Interfacing Aircraft to Commercial Personal Computers

Dan W. Christenson
USAF

ABSTRACT

The focus of this paper is the concept of utilizing commercial PC products and interfacing them to military and commercial aircraft. The problem of the life cycle of the different products is examined from multiple viewpoints. Existing products are described, architecture for each implementation is derived, and their strengths and weaknesses are explored. Finally an attempt to define the root causes for the problem of implementation of interface architectures in this environment will be presented.

A new developmental architecture will be introduced. This architecture is designed to maintain the strengths of the traditional architectures and eliminate some of the weaknesses and inefficiencies.

A series of hardware/software co-development projects will be described to demonstrate the new architecture. The relative performance of the architecture has been evaluated and refined by multiple implementations. These will be described and future implementations examined.

INTRODUCTION

In response to a growing need within the United States Air Force (USAF) to lower operating costs, a significant amount of research has been initiated to find logical, supportable opportunities to utilize commercial products to replace products that have historically been custom designs. Multiple development efforts have helped to refine concepts that have proven their utility at lowering acquisition costs. Other efforts have proven to have lower sustainment costs. Recent development efforts have shown that by managing the architecture of the developed equipment, it is possible to lower the overall life cycle cost, while providing long-term, technically viable, and user friendly equipment.

BACKGROUND

For the last decade the Department of Defense (DoD) has been faced with budget cuts that have translated into personnel lost, weapons systems development budgets slashed, maintenance budgets curtailed, and weapon systems lifetimes extended. In this era of doing more with less, one of the easiest implemented directives was to use, to the greatest extent possible, Commercial Off-The-Shelf (COTS) products. Because the DoD does not command a significant part of the electronics market share, it has little ability to affect the direction of the overall market place. This has been further underscored by the cancellation of most military standards,

Author's Current Address:
Ogden Air Logistics Center, Software Engineering Division (OO-ALC/TIST), 7278 4th
Street, Hill AFB, UT 84056-5205, USA.

Based on a presentation at Autotestcon '00.

US Government work not protected by US Copyright.

Fig. 1.

because, among other reasons, the standards themselves could not be updated quickly enough to allow military product developers the opportunity to use current technology before it became obsolete.

Some EARLY uses of COTS included applying commercial PCs to aircraft back shops and flight lines. Several generations of COTS PC products have been in use by the USAF.

Each of the PC products introduced into the DoD has faced a similar set of initial requirements, each has taken a similar path to implement the requirements, and each has had similar problems at the end of the short product lifetime. These PCs are used for a variety of uses, including: user interfaces for embedded computers, memory loader/verifiers for embedded computers, test equipment, test equipment controllers, technical order delivery systems, and digital communications equipment.

A recent picture that ran in many aerospace and local publications highlights the problem that the USAF is facing. The picture was a family photo of a B52 commander, his father, and grandfather. All three had served on the same aircraft. As weapons system lifetimes are extended the opportunities to update the systems becomes more challenging. While every electronic system in the B52 may have been updated, remnants of the original infrastructure remain. Much like today's railroads have track separation distances based on the wheelbase of Roman chariots, the avionics systems of the USAF have interface specifications which have outlived their authors.

When the F-4 left the USAF inventory in the 1990's, it still retained interface descriptions that reflected its Resistor Transistor Logic (RTL) roots from the 1950's. The F16 discrete signal interface descriptions that were written in the late 1970's have specifications most easily implemented by switches and relays.

Only in the last 10 years has the AIM-9 missile provided an interface that did not reflect its original servo type interface developed in the 1950's. For many years, both the aircraft and the weapon implemented the original archaic analog interface using a mixture of analog and digital circuitry only because it was the easiest way to make sure the weapon and weapons system would be interoperable. Ultimately, just as in the case

of the AIM-9 missile interface, the designer of today's computer to aircraft interface is forced to be compliant with the existing weapons system interfaces.

Traditionally, with each new embedded computer, a new method to communicate with and control it was introduced. This is unfortunate for today's interface design engineer. When you examine the historical rationale, there were at least four significant reasons to create one's own protocol:

1. Forced by the aircraft, unique throughput or communications needs.
2. Were not aware of a standard that would meet their needs.
3. Chose because of management concerns.
4. Chose because of convenience.

In many cases this uniqueness extends to voltage levels, drive current, timing, and data protocol. The number of electrical interface "standards" now exceeds 100, the number of data protocol "standards" is several times that number. This means, that in most cases, each interface that the designer approaches is different from the last. It has only been since the late 1970's that any significant communication standards have existed for aircraft. If a designer is to interface with many different aircraft interface types, flexible interface techniques must be developed.

As this set of issues was evaluated, it became apparent that addressing this problem was the central issue for the architecture. Because the aircraft life cycle and the commercial PC life cycle are so far out of synchronization, and because that gap is growing, providing a long term, supportable method to "buffer" the two environments is the essential artifact of this architecture. A graphical representation of the concept is shown in Figure 1.

Since with each new interface type, the adapter between the aircraft and the PC had to be addressed as part of the design, the logical place to build a "standard" was at that point. This point was named the Aircraft Adapter Group (AAG). The name was chosen because the predecessors of this architecture used AAGs to interface their standards loader/verifier to the

weapons systems. Therefore this historical name was chosen because it is somewhat analogous to the function.

EXAMPLES OF PC BASED SUPPORT EQUIPMENT

Three USAF examples of aircraft support equipment based on PC technology include: the ATS/PGM's DCS, the F-16 EDNA, and the F-15 PLV-NT. Each of these PC based systems was introduced into the USAF inventory in the last 15 years.

Each was acquired with similar standards that have traditionally been levied on all support equipment. Virtually none of the PC products utilized for aircraft support equipment were used without modification. The necessity to modify the interface was driven by additional requirements associated with the unique environment of use. These environmental requirements fall into two basic categories:

1. Security environment to avoid compromise of classified data when the equipment is operated in the close proximity of those who had no need-to-know.
2. Physical environment that required all I/O be installed inside the PC and that the PC be made environmentally compatible with a USAF flight line.

Forcing the PC to comply with these requirements has at least three negative effects:

1. They drive up the acquisition cost because the COTS PC selected is virtually a custom product.
2. They drive up the re-host cost because the new PC has to be re-procured from the original source because of proprietary data issues.
3. Compliance drives down the overall performance because the custom computer market lags standard PCs by as much as 2 years.

As these pieces of equipment were introduced into the inventory, they were initially well received, but quickly were considered archaic when compared to traditional PC equipment. Their lag behind technology, the inability to use current hardware and software products, and the cost to acquire and maintain the equipment made them unpopular. Within a fraction of the traditional USAF product lifetime, each was considered obsolete and in need of update and/or replacement.

The USAF has not ignored this problem and as early as seven years ago, efforts were made to begin to create support equipment standards. Efforts have also been made on the weapons systems acquisition system to drive standardization. At this point the electrical interface "standards" fall into the following standards: IEEE488, RS232, RS422, MIL-STD-1553, and "unique." Depending on the weapon system type about 60% of the interfaces are MIL-STD-1553, 20% are RS422, RS232 and IEEE488. Of the "unique," many are simply the electrical interface between the micro-processor

and its memory. Techniques to address these interfaces have been developed. There are interface devices that implement all of the standard interfaces. With the development of the Field Programmable Gate Array (FPGA), interfacing to "unique" interface standards was greatly simplified. The "unique" interface timing as a minimum can be fully implemented. In the case of Transistor Transistor Logic (TTL) based standards, the electrical portion of the interface can be addressed as well. These technologies were incorporated into EDNA and PLV-NT, driving the acquisition costs to 1/3 of the traditional loader/verifier. This was considered a great feat, until it was recognized that even though the new devices were designed to last 10 years, the products became obsolete in less than 3 years. This made the products no cheaper than their predecessors. The lesson learned is that not only must the acquisition cost be lower, the product acquired must be an "add on" so that neither internal installation nor modification to the PC is required. This allows the PC, weapons system and the AAG to be independently modified to accommodate updates in any of the three.

REQUIREMENTS DEVELOPMENT

Three years ago a team of users, program managers, and engineers were convened to begin looking at the growing problem. The support equipment requirements that forced modification of the PC were addressed.

At the core of this development effort is the requirement to address a problem that plagues the entire DoD, commercial product lifetimes are becoming shorter and DoD product lifetimes are becoming longer. As the evaluation proceeded, the basic requirement for developing a stable architecture emerged: develop a suite of standards based tools and products that can be functionally implemented with many technologies.

The significant driving function, as mentioned earlier, is the rapid development cycle of the commercial PC. The PC must be allowed to change to utilize current technology. For this reason and for this application, the USAF has adopted a non-traditional approach, allowing functional configuration instead of traditional physical configuration. This means no effort is to be taken with the new equipment to physically configure the PC. Any PC that complies with the functional configuration document is acceptable for use.

The need to modify the PC to accommodate security requirements was replaced with tests and procedures that accomplished the intent of the modification. These tests must be accomplished on a relatively small sample lot and are the basis for the technical data that describe additional security protocols that are necessary to protect the classified information being processed.

The need to have an integrated PC that addressed all the interface requirements was replaced by a lightweight PC with a small number of external interfaces that address each type of aircraft interface.

To accommodate MIL-STD-1553 remote terminal and monitor functions, without significant local buffer in the

Fig. 2.

AAG, any external interface must exceed 1Mbit/sec. Realistically the interface should be 10Mbit/sec to allow time for processing data and calculation of responses. This limited the commercial standards that were examined to accommodate the need to: SCSI, Ethernet, FireWire, MIL-STD-1553, and USB.

Because the external interface would have to be powered, an interface that could provide the needed power was desirable. This limited the selections to FireWire and USB.

Because USB is part of the PC standard it became the choice. However, because USB is still an emerging standard, and because we have demonstrated that any standard has a limited acquisition lifetime, the number of interfaces that depend on this interface must be limited.

As implementations were examined, it became obvious that MIL-STD-1553 would be best accommodated in a separate interface, and because of the availability of commercial USB-IEEE488, initial implementations will be procured commercially until an IEEE488 core for the (FPGA) can be developed. Figure 2 represents the block diagrams of the interface elements that currently implement the AAG architecture.

The strengths of prior developments include utilization of FPGAs to implement most of the weapons system interfaces and PC based user interfaces to lower the recurring costs. Those strengths are preserved with this architecture. In addition, by limiting the host PC interface to one type, in this case USB, and by limiting the dependence to only two points, if the interface type becomes obsolete, the amount of re-host required to update to current technology is minimized. While USB is current in the PC environment, the host PC can be updated independently of the AAG hardware.

PRIOR IMPLEMENTATIONS

Variants of this architecture were successfully utilized with minor variation to implement USAF subsystems.

1. The Ogden Data Device (ODD). This device is used to interface with data transfer cartridges on F-16 and A10. The ODD was utilized for Mission Planning purposes for over 7 years with only minor modifications and updates to the driver software.
2. The Personal Computer Memory Loader Verifier (PCMLV). The USAF used this device for F-4 reprogramming during Desert Shield. It has been in continuous use by allied countries for over five years, and has performed flawlessly.

ADDITIONAL BENEFITS

Because the development tools can be hosted on the computer that is being utilized to host the interface, a simple quick and mobile development environment can be established. This allows the development environment to be taken to the integration environment during integration. This is extremely convenient when no local hot bench or integration facility is co-located with the AAG development environment. Many times the equipment to be interfaced is in remote, otherwise inaccessible locations.

The equipment is usable in multiple environments: flight line, back-shop, development, and integration facility.

Because the equipment is based on prior implementations, the development costs can be lowered by re-use of development artifacts.

SUMMARY

The USAF has selected the architecture described for implementation of the next generation loader/verifier. The Common Aircraft Portable Reprogramming Equipment (CAPRE) was chosen by the USAF as the next generation loader / verifier. The benefits of this implementation are:

1. Long term supportability.
2. Simple re-host.

3. Supports shorter PC life cycle and longer weapons system life cycle.
4. Supports hosting of the development tools on target platform.
5. Mature and stable technology.
6. Useful in multiple environments: development, back-shop, as well as flight line.

This program is being implemented under program direction of SA-ALC/LDA with technical implementation accomplished by OO-ALC/TISMD.

2001 MAPLD Conference

JHU / APL ▲ Laurel, Maryland ▲ September 11-13, 2001

The 4th Annual Military and Aerospace Applications of Programmable Devices and Technologies International Conference will address devices, technologies, usage, reliability, fault tolerance, radiation susceptibility, and applications of programmable devices and adaptive computing systems in military and aerospace systems.

This year's conference includes papers and an emphasis on CPU design (both traditional processors as well as those embedded in ASICs/SoC and programmable devices), logic design, and device reliability. The program consists of oral and poster technical presentations and industrial exhibits.

This unclassified conference is open to US and foreign participation. Select papers will be published in the *AIAA Journal of Spacecraft and Rockets*.

Two tutorials / seminars will be given:

1. *Programmable Logic Devices and Architectures*; and
2. *Advanced Design: Designing for Reliability*.

Invited speakers include: Arthur F. Obenshain, NASA Goddard Space Flight Center, Director, Applied Engineering & Technology Directorate; LTG Ronald T. Kadish, US Air Force, Director, Ballistic Missile Defense Organization; Roger D. Launius, Chief Historian, NASA; James E. Tomayko, Carnegie Mellon University; David A. Bearden, The Aerospace Corporation; and Steve Guccione, Xilinx Corporation.

The conference is sponsored by: NASA Goddard Space Flight Center, JHU/Applied Physics Laboratory, National Security Agency, Electronics Radiation Characterization Project, Digital Engineering Institute, Military & Aerospace Programmable Logic Users Group, American Institute of Aeronautics and Astronautics, IEEE Aerospace & Electronic Systems Society (AESS), and the Air Force Research Laboratories.

For further information, see the conference home page: (<http://rk.gsfc.nasa.gov/richcontent/MAPLDCon01/MAPLDCon01.html>).