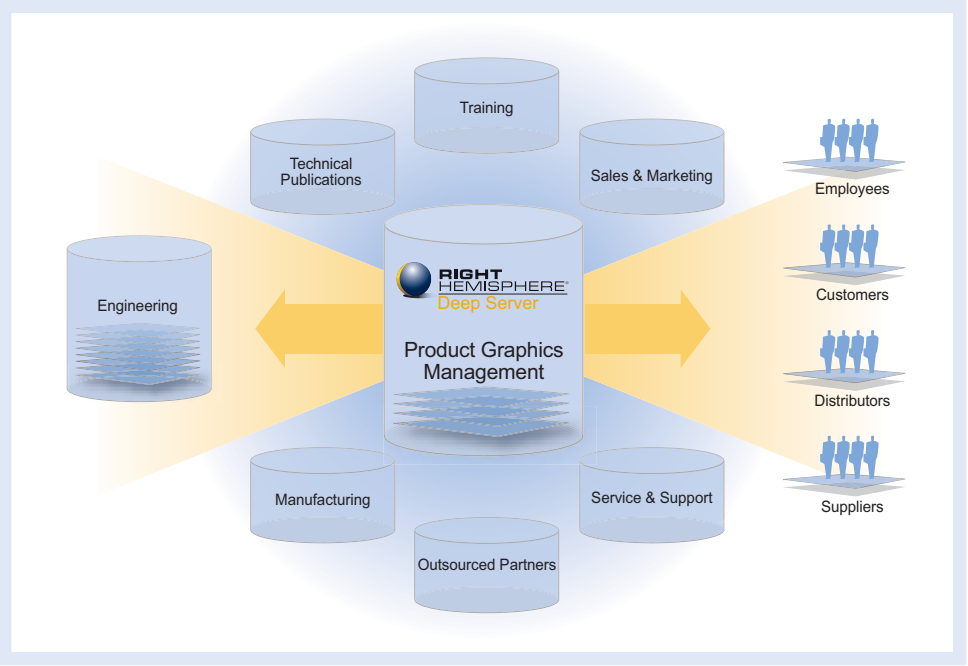

Figure 2. Product Graphics Management Landscape

PGM manages 2D and 3D products graphics in a unified repository that is easy to access, yet secure. Home for lightweight graphical models and derivative graphics (technical illustrations, photoreal images, and interactive scenes), this repository supports all the leading modeling and graphics formats.

This allows subject-matter experts, illustrators, graphics designers, and others to author and publish using whatever tools and formats works best, while eliminating the need for engineering involvement. Leading manufacturers are adopting PGM to accelerate time to market, increase revenue and competitive advantage, and reduce product lifecycle costs.

Product Graphics Management Applied to Interactive Training

As a result of their work with companies such as Boeing, Sikorsky, Northrop Grumman, Lockheed Martin, Airbus, Pratt & Whitney and other leading companies in the military and aerospace markets, Right Hemisphere has developed a solution specifically aimed at resolving the problems of inefficient content creation workflows by automating the repurposing and publishing of 3D CAD data for interactive training. The Right Hemisphere Interactive Training Solution integrates, automates, and manages graphics required for interactive training.

This solution accelerates today's multiple, fragmented and manual interactive training workflows to enable:

- Streamlined publishing of interactive training courseware including IETMs, CBTs, ILTs, simulations and virtual reality
- Creation of more effective, differentiated interactive training
- Leveraging of existing CAD and training investments



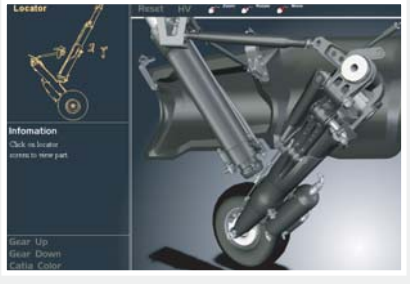

Figure 3. Examples of Interactive Training applications.

"With Right Hemisphere's Product Graphics Management software, a much greater level of sophistication is now available to maintenance, operations and other support personnel, offering an engaging and interactive environment that delivers instant gratification while working or learning. Instructor led training and e-learning will continue to provide sound experiences for the trainee.

However, moving 2D interactivity and 3D simulation into electronic technical documents and Web-based learning modules revolutionizes the learning experience to the degree that the people using these on-demand technologies will become more involved in their business processes and empowered by the accelerated accumulation and retention of the skills and knowledge they acquire".

Corey Peters,
Technology and Training Group,
Booz Allen Hamilton

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Aerospace & Defense Selected Customers

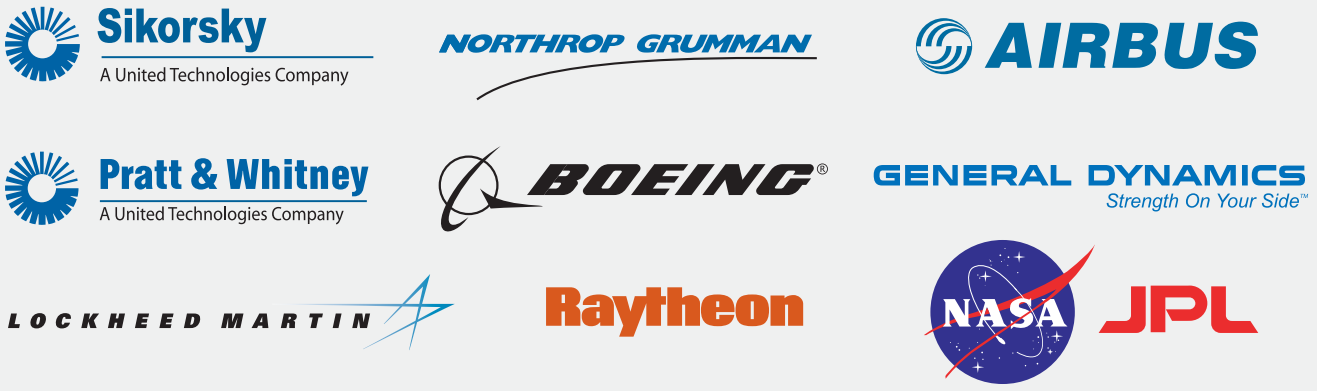

Figure 4. Nine of the top ten US aerospace and defense contractors are using Right Hemisphere software today.

Characteristics of Product Graphics Management Software

Product Graphics Management software must integrate existing applications and workflows. This requires compatability with a wide range of CAD systems and the ability to handle the thousands of 2D and 3D graphical files normally associated with military or aerospace systems projects. Further, Product Graphics Management software must also manage, manipulate, audit, search, and publish this content as and when required.

Essential Characteristics of Product Graphics Management Software

Input	Processing Capabilities	Output
Support for multiple CAD, 2D and 3D content file formats	Script and execute business rules to enable a variety of interactive training publishing pipelines.	Configured publishing pipeline processes.
	Convert 3D CAD using rules-based automation.	Publishable graphic content in a wide number of 2D and 3D file formats.
	e.g. customized scripts automatically generate pre-determined views of 2D images from 3D data.	Published content in illustration formats.
	Generate lightweight 3D models automatically.	Published content in 3D animation / interactive authoring formats.
	Store and asset manage converted rich media files including access & version control in order to track and propagate changes and Google-like search functionality of the content repository.	Repository of up to date product graphics as learning objects for IETMs, CBTs, Simulations, and Virtual Reality.
	Capture metadata (for search and publishing).	Repository of graphics with metadata.
	Integrate with Digital Content Creation, Enterprise Content Management, and Dynamic Enterprise Publishing applications.	Integrated publishing pipelines with interactive 3D application authoring tools as well as MS Office™ documents such as Word and PowerPoint and with Acrobat & PDF.
	Record audit trail of actions taken on CAD asset during publishing process.	Clear audit trail for tracking actions on CAD design data from design through to training content.

Table 5. Essential characteristics of Product Graphics Management software.

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The Product Graphics Management capabilities above deliver a number of benefits across the training staff. These are summarized in Table 6.

The Benefits of Product Graphics Management to the Training Content Creation Team

Team Role	Responsibility (as defined in SCORM)	Benefits of Product Graphics Management	Return on Investment
Instructional Designer (ID)	Conducts the needs and audience analysis. Designs basic content structure. Creates design documents and design specifications and initial content outlines. Works with other team members to ensure the instructional integrity of final materials.	Access to searchable repository of 2D & 3D content from which they can quickly flesh out design documents and content outlines. Ability to design new courses from pre-existing content.	Reduce time to market for new courses. New revenue through just in time course design in response to client problems. New revenues through ability to more effectively reuse existing learning objects.
Subject Matter Expert	Works with IDs and authors/developers to ensure the instructional materials are technically correct and appropriate in accordance with client needs. May work directly for the client.	Faster time to prototype reduces time to evaluation.	Increased productivity due to faster time to prototypes enables reduction on rework and faster time to course introduction.
Content Author/ Developer	Takes basic instructional design and content outline from ID and researches and writes all instructional text or scripts. May request or outline design assets to be supplied by Media Producers and Multimedia developers.	Access to searchable repository of 2D/3D and associated files, rapid review of related material, fast way to identify potential suitable assets and review related materials. Using existing learning objects stored in the repository, a content author can create new courses from existing material.	Increased productivity due to faster time to prototypes enables reduction on rework and faster time to course introduction. Ability to create complete courses from existing learning objectives.
Multimedia Programmer/ Developer	Responsible for creating the content package required by the design in accordance with SCORM guidelines. The developer may also be responsible for the LMS and for ensuring LMS integration functions properly before delivering instructional material to students. Likely to use tools including, 3ds Max, Macromedia Flash and Deep Creator from a programming perspective to create interactive media applications and integration of content created by Media Producers with learning script. Works closely with instructional designers to ensure content structure and sequencing behaviour meet SCORM technical implementation guidelines.	Scriptable output and database associations mean a faster way to generate materials for integration into a SCO. Will also generate manifest and package automatically. Strong integration of publishing platform with 3D application authoring tools such as Deep Creator, Virtools and others enables highly streamlined interactive content authoring workflows. Use of authoring tools JavaScript API and scripting language to communicate with page resident JavaScript SCORM API means development time can be focused on application - not developing frameworks to enable SCORM integration.	Increased productivity due to time saved collating assets. Strong integration with leading interactive 3D authoring tools such as Deep Creator, Virtools, EON Reality and others reduces time to application production by removing problems of integrating content. RH's authoring solution Deep Creator's JavaScript API integration eases development of interactive 3D SCORM compliant learning objects.
Graphic Artist/Media Producer	Responsible for creating assets (2D/3D graphics, video, animation etc) and interfaces in accordance with requests from IDs and content authors/developers.	Automating current manual workflow through: - Access to searchable repository of 3D content for rapid generation of assets suitable to the task-at-hand. - Massively reduced time required to convert 3D CAD files to suitable source objects for creating learning objects. - Rapid generation of 2D imagery assets direct from 3D sources.	Increased productivity due to automated 3D CAD repurposing eliminating manual work. Propagating use of CAD assets through downstream business activities means a better ROI on existing CAD, PDM/PLM & content production tool set investments.

Table 6. The Product Graphics Management capabilities above deliver a number of benefits across the training staff.

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Making Technical Illustrations and Interactive 3D Scenes as Common as Text

Today's 2D digital publishing processes take highly structured, categorised text that is created by authors and designers and store it in a neutral format based on the extensible mark-up language (XML) description format. In order to publish this text to different media - be it HTML for the Web, PDF for portable documents, CD-ROMs or print, they apply a series of presentation rules (known as Extensible Style Sheet Language for Transformations - (XSLT) style sheets to this content as it passes through a publishing pipeline (see Figure 6).

These presentation rules will dictate the final output, its look and feel, and will specify fonts, layout, positioning and more. It is increasingly common for one publishing platform to be able to drive multiple publishing pipelines, with each configuration simply being designed as a series of business rules or scripts. These rule based 2D publishing platforms are driving the current revolution in cross-media or multi-channel publishing and are supplied by companies such as Arbortext, Astoria, Enigma and Stilo.

For instance, Astoria Software's Astoria Configuration Publishing System (ACPS) was developed in conjunction with Boeing to enable content reuse, version control, knowledge management, collaboration, and delivery of 2D content through flexible rules- based publishing. Using pipeline based publishing rules, ACPS equips users with the ability to build customized documents on the fly, including flight and technical manuals, from a single repository based on a unique set of configuration data.

Right Hemisphere's Product Graphics Management software bring exactly the same content transformation capabilities to 2D and 3D graphical content creation as Astoria's, Stilo's, or ArborText's capabilities deliver to 2D text publication. 3D model data is imported as source information, a series of business rules are then applied, transforming the CAD data as it is pushed through the publishing pipeline into an open extensible format. This data can then be published as illustrations, animations, interface imagery and lightweight 3D content suitable for rapid development of interactive 3D simulation to full immersive virtual reality scenes for CAVEs and powerwall displays.

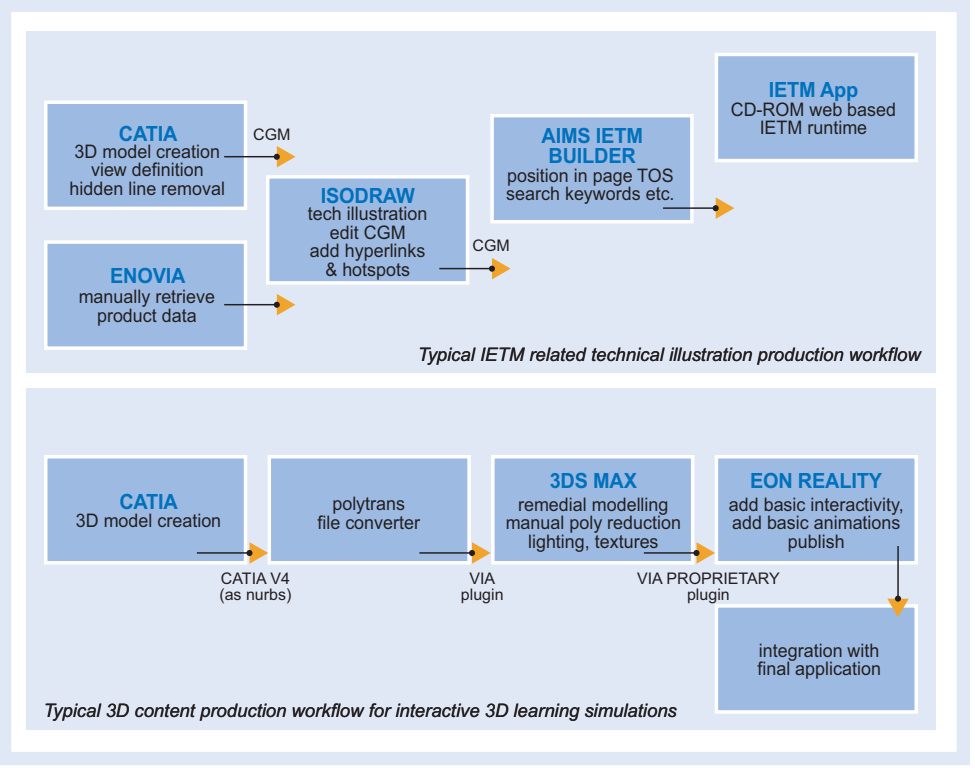

Figure 5. Traditional workflows for IETM and 3D content creation

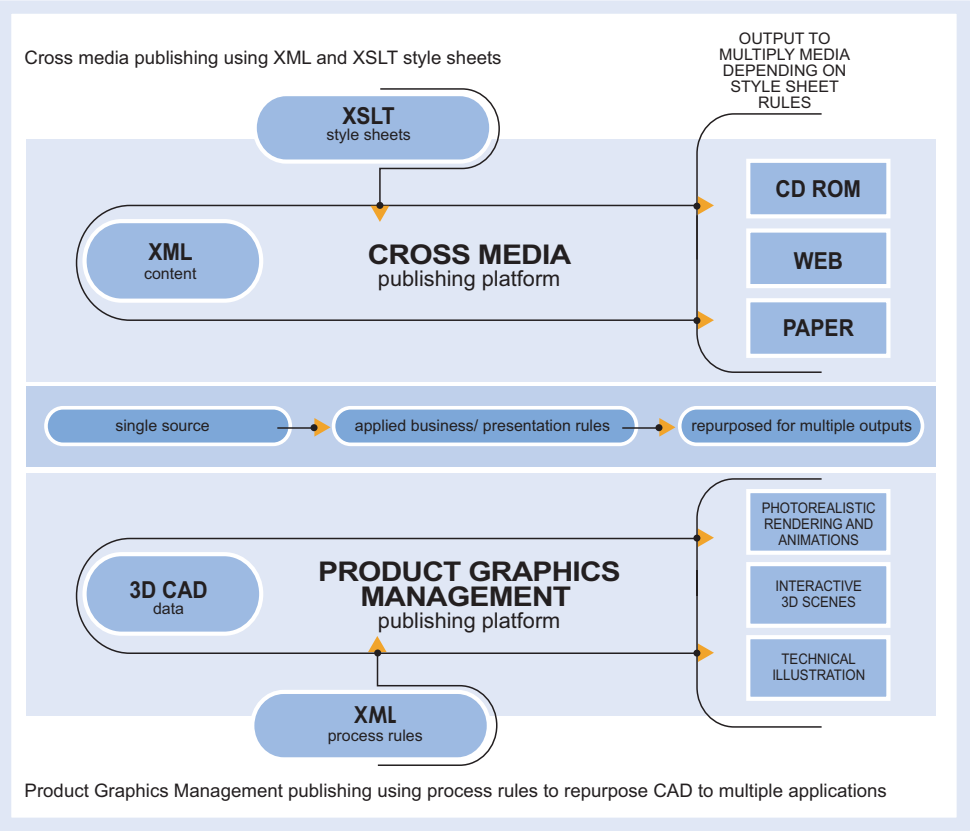

Figure 6. Comparing Cross-media publishing using XML and XSLT style sheets and Product Graphics Management using process rules to repurpose CAD to multiple applications

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Supporting Modular and Just-In-Time Training

Approaches to training delivery change based upon economic pressures and evolution in the availability of affordable and appropriate technologies. Future-proofing against new trends is an important aspect of investing in new, flexible production processes. While the initial benefits of using Product Graphics Management to support training have largely been found in training centres, research findings indicate these benefits are readily transferable to the increasing on-site and distributed learning requirements of both military and commercial aerospace operators.

Product Graphics Management software is designed to enable multiple business functions including:

- Rules-based publishing that incorporates derivative 2D graphics automatically generated from 3D CAD data according to publishing requirements.
- Facilitates intelligent automated large volume batch conversion of CAD data to graphical derivatives that are used in post engineering business processes such as interactive training course ware development, marketing and technical illustration
- Enable rapid asset access and search for existing assets
- Enable just-in-time repurposing of existing CAD assets and creation of derivative assets e.g graphics from a different view, different associated animation etc

Product Graphics management platforms such as Right Hemisphere Deep ServerTM provide a single, unified workflow solution that enables the effective reuse and repurposing of design assets throughout the enterprise in a highly cost effective manner.

Four Steps to Publishing an Interactive 3D Content Object from CAD Data

In response to a customer request for a specific training program, the instructional designer, subject matter expert and content author/developer will design a course to meet the customer needs. Using metadata, the teams' media producer can quickly search for assets in the repository and select those assets for publishing, either as interactive 3D graphical models, animations, or interactive scenes, depending on his need. For authoring interactive 3D content, the multimedia developer is notified by email as soon as the necessary 3D objects he needs have been published. At this point, he imports the model data directly into one of many 3D authoring packages available, such as Right Hemisphere's Deep Creator, or third-party applications from Virtools, EON Reality or others, where he adds the required interactivity needed by the training script and integrates this with calls to the SCORM JavaScript Runtime, so the trainees' performance can be recorded and reviewed.

After interlinking all other media (for instance, the assembly/disassembly animation generated by Deep Server and different viewpoint images used as part of the user interface), the multimedia developer simply compiles his shared content object using a SCORM packaging tool such as RELOAD (freely available from www.reload.ac.uk) and the learning object is ready for testing with the customer's learning management system.

Right Hemisphere Deep Creator 2.2 enables developers to easily publish a test SCO containing an interactive 3D scene direct from within the Deep Creator authoring environment ready for evaluation in a Learning Management System.

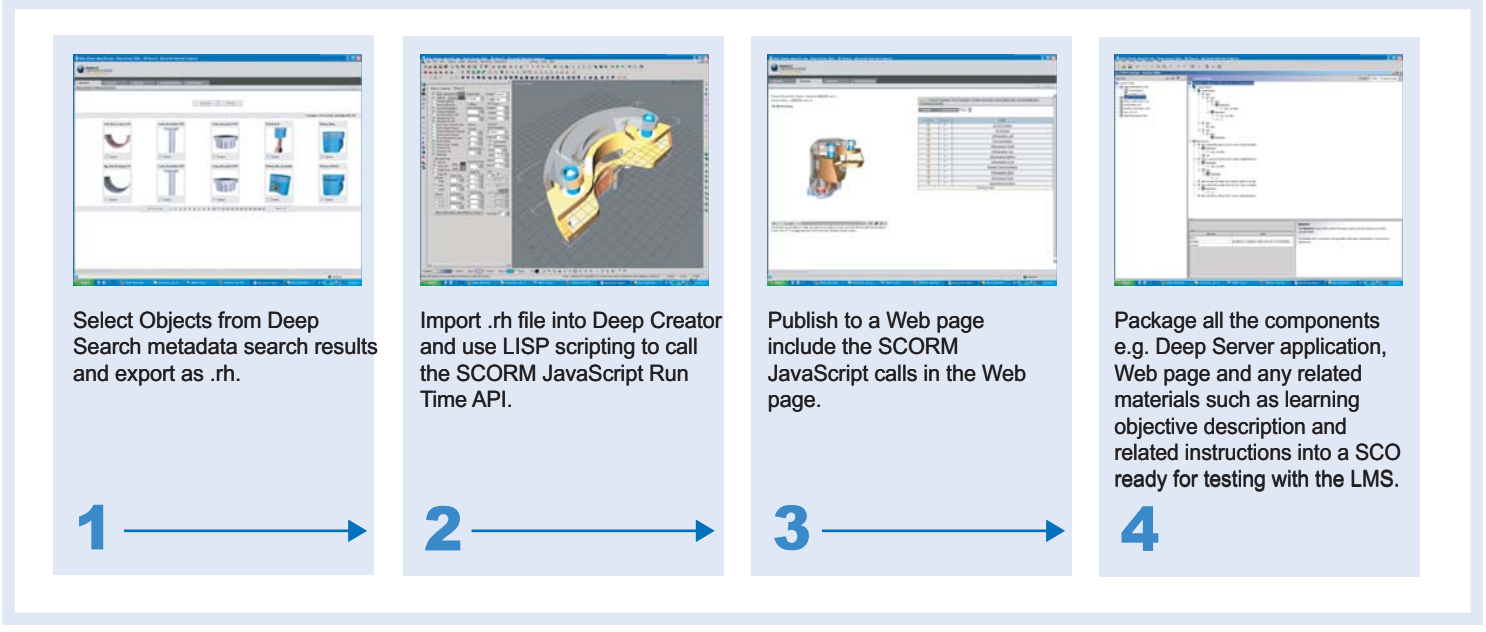

Figure 7. The 4 main steps in creating an interactive 3D based shareable courseware object for a given learning objective

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Cost-Benefit Models

Interactive 3D provides more effective learning materials for both trainers and trainees. Optimizing workflows using streamlined product graphics management pipelines enables training content production teams to work more efficiently and successfully meet emerging market requirements for multi-solution delivery (IETM, CBT, Simulation, Virtual Reality), as well as multi-channel delivery (Web, CD-ROM, Print), while empowering them to reduce costs, accelerate time-to-market, and achieve extremely attractive returns on investment. Tables 7 and 8 below provide summaries of real-world savings achieved by deploying Right Hemisphere's Deep Server for training content creation.

Customer A	
Challenge	**Deep Server Results**
300,000 (+) parts to re-model Avg. 4 weeks per part to re-model (160 hr per part) Graphic Artists & Illustrators re-model parts.	160 hrs per part reduced to 5 minutes per part.
Original budget was 10% parts to be done in 3D.	86% of parts able to be repurposed in 3D for same budget.

Table 7. Customer A

Customer B	
Challenge	**Deep Server Results**
- Takes an average of 40hrs to remodel Pro-E 100-200MB file into a 3ds MAX file - Graphic Designers & Illustrators perform remodel work - $36.75 burden rate (x) 40 hours = $1,470 per 100-200MB file	- 40 hours per file reduced to 5 minutes - $3.06 per 100-200mb file vs. $1,470 oSavings of $1,466.93 per 100-200MB file

Table 8. Customer B

In addition to the convenience of publishing to multiple processes, dramatically reducing time to market, improving secure management of content, and creating new opportunities for content reuse and just in time delivery - Deep Server delivers significant real world savings.

Right Hemisphere adds value in many ways. Using Deep Server, Customer B reduced the costs per file from $1,470 to a mere $3.06 per 100-200MB file. By reducing the process time from 40 hours to five minutes, not only can the developer deliver before competitors, he reduces his need to use contractors for file conversion and repurposing. In effect, his Deep Server investment is creating nearly 37 hours of virtual man hours for every 100-200MB file re-modeled without the overhead cost of traditional processes.
- Beyond these benefits, richer 3D graphic files and enhanced e-learning solutions provide a significant competitive advantage to the competition offering traditional 2D and 3D content materials.
- Initial Deep Server investments ensure that future or on-going projects and contracts maintain lower operating expenses and thus maximize profit.

The JSF Program - The World's Most Ambitious Training Project

In the final part of 2003 Northrop Grumman, the lead integrator for training courseware for the JSF-F35 program - (a new stealth fighter being built by Lockheed Martin) selected Right Hemisphere's Deep Server as the foundation for 3D publishing for the interactive training required for operation and maintenance of the aircraft. The JSF program is the largest defense department acquisition to date. It consists of 1250 hours of courseware that needs to be created. Approximately 40 subcontractors will work on the training courseware for 5 different versions of the aircraft.

In the past, Northrop Grumman took drawings from engineering and passed them to its art department to be redrawn - a long, costly and inaccurate way to create courseware graphics. Right Hemisphere's Deep Server software will enable Northrop Grumman to process its own CAD conversions into a transportable file format, and instantly incorporate those into training

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materials where users can interact directly with different parts of the aircraft design. Interactive 3D as a component of the JSF training program is considered essential since animation of aircraft parts, such as the rudder pedals, illustrate their precise movement and provide an intuitive and compelling way for trainees to familiarize themselves with the operation and maintenance requirements. It is worth noting that given the date scheduled for completion of the aircraft, the future initial maintenance trainees are today 11 years old and the future initial pilots of the aircraft are 8 years old. These kids are the Playstation™ and X-box™ generation. They know their way around 3D gaming technologies as never before. It seems logical that as they grow up and graduate to their professional military and commercial careers, the best way for them to learn and grow in their jobs is through the compelling communicative power of hands-on interactive 3D learning.

Enabling Future Developments

While paradigm shifts are often characterised by dramatic cost savings - for instance, those achieved by using Internet technologies for text publishing instead of paper-based publishing models, the real characteristic of a revolutionary technology is the creation of new opportunities for entire industries.

While many of the examples used in this paper have been drawn from military-related developments, these are simply because they are the early adopters of this technology. In the same way that real-time 3D graphics applications migrated from high-end military and aerospace research developments in the 1980's and early 1990's through to today's living room and videogame based entertainment - Product Graphics Management will drive 3D training content into a whole new domain of activity. For instance, imagine, if you will, the following scenario:

An embedded server installed on an aircraft tracks the performance of the plane while in flight. Using a small expert system, it classifies performance data against known tolerance profiles. Any faults or potential faults can be beamed and transmitted via radio to a central messaging system, which transmits the information to the nearest relevant maintenance centre. As soon as the information is received, maintenance technicians can begin rehearsing part removal, search for replacement parts and double check procedures required to test the part in question on desktop Web-enabled computer based training applications.

Unlike avionics boxes that are designed for specific functions on the aircraft, this miniature embedded server combines signals from traditional hardware/firmware applications that interface and collect data from specific sub-systems and feeds them into a maintenance application that not only can help diagnose issues and identify specific processes with potential problems, but can also associate and cross-reference this information with 3D data used for IETMs and training manuals for this specific aircraft. This serves to combine airframe and engine configuration information into a unique data set, along with operational updates and maintenance history.

A technician, using a tablet PC or a small head-mounted display, communicating wirelessly and connecting through a secure channel using wireless technology to the aircraft's embedded information server, can approach the aircraft and have it send him not only fault information, but the updated 3D IETM application tutorial in situ. This will tell him how best to address the issues registered by the management diagnostics software. Such value-added services will enable airline operators and their supply chain to improve their on the ground turn around times, reduce their compliance costs and increase their overall efficacy. Increasing service effectiveness and reducing the time taken for routine on-the-ground aircraft 'turn-around' increases the amount of time a plane can be used to movie passengers and cargo from departure to destination. Ultimately reductions in 'turn-around-times ' reduce the number of aircraft required to service a given route. The more often a plane can fly - reducing the need for more aircraft to service a given route.



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Imagine a similar scenario for automotives. As soon as the car is brought into the service center, the technician connects to the car's diagnosis system wirelessly. The car's fault diagnosis database automatically flags the profiled problem, loads the relevant maintenance procedure, providing him an interactive 3D model, which shows all necessary procedural stages, and displays the relevant maintenance information on a head mounted IETM display, worn by the technician. Sound far fetched? The majority of automotive Engine Management Diagnostics ("EMD") systems in modern engines carry fault profiling tools, which generate an error number that matches to a given circumstance and profiled problem.

These types of applications are already under investigation and development using Right Hemisphere's interactive 3D publishing technologies with partners including Pratt & Whitney. The limiting factor so far in delivering these applications has been the cost and time required to generate enabling content. With Product Graphics Management, this is no longer a limitation. The same training techniques that were once the sole province of military and aerospace research are now rapidly migrating into mainstream manufacturing because Product Graphics Management platforms such as Right Hemisphere's Deep Server™ are removing the final cost barrier to widespread use of 3D content.

In the same way that today's flat packed furniture comes with isometric drawings to show basic assemble instructions, tomorrow's manufactured products will come packaged with (and in some cases have embedded within) interactive 3D maintenance and training content generated directly from computer-aided design data. Imagine the day, when your Trek mountain bike is shipped to you from the manufacturer, after you have configured it to your requirements over the Web using 3D interactivity, and it arrives with a CD-Rom. That CD-ROM contains a full suite of interactive 3D training modules for self-service of the most common types of maintenance problems. You'll feel empowered in not having to go to the bicycle repair shop to change a punctured tire or adjust the brakes or gear system to your needs. In some cases, this training content will be supplied in standard documents such as 3D PDF and Microsoft Office for home use. Others will be beamed wirelessly from embedded servers to display devices; and in some, it will be displayed on stereo project 3D powerwalls by design and maintenance teams during training.

The interactive 3D content will help teach owners and operators how to best preserve their investments. Effective training materials and training reduce operational and owner costs, they deliver real business benefits and greater product lifetimes, and they are core to product and service differentiation in manufactured goods - be it for today's military attack helicopters, or jet engines, or your child's next generation scooter.

Further information and reading:

Right Hemisphere: www.righthemisphere.com

"Aircraft maintenance: preparation in 3D" by Professor Stefan Stuering, Fraunhofer I.F.F. Available to download from: http://www.fraunhofer.de/fhg/Images/mag1-2003-22_tcm6-11220.pdf

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