Executive Brief

Seaweed Systems® and Safety-Critical Avionics Graphics Software

April 2006

Contents

Chapter 1

The Changing Face of Avionics

The Transition to Computer-Generated Displays

Figure 1. Electro-mechanical instrumentation has given way to LCD displays that convey far more information in flexible, configurable formats.

Image created using Quantum3D® iData™ software and provided courtesy of Quantum3D

The face of aircraft instrumentation is changing rapidly in both the commercial and military domains. Where cockpits were once instrumented with reliable, but simple electro-mechanical devices, today they are equipped with computer-graphics displays that give pilots and other specialists an unprecedented amount of flexibility and mission-critical information. Pilots can arrange graphical representations of traditional instruments across a virtual cockpit on Liquid-Crystal Displays (LCDs), with the flexibility to access alternate display configurations at the touch of a button (Figure 1). No longer must they only imagine an approach plot — with graphical displays pilots can fly their aircraft through a 3D tunnel that defines the desired glide path. Military pilots and weapons specialists can view terrain, obstacles, threats, and targets in 3D-animated displays, allowing them to process considerably more information in real time and carry out their missions with pinpoint accuracy. As these sophisticated graphical displays prove their superiority, they occupy an increasing amount of cockpit real estate.

The transition to computer-based avionics does not come without risk. With the increasing number of computer-generated displays comes an explosion of computer software running them. Software now carries an increasing amount of the risk associated with an instrument or even more catastrophic failure. In order to mitigate the risk of instrument failure, governmental organizations have phased in certification requirements for both the hardware and software components of modern avionics. In the United States, the Federal Aviation Administration (FAA) has mandated compliance with RTCA/DO-178B for airborne software. These guidelines force strict limitations on software complexity, with regulations dictating every phase of the software lifecycle. Recognizing that hardware devices to some extent codify software algorithms in silicon, the U.S. government

and aircraft manufacturers themselves have begun to stipulate to their suppliers the DO-254 certification requirement for airborne hardware.

The good news is that having certification requirements for both avionics hardware and software components significantly reduces the risk of failure — and a reputation for reliable, safe avionics is good for every vendor and for the industry as a whole. The bad news is that increasing the certification requirements for avionics systems places greater demands on those responsible for product design, production, and testing. As avionics manufacturers strive to produce the most reliable hardware and software imaginable, their staff is increasingly stretched to maintain expertise in each of the separate disciplines that must be covered in order for their products to successfully pass the certification examination.

Certifiable, Commercial Off-The-Shelf Software

The core business of avionics manufacturers is to develop innovative, market-leading products by developing unique application software that runs on certifiable embedded platforms. One way in which manufacturers can free their staff to focus on their core business while producing safety-critical avionics is to incorporate certifiable, Commercial, Off-The-Shelf (COTS) products into their designs. Using certifiable COTS products outsources areas of expertise to vendors that support multiple manufacturers, bringing domain-specific expertise to the problem at hand. It amortizes development and certification costs across multiple customers, helping to reduce cost. And using software that is available today reduces risk by limiting new hardware and software development tasks.

For graphical displays in aircraft, OpenGL® is the standard graphics API of choice. OpenGL is a device-independent Application Programming Interface (API) that allows avionics software to draw both 2D vectors and 3D polygons with lighting, shading, and texture mapping. OpenGL is a broad standard, supporting the needs of devices ranging from personal computers and video games to medical imaging systems and avionics. For safety-critical systems, the standard OpenGL SC API provides a 3D subset of the larger OpenGL API to provide the power of OpenGL to safety-critical devices while simplifying the range of interfaces to the core set required to get the job done. Simpler software helps to lower the certification risk and cost because the resulting OpenGL driver code is smaller and less complex.

Chapter 2

Industry Leadership from Seaweed Systems

Positioned to Meet Industry Needs

No embedded graphics company is better positioned to meet the needs of avionics manufacturers than Seaweed Systems, Inc. With more than 100 man years of high-end graphics experience and 70 man years of OpenGL experience, Seaweed Systems is the first vendor to offer a certifiable off-the-shelf OpenGL SC implementation along with the documentation, certification artifacts, test harnesses, and support needed to help its customers through the certification process. Where some vendors view the production of safety-critical software and certification artifacts as a nuisance, Seaweed Systems embraces the process through objective software complexity measurement, continuous testing with complete code coverage, and consistently-maintained certification artifacts. Nothing testifies more to Seaweed Systems' dedication to the market than having its own, on-staff Federal Aviation Administration (FAA) Designated Engineering Representative (DER) to help maintain and improve its quality and certifiability standards.

Long History of Embedded Systems Graphics Products

Seaweed Systems has established a leadership position in the real-time, embedded graphics driver market because it has maintained a single focus on high-quality, fully-tested, and fully-supported graphics products since its inception. Founded in 1993, Seaweed Systems first delivered state-of-the-art X Window System implementations for embedded systems. Having gained experience developing software to meet the demands of the embedded and real-time systems market, Seaweed Systems introduced its family of OpenGL products in 1996. Having added several key staff members with safety-critical software development and certification experience, Seaweed Systems has been able to deliver the first certifiable, commercial, off-the-shelf family of OpenGL graphics products available anywhere.

Today, Seaweed Systems offers a modular, flexible family of certifiable graphics solutions based on the OpenGL API standards. Customers begin with the Seaweed Systems® SeaWind®/178 Certifiable Core API, which implements the open standard OpenGL SC API, and includes built-in real-time performance monitoring functionality. If necessary, they purchase additional certifiable software products to provide increased functionality, including: digital mapping, real-time video, windowing, and a set of APIs commonly used by avionics applications. With the ability to integrate only the software they require into their products, avionics manufacturers reduce memory footprint, which helps to reduce both hardware and software costs.

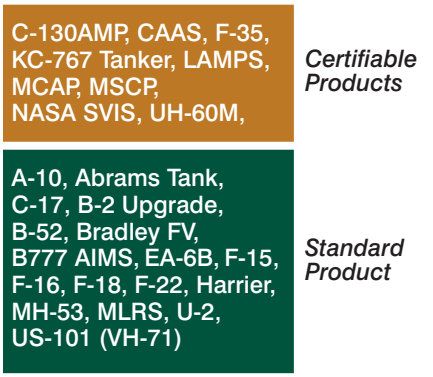
Seaweed Systems offers its products in three different packages so that customers can choose the option that best complements their level of expertise:

- *SeaWind/178 CertCode* includes the SeaWind/178 Certifiable Core API and any additional software products that customers require,
- *SeaWind/178 CertKit* includes the software plus the kit of documents needed to support the DO-178B certification process, and
- *SeaWind/178 CertAssist* includes the software, kit of documents, and the services required to assist with certifying the implementation in the target system.

Seaweed Systems' certifiable, commercial off-the-shelf OpenGL graphics driver software product line, its complement of services, and its experienced staff — including its in-house DER — support the entire software lifecycle needs of its customers, from requirements and design through the certification process. When avionics manufacturers use Seaweed Systems COTS OpenGL graphics driver software, they reduce cost, minimize risk, and free themselves to concentrate on their core business.

With benefits like these, it's no surprise that Seaweed Systems customers include aerospace companies like Boeing, Lockheed Martin, General Dynamics, EADS, BAE SYSTEMS, Northrop Grumman, Rockwell Collins, Honeywell, Smiths Aerospace, Harris, L-3 Com, DRS, and Elbit Systems. Seaweed Systems software has been used on a large number of United States and overseas military aircraft and ground vehicles, including several with DO-178B certification requirements (Figure 2).

Figure 2. Seaweed Systems software flies on many major aerospace projects.



Seaweed Systems has either already delivered or is under contract to deliver the products described in this document. Seaweed Systems does not wish to imply that its software has actually been certified for use on a civil aircraft as of the date of this document.

Chapter 3

The Value of Good Partnerships

Long-Term Relationships

Seaweed Systems understands that providing certifiable OpenGL graphics solutions isn't like selling shrink-wrapped software. It requires an understanding of project requirements, the environment in which its software is to run, and support to see customers through the certification process. Seaweed Systems believes in establishing long-term relationships with its customers and every supplier whose products interact with its products, including graphics devices, real-time operating systems, and application-generation tools.

Partnerships with Customers

Seaweed Systems is dedicated to the safety-critical, embedded OpenGL software market. This is a niche market in which survival depends on building good, long-term relationships with customers and consistently delivering on commitments. Recognizing this fact, Seaweed Systems first offers a range of products that can be assembled to best support its customers' projects, from graphics devices themselves to certifiable graphics driver software. Then, Seaweed Systems works through the certification process with its customers to help ensure that its software never creates an obstacle to certification.

Through its support programs, customers receive all of the documentation necessary to include Seaweed Systems software in their certification submission, along with any updates required during the process. Seaweed Systems has an exceptional set of resources dedicated to making its customers' projects successful. Its software certification team combines years of experience with flight-certified software, from safety-critical jet engine control software to Seaweed Systems' safety-critical graphics software. Its hardware design and support staff can help with graphics device integration issues and reference architectures. Its on-staff DER is accredited to Design Assurance Level A for

both DO-178B and DO-254 Part 23 and 25 projects. The Seaweed Systems DER is also available for consultation on software and electronic hardware compliance and certification issues.

Partnerships with Vendors

The Seaweed Systems SeaWind/178 family of software products insulates its customers' applications from the details of the graphics hardware, allowing them to prepare substantially device-independent avionics applications. Seaweed Systems software works intimately with the underlying graphics devices, the operating systems that manage hardware resources, and the application software that utilizes the OpenGL and any additional graphics APIs (Figure 3). Because Seaweed Systems products integrate with a wide range of hardware and software components, intimate knowledge of each component, and good working relationships with their vendors is key.

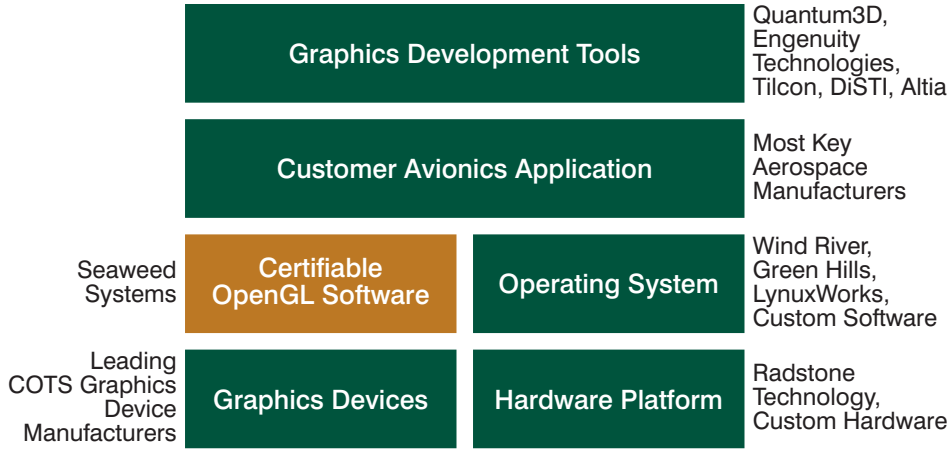


Figure 3. Good partnerships up and down the software stack mean that Seaweed Systems customers get an experienced team working for them.

Seaweed Systems invests heavily in relationships with its partners up and down the hardware and software stack, understanding how every component must work together in order for a graphics system to successfully make it through the certification process. Nothing beats a team of vendors whose products integrate seamlessly, whose engineers have experience working together, and who can quickly resolve issues without multiple layers of overhead. Good working relationships are key assets for getting software through DO-178B certification, and they are also key assets for customers wishing to minimize risk, reduce cost, and speed time to market.

Graphics Devices

Today's graphics device technologies are complex, which makes the hardware and software inseparable, and requires close partnerships between graphics device manufacturers and driver providers. Seaweed Systems establishes long-term, preferred-vendor relationships with leading COTS graphics device manufacturers and supply their parts

into the embedded-systems market. These are no ordinary relationships. In order for Seaweed Systems to prepare certifiable software and firmware for a graphics device, it must have far more intimate knowledge of the device and its architecture than an ordinary customer is allowed to have. Indeed, in order to help its customers through the certification process, Seaweed Systems must have direct access to the manufacturer's design data and its graphics device engineering team.

In addition to trusting Seaweed Systems with internal documents, graphics device partners also trust Seaweed Systems to provide both sales and support for their products in the embedded systems market, providing customers with a single point of contact for technical issues surrounding graphics hardware and software, and insulating the manufacturer from this role. The level of cooperation that Seaweed Systems establishes with its graphics device partners is unmatched in this industry, and it is essential to the successful production of high-performance, certifiable embedded graphics driver software.

Understanding that aircraft avionics systems have a significantly longer market life than do graphics engines for the personal computer and video game market, Seaweed Systems offers a Supply Guarantee Program. This program allows avionics manufacturers to virtually eliminate the risk that the graphics chips on which their products are based might cease to be available part way through their programs. Because of its close relationship with device manufacturers, Seaweed Systems is able to harmonize its OpenGL software products and release cycles with those of the graphics devices, reducing risk of incompatibilities between the companies' products.

Most important to Seaweed Systems customers is that the company acts as a knowledgeable liaison to the fast-paced COTS graphics device industry. Seaweed Systems can be trusted to bring the very best COTS graphics devices to its customers in support of their product roadmaps, helping them to keep their products competitive for the long term.

In addition to its relationship with graphics device manufacturers, Seaweed Systems software also runs on off-the-shelf graphics boards from leading hardware providers like Radstone Technology.

OpenGL Standards

For more information on the Khronos Group, please visit: www.khronos.org.

Seaweed Systems chairs the Khronos Group's OpenGL SC working group, which has defined OpenGL SC as a standard, 3D subset of the OpenGL API for small memory footprint, safety-critical applications. By encouraging the use of a standard set of OpenGL APIs, the OpenGL SC specification helps to promote interoperability between graphics development tools and the underlying driver software. The Khronos Group acts with the endorsement of the OpenGL Architectural Review Board, and Seaweed Systems offers the first implementation of the OpenGL SC specification available anywhere.

Embedded Operating Systems

The operating systems used in safety-critical systems are designed to support applications with real-time performance requirements, and they have a significant impact on the

design of OpenGL graphics drivers. Seaweed Systems works closely with the key embedded operating system suppliers, including Wind River Systems, Green Hills Software, and LynuxWorks. These operating-system software vendors recognize Seaweed Systems as a key partner because of their ability to provide complete solutions — one reason why Seaweed Systems is often invited to participate with these vendors at tradeshows, during co-marketing, and sales activities.

Graphics Development Tools

Understanding that qualifiable graphics tools can generate readily-certifiable graphics software, Seaweed Systems works closely with vendors like Quantum3D, Engenuity Technologies, Tilcon, DiSTI, and Altia to ensure that their products work well with technology from Seaweed Systems. Seaweed Systems has joint marketing agreements with all of these graphics development tool providers to enable this cooperation.

Chapter 4

Focus on OpenGL Software

First OpenGL SC Compliant Product

Seaweed Systems is the first company to market a commercial, off-the-shelf, certifiable OpenGL SC specification-compliant product for safety-critical embedded systems together with a complete suite of tests, certifiable documentation, and other certification artifacts. The Seaweed Systems SeaWind/178 product family provides a range of options for customers implementing OpenGL graphics in applications requiring DO-178B certification.

Designed and Built to be Certified

Unlike other driver providers, Seaweed Systems has designed and built its SeaWind/178 family of products from the ground up, with DO-178B-mandated plans, standards, documentation, review evidence, and test harnesses created as an integral part of the software development process. By designing its software for safety-critical environments from the beginning, Seaweed Systems eliminates the many pitfalls of retro-fitting existing code and reverse engineering DO-178B documents, evidence, and artifacts from existing software. Indeed, Seaweed Systems decided that basing their certifiable products on their own existing commercial products would be too costly, risky, and inherently against DO-178B software process principles to be practical. Rather than having to pull complexity out of its software in order to meet certification requirements, Seaweed Systems has built its software with reduced complexity from the start. The result is a higher-quality product, ease of certification, and high performance. Seaweed Systems SeaWind/178 products are certifiable to the highest level, Design Assurance Level A.

Carefully-Designed OpenGL Subset

One factor contributing to the certifiable nature of Seaweed Systems software is the carefully-designed OpenGL API subset that is implemented by its SeaWind/178 products. By implementing the OpenGL SC subset, rather than the full OpenGL API, Sea-

weed Systems is able to maximize the functionality available to 2D and 3D avionics applications while minimizing the inherent complexity. Subsetting the OpenGL API does not impact the richness or interoperability of a graphics application — SeaWind/178 products support code emitted by Engenuity Technologies VAPS®/QCG and Quantum3D® iData™ products. Seaweed Systems architected its driver software to minimize its dependency on operating systems, and it already runs in many environments including Green Hills® INTEGRITY® and INTEGRITY-178; LynuxWorks™ LynxOS®-178; and Wind River® VxWorks® and VxWorks 653.

Introducing the SeaWind/178 Product Family

Seaweed Systems SeaWind/178 Certifiable Graphics Software is a modular, flexible family of products that is built around the OpenGL SC API, with additional modules to support specific target system requirements including video, digital mapping, and windowing (Figure 4). The modular nature of the components allows customers to purchase only the software they actually need, helping them to minimize the software's memory footprint and the amount of software that must be certified on the customer system.

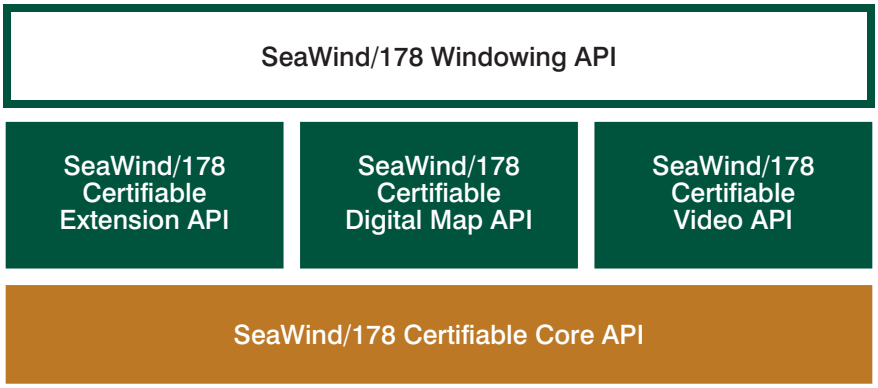


Figure 4. The SeaWind/178 family of certifiable graphics driver software products is based on the SeaWind/178 Core API, with optional modules available that add functionality according to customer requirements.

SeaWind/178 Certifiable Core API

The SeaWind/178 Core API is the basic graphics subsystem that includes the OpenGL SC-compliant API, graphics driver, and an API for managing the graphics subsystem in the embedded environment, including graphics device, context, and buffer management. The Core API is the product family's foundation, and additional SeaWind/178 products require the Core API to operate.

SeaWind/178 Certifiable Extension API

The SeaWind/178 Extension API includes a set of standard OpenGL APIs and other extensions that are beyond the set defined by the OpenGL SC specification. Some of the

APIs are commonly used in the avionics industry, some of them are used by graphics-development tools, and some of them are used by legacy graphics applications.

SeaWind/178 Certifiable Video API

The SeaWind/178 Video API supports high-speed data movement for real-time video. The API integrates video into the OpenGL API model as an OpenGL texture. Even though video is not part of the OpenGL specification, Seaweed Systems has implemented it consistently with the OpenGL model, so it can be manipulated using the OpenGL API. For example, OpenGL texture-mapping functions can scale and map video onto 2D and 3D planes, or wrap it onto complex 3D polygonal surfaces. Additional objects, including targeting, navigation data, and digital maps, can be layered above or below the video images through standard OpenGL functions.

SeaWind/178 Certifiable Digital Map API

The SeaWind/178 Digital Map API transforms Digital Elevation Map (DEM) data into terrain maps directly on the graphics device, offloading the system CPU, memory, and bus, improving performance and quality over application-based approaches. The API renders map tiles as OpenGL textures, allowing developers to use many familiar OpenGL functions to manipulate the resulting maps, helping to increase productivity. Developers can specify any combination of three effects, and can combine them with their own additional graphics and satellite imagery:

- Slope shading gives a 3D visualization of terrain as illuminated by a fixed light source.
- Fixed-interval contour lines are rendered at constant width regardless of zoom level.
- Colored elevation bands display height ranges as different colors, enabling intuitive threat and altitude cues.

SeaWind/178 Certifiable Windowing API

Today's cramped cockpit environments require instruments to serve multiple purposes, with displays able to flip from application to application, and with multiple applications sharing the same display. The SeaWind/178 Windowing Extensions allow OpenGL contexts to be attached to windows, with each context securely separated from the other, virtually eliminating the possibility of undesired interaction. Each window clips its context as dictated by the application software, and the contents of each window is displayed with geometry and priority specified at initialization time. The SeaWind/178 Windowing API can be used to allow multiple applications to share the display at the same time, and it also can be used to map and unmap multiple windows on a display, allowing operators to flip between functional contexts with immediate response.

SeaWind/178 Real-Time Performance Monitor

SeaWind/178 Real-Time Performance Monitor (RPM) works with development versions of the SeaWind/178 product family to give developers the tools they need to evaluate the inner workings of their graphics systems, from the application through the driver and into

the graphics device itself. Included with the SeaWind/178 Core API, SeaWind/178 RPM runs on the target system, independent of applications. From its unique position in the graphics driver itself, SeaWind/178 RPM can observe and present real-time information on the target system's graphics display to help answer questions including:

- Is the graphics system performing optimally?
- Is the graphics processor pipeline working smoothly?
- Is the memory bus or the DMA buffering strategy a bottleneck?
- Is the graphics processor stalled waiting for the CPU?
- Is the OpenGL software operating as efficiently as possible?
- Is one application monopolizing system resources?

Certification Support to Match Customer Needs

Once customers have made their choice of the SeaWind/178 Core API and any additional products they require, they can choose the level of certification support that best complements their organization. Seaweed Systems offers an incremental set of packages, each one incorporating all of the features of those preceding it.

SeaWind/178 CertCode

The SeaWind/178 CertCode includes the SeaWind/178 Core API, SeaWind/178 RPM, and any additional software products that customers have purchased. This support option supplies the software only. Source code is available as a separate option.

SeaWind/178 CertKit

The SeaWind/178 CertKit adds to CertCode all of the documentation necessary for customers to construct the DO-178B documentation required for the certification submission. CertKit includes both the documents and test software that can be completed by the customer and integrated into their submission. The product includes DO-178B Plans and Standards, DO-178B Data Documentation, Review evidence, Test procedures and harnesses, Instructions, and Lifecycle support. Seaweed Systems maintains additional software-design assurance and configuration-management records which are available for review and audit as required.

SeaWind/178 CertAssist

The SeaWind/178 CertAssist includes the software, documents, and the consulting services necessary to conduct the verification program on representative target hardware. Through the included Certification Year Support program, Seaweed Systems:

- Establishes the verification environment,
- Executes the verification program,
- Maintains all configuration management and design-assurance records,
- Provides program management services for all activities,
- Supports certification reviews and audits, and

- Completes all of the necessary documentation for the certification submission.

The CertAssist option helps customers successfully complete safety-critical embedded systems projects on their own platforms and within their market time frame. It helps to minimize the impact of the certification process on a customer's application developers, and it allows CertKit completion to proceed in parallel with application development. CertAssist customers enjoy all of the benefits of Seaweed Systems' COTS products with the confidence that their certification activities are conducted by Seaweed Systems engineers intimately familiar with the product.

A Low Cost, Low Risk Proposition

As the product offerings above suggest, the code itself for certifiable graphics driver software is only a small part of the picture. The entire software lifecycle is dictated by certification requirements. Supporting documents, testing frameworks, and complexity management dominate the amount of work involved — another reason why it is risky and difficult to reverse-engineer existing software to meet the requirements of safety-critical environments.

Undertaking such a project requires OpenGL and graphics hardware experts that are willing to undertake a software project with little code to write, but with an extraordinary amount of documentation, test harness development, and testing to complete. This requires a rare combination of talents, and for companies developing safety-critical applications, Seaweed Systems is a rare asset.

Companies that choose to develop their own OpenGL software must train existing graphics engineers in the rigors of developing certifiable software, or they must train their application developers in the nuances of the OpenGL API and the intricacies of graphics devices. Add to this the requirement for an intimate understanding of the operating system used for the project, and it is clear that climbing the learning curve that Seaweed Systems has already mastered is a daunting proposition — and it introduces the risk of missed deadlines and cost overruns that can endanger a company's higher-level objective: flight-certified avionics.

Let Seaweed Systems Manage Cost and Complexity

Managing complexity in safety-critical software is costly, and the expense of developing OpenGL graphics driver software in addition to application-specific avionics software is a choice that manufacturers must not take lightly. One benefit of using off-the-shelf OpenGL software is that development expenses are accrued across multiple customers, making the choice of SeaWind/178 certifiable graphics software a low-cost as well as a low-risk approach. Because Seaweed Systems has experience developing both standard and safety-critical OpenGL software, the company is intimately familiar with its costs, and can provide a side-by-side comparison of each implementation's cost and complexity.

Objective Complexity Measures

Seaweed Systems SeaWind/178 software is considerably smaller in size and complexity than its non-certifiable counterpart, resulting in greater efficiency, maintainability, performance, and certifiability. While Seaweed Systems' standard, non-certifiable OpenGL software requires almost 304,000 lines of code, the certifiable product developed prior to the OpenGL SC specification was implemented with a total of *less than 30,000 lines*. The standard product's memory footprint is approximately 5 MB, while the certifiable software's footprint is a mere 220 KB. In terms of lines of code, the certifiable software is only 8.6 percent the size of the standard product.

Software metrics described in this section are accurate as of July 2005. At this time, the certifiable product consisted of roughly, but not exactly, the SeaWind/178 Core API plus the SeaWind/178 Extension API.

Objective complexity measures are based on the number of potential paths through the code. If software is written with a complexity of 10 or less, achieving the structural coverage necessary for RTCA/DO-178B compliance may be done with fewer requirements-based test cases than with software derived from more complex requirements and source code. Simplicity in verification test cases and procedures is generally considered to be less problematic, time consuming, and costly than for software whose complexity is outside of this range. Table 1 illustrates the number of functions in complexity ranges from 0 to more than 50 for both the standard and the certifiable product. The certifiable product has only 31 functions (under 4 percent) with complexity in excess of 10, whereas the standard product has 2321 (more than 22 percent). The OpenGL software for a specified platform has an average McCabe complexity of 2.7, and its code is so linear that fewer than 1000 conditional statements are used in the entire product.

	Complexity		Number of Functions in Complexity Range						
Product	**Maximum**	**Average**	**0**	**1-10**	**11-20**	**21-30**	**31-40**	**41-50**	**51+**
Certifiable	95	2.7	0	834	19	10	0	0	2
Standard	264	8.6	4	7991	1222	459	275	110	255

Table 1. The SeaWind/178 product family is significantly less complex than its non-certifiable counterpart, resulting in greater efficiency, maintainability, and certifiability.

Objective Cost Measures

A broad set of cost drivers make developing, documenting, testing, and supporting certifiable software expensive. The organization and its developers must have experience with DO-178B-compliant development processes, OpenGL implementations, graphics device, CPU, and the operating system. The DO-178B guidelines specify requirements-based testing for normal and robustness cases, including 100 percent functional and structural coverage. The degree of structural coverage depends on the desired Design Assurance Level: Level C requires 100 percent statement coverage; Level B adds decision coverage; Level A adds modified condition/decision coverage, where every condition in a decision has taken all possible outcomes, and each condition in a decision is shown to independently affect the decision's output. In addition to software verification requirements, more intensive independent reviews and analyses are required with increasing Design Assurance Levels. Finally, the software development process must

For an in-depth study of Seaweed Systems cost measures, please refer to the article: "Aviation quality COTS software: reality or folly," available at: www.seaweed.com.

provide suitable evidence that the developer has satisfied each of the associated DO-178B objectives.

The COCOMO II model is available online at: sunset.usc.edu/research/COCOMOII/index.html and www.jsc.nasa.gov/bu2/COCOMO.html.

The cost of developing software under these requirements can be estimated by the COCOMO II model developed by Dr. Barry Boehm in 1981, and presented in his seminal work *Software Engineering Economics*. When Seaweed Systems applied Boehm's model to estimate the cost of developing its 30,000 lines of OpenGL graphics driver software, the model predicted a total amount of effort ranging from 24,300 to 38,880 hours. Having actually implemented the software, Seaweed Systems can report that its actual experience is in the upper range predicted by the modeling exercise. The first release of SeaWind/178 CertKit software required approximately 35,000 development hours.

Why is it important to estimate and measure the cost of developing safety-critical software? Because it is easy to underestimate the full cost when deciding to undertake graphics driver software development projects, with the result being spiraling costs and missed deadlines. Most organizations do not track all of the costs associated with such an undertaking in one place. Estimating the pure effort to develop the driver is simply inadequate given that the bulk (around 90 percent) of the cost is associated with the certification process. If the price of Seaweed Systems software were merely equivalent to the actual development cost per customer, each one would benefit in terms of reduced risk because the product is available today. Given that the software's price is much lower than the development cost to virtually any organization, SeaWind/178 software is both a low-cost and a low-risk proposition.

Chapter 5

A Compelling Opportunity

Leveraging Off-The-Shelf Components

The availability of commercial, off-the-shelf hardware and software components presents a compelling opportunity for avionics manufacturers. Where building instruments once required creating complete software and chip-level hardware implementations, today manufacturers can leverage the same technologies that have caused prices and product development times for consumer electronics to plummet.

Developing safety-critical avionics takes more than a personal computer and a box of shrink-wrapped software. It requires software that has been developed with flight certification as a goal from the very beginning, and it requires hardware that has been qualified for reliability and continuous operation under extreme environmental conditions. When shopping for certifiable, off-the-shelf components to reduce cost and development times in avionics, manufacturers must seek out the best products available anywhere.

Choosing the Best Products Available

Seaweed Systems offers an excellent alternative to custom or in-house development with its SeaWind/178 product family. Seaweed Systems has a long history of developing OpenGL software products, and has developed the first commercial implementation for safety-critical environments. One software component cannot live in a vacuum, however, which is why Seaweed Systems works with best-of-breed vendors in every area that its products touch. It has agreements with device manufacturers to provide their products into the embedded market. It works with the leading embedded operating system vendors, and its products work seamlessly with key application-generation tools. All of the relationships in which Seaweed Systems invests heavily contribute to a manufacturer's ability to produce its products on time, with a predictable budget, and with a high degree of confidence that its final product will pass the test of flight certification.

A Compelling Opportunity

Choosing Seaweed Systems is more than just a point product choice. It is a choice that brings a team of experts together to deliver the products and support that can make the development, certification, and product maintenance process run as smoothly as possible. Better yet, Seaweed Systems can deliver its products today, and at a fraction of in-house development costs. Reduced risk, predictable, fixed pricing, and the freedom to focus on the business of developing aircraft instrumentation are key reasons why the major aerospace manufacturers already use Seaweed Systems software. With its software products available today, its expert staff ready to assist its customers through the development and certification process, and its industry partnerships, there is no better choice for safety-critical, embedded OpenGL software than Seaweed Systems.

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