AVIONIC SYSTEMS STANDARDISATION COMMITTEE

PROCESSING WORKING GROUP

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REAL TIME OPERATING SYSTEMS *

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1 INTRODUCTION

The objective of this report is to provide the Processing Working Group with information on the range and utility of commercially available (or under development) real-time operating systems.

There are currently a number of operating systems available which purport to support real-time operating system (RTOS) requirements. This report identifies and describes commercial off the shelf (COTS) operating systems which have features that may be applicable to real-time military avionics applications. Features such as system performance, through life support and adherence to standards such as the portable operating system interface for computing environments (POSIX) have been considered.

The information contained in this report was principally generated through a search using library and electronic means. In addition to this search a visit to the Embedded Systems Show provided further information on several operating systems. The overall effort was underpinned by a literature review investigating the functionality required of a real-time operating system for military avionics.

It should be noted that the features of each product are determined on the basis of available information. Information provided by vendors is of varying quality and this should be borne in mind particularly when considering benchmark figures which cannot be accurately compared across products.

2 CANDIDATES

2.1 C Executive and PSX

C Executive from JMI Software Systems provides a real-time software environment for embedded applications. It is written in ANSI standard C and functions such as task scheduling, context switching and interrupt handling are implemented in optimised assembly language.

C Executive is available for 8-, 16- and 32-bit CISC and RISC processors and is ROMable from 5 KB of memory. The use of C ensures that C Executive is portable, however the downside is a 10 to 20% speed sacrifice when compared to code written in the “native” assembly language of the processor it serves. PSX adds a subset of

POSIX.1 system calls to the C Executive kernel allowing applications to migrate from POSIX conformant UNIX platforms to board level systems.

Current applications of C Executive include military avionics and Federal Aviation Authority radar control systems.

2.2 Vx Works

At the heart of the Vx Works run-time system is a microkernel which supports a range of real-time features including multitasking, interrupt support and both pre-emptive and round-robin scheduling. Kernel operations are fast and deterministic. For example, context switching requires 3.8 microseconds on a 68k processor (MV167C board) and interrupt latency is less than 3 microseconds. Vx Works is designed for scalability and is suitable for embedded systems requiring a few kilobytes of memory or large distributed systems.

Vx Works supports a range of industry standards including POSIX.1003.1b real-time extensions and it is ANSI C compliant. Vx Works is supported by the Tornado toolset which includes a system debugger, a real time data monitor and a rapid prototype development environment.
Further information is available from Wind River Systems at web site http://www.wrs.com/vxwks52.html or via Email to enquiries@rtp.co.uk

2.3 LynxOS

LynxOS is a proprietary UNIX like RTOS. It provides pre-emptive, deterministic, real-time responsiveness while still providing UNIX looks, feel and compatibility.

Average interrupt response times of 7 microseconds can be achieved on an MVME177 microprocessor platform at 50 MHz. LynxOS is modular, scalable and ROMable.

C and ADA language support are available for the LynxOS and a complete set of development tools including a performance analyser and debugger are available.

LynxOS is conformant with POSIX 1003.1, POSIX1003.4 and supports the POSIX.1, POSIX.4, POSIX.4a, Berkeley (4.3 BSD) and AT & T System V (SVID) application program interfaces. This support is not, however, appropriate for real-time modular avionics systems in all cases. POSIX.4 does not support message passing using data busses such as would be found in a modular avionics system. Current development work is concerned with achieving compliance with POSIX.1003.21. Further information is available from web site http://www.lynx.com or via Email to sales@lynx.com

2.4 Chimera

Chimera is a multiprocessor real-time operating system designed to support the development of dynamically reconfigurable software. Chimera offers a multiprocessing real-time kernel which supports both static/dynamic scheduling and several multiprocessor communication and synchronisation primitives. Error detection and error handling are offered at a global and deadline level.

Every aspect of kernel processes may be overridden by user generated code and both C and C++ programming languages are supported within Chimera's integrated development environment.

Chimera has been incorporated into systems at the US Air Force Institute of Technology and The Jet Propulsion Laboratory. It is not presently suitable for real-time military avionic systems as it cannot guarantee a deterministic response. More information on this product is available via Email to Prithvi.Rao@k.gp.cs.cmu

2.5 Allegro

Allegro is a modular multi-tasking operating system for 386, 486 and Pentium based computers. The Allegro file system is DOS compatible and multiple 16 and 32 bit processes are supported. Hardware interrupts are enabled at all times (except during short intervals as required for interlinking) and scheduling is provided by a pre-emptive scheduler with dynamic priority determination.

Up to 1024 simultaneous processes with up to 4090 open files or devices per process are supported. Allegro offers a multi level, prioritised signal system which, it is claimed, provides all of the capabilities of a multi-thread system.

Allegro is implemented primarily as an operating system for PC and PC compatible hardware although it can be customised for ROM based embedded systems. It does not comply with any industry standard and does not lend itself to embedded applications. Therefore it may not be appropriate for use in military avionics systems. Further information on this product can be obtained at web site http://www.allegrosys.com/desc.html

2.6 Harmony 4.1

Harmony is a multitasking, multiprocessing RTOS developed at the Canadian National Research Council Laboratories. It was developed for applications where predictable

temporal performance is required. As such it supports task priorities and offers a guaranteed response time to an interrupt of 20 microseconds on a 25 Mhz Motorola MC68040 processor. Harmony has facilities for dynamic task creation and supports dynamic memory allocation. Harmony is ROMable, extensible (from a 25-30 KB kernel) and portable across a range of host microprocessors (currently 50 valid combinations of processor type and board models have used Harmony).

The development environment is portable and code is compatible with the ANSI x3.159-1989 definition of C and with the ARM definition of C++.

2.7 RTEMS (Real Time Executive for Military Systems)

RTEMS is a real-time multiprocessing executive based on standard interface specifications. It is portable across applications, programming languages and computer architectures. Implementations are available in two languages, C which supports 68020, 80386 and I80960 based machines and ADA which supports 68020 based machines.

RTEMS has been designed to provide event driven, priority based, pre-emptive scheduling and executes in a deterministic manner . Interrupt latency time is determinable ensuring that a system will respond to external events in a timely and predictable manner. RTEMS supports dynamic memory allocation and provides mechanisms to detect and process unrecoverable errors.

RTEMS is modular and may be scaled to meet performance and code size requirements. It may be configured at both the object and system level. Standardisation of this product is to US Military specifications.

2.8 Real-Time Mach

Real-Time Mach is based on the Mach kernel but offers specific services and models to accommodate the requirements of real-time systems. The kernel approach defines a minimal set of services which are fundamental to the operation of the system and allows the user to develop system applications and functions on top of these kernel services.

The basic premise of the design has been to provide the system designer with the ability to predict the schedulability of hard and soft real-time tasks, thereby allowing real-time systems to meet their requirements. To this end the timing attributes are included in the service calls which create the threads (tasks). The ability to apply different scheduling schemes makes the Real-Time Mach approach inherently attractive for real-time systems.

If an appropriate level of international availability and standardisation can be achieved Real-Time Mach may be suitable for use in military avionic systems. Further information is available via Email to raj+@cs.cmu.edu

2.9 Chorus

Chorus is a micro-kernel which provides a set of basic services onto which the developer can build his system as required. The kernel was explicitly designed to support real-time distributed systems.

Chorus is portable, ROMable and scalable. The micro-kernel has been designed to provide UNIX like services, however it is a specific commercial product and offers little scope of internationally standardised implementations.

2.10 QNX

QNX offers a RTOS for the x86 chip family. It is based upon a 10 KB micro-kernel providing basic process scheduling (choice of round robin, adaptive, priority driven or FIFO), interprocess communication and interrupt handling facilities. This results in a flexible architecture allowing QNX to be scaled down for an embedded system or up for a large distributed system.

Mission-critical applications are supported through the incorporation of multiple redundant links and “hot standby” systems. Interrupt latency is typically 5 microseconds, context switching requires 5 microseconds and process latency is predictable . QNX is compliant with POSIX.1003.1, POSIX.1003.2 and POSIX.1003.4 standards. Further information is available via Email to info@qnx.com

2.11 Maruti 3.0

Maruti is a RTOS project based at the University of Maryland. Maruti 3.0 is an embeddable hard real-time system for distributed and single node systems. It features a small core (14 KB for a single node core and 25 KB for a distributed core) and runs on Intel 386, 486 and Pentium processors. The core provides a calendar based scheduler, threads and for the distributed option, time division multiplexed access and time synchronisation between network nodes.

A full development environment utilising the Maruti Programming Language (based on ANSI-C) is available.

Current research topics include the integration of Maruti 3.0 with industry standards and the use of ADA for Maruti programming. A copy of Maruti 3.0 is available on request, via Internet ftp. Requests should be sent via Email to maruti-dist@cs.umd.edu

2.12 RTXC

RTXC is a real-time executive offering over 70 kernel services and guaranteed response times. Much of the code is written in C and RTXC supports a wide variety of CISC, RISC and DSP microcontrollers and microprocessors. RTXC uses signals and queuing as a basis for managing and scheduling tasks. Scheduling is based on assignable priorities and, within the same priority, by round-robin.

RTXC is distributed as ANSI C source code which has been optimised for applications requiring high performance (current applications include civil avionics and medical equipment). RTXC is available free but is not public-domain software. Further information is available via Email to mikep@world.std.com

2.13 ARTX/OS

ARTX/OS, developed by Ready Systems from the VRTX operating system, is a real-time multitasking operating system specifically designed for ADA applications. Based on the industry standard ARTX kernel it offers deterministic performance and interrupt handling routines with an interrupt disable time of 10 microseconds or less (based on a 25 MHz 68020 processor). ARTX/OS technology is used in military avionics, space systems, radar and sonar. Further information has been requested from suppliers of this product.

2.14 OS-9

OS-9 is a modular real-time, multi-user, multitasking operating system developed by the Microware Systems Corporation. The kernel and all user programs are ROMable and OS-9 can run on any 680x0 based hardware platform.

Priority based, pre-emptive task scheduling, interrupt and exception handling services are provided. OS-9 does not appear to comply with industry standards and as such may not be appropriate for use in real-time military avionic systems.

Further information is available via Email to info@microware.com

2.15 Spring Kernel

The Spring Kernel has been developed at the University of Massachusetts as part of their real-time systems research. The system is intended to provide predictability, on-line dynamic guarantees, atomic guarantees, end to end scheduling and resource reservations. It utilises a micro-kernel design for multiprocessor architectures and provides an interface to remote processes, support for distributed shared memory and predictable low level communication.

The Spring Kernel RTOS is still in development and current work includes the integration of subsystems such as RT-POSIX and the incorporation of a predictable real-time “sterile” thread capability.

Further information is available at web site
http://www-ccs.cs.umass.edu/spring/os.html

3 CONCLUSIONS

There are currently a wide range of COTS operating systems available and the market place for these products is growing rapidly. Much of the raw data analysed in generating this report was supplied by system vendors and it has proved impossible to accurately compare different operating system performances. However, it is possible to sort the candidate sample into three broad classes according to their suitability for real-time military avionic applications. These three classes are.

Suitable candidates.
Candidates worthy of consideration.
Candidates unlikely to be suitable.

3.1 Suitable Candidates

RTOS in this group appear to offer functionality appropriate to real-time military avionic applications. In particular they offer deterministic processing and guarantee system latency times appropriate to a hard real-time environment. Factors such as conformance to industry standards and the likelihood of through-life support being available from a supplier were also considered in selecting candidates for this group.

C Executive and PSX
Vx Works
RTEMS

3.2 Candidates worthy of consideration.

Candidates falling into this group offer features that may be applicable to real-time military avionic applications. However they are not classified as suitable candidates as they fail to provide the balance of features offered by suitable candidates or a full assessment of their suitability was not possible due to insufficient information.

LynxOS
Harmony 4.1
Real-Time Mach
QNX
ARTX/OS
OS-9

3.3 Candidates unlikely to be suitable

These candidates fail to provide the basic features required of a RTOS appropriate for military avionic applications. Several reasons exist for a candidate falling into this group. These include failure to provide deterministic processing times, non adherence to standards or an incompletely developed processing environment.

Chimera
Allegro
Chorus
Maruti 3.0
RTXC
Spring Kernel

4 RECOMMENDATIONS FOR FURTHER WORK

This report provides an overview of currently available RTOS that offer features which may be applicable to real-time military avionic applications. It is clear that further work is required in order to establish which operating system provides the optimum performance for a particular operating environment. Further work should focus on determining the suitability of shortlisted candidates for particular applications.