11.0 Software Infrastructures and Standards

Introduction

Computer software exploits the capability of computers and their attendant communications and enables all the applications to which computers are being put. The breadth of computer use in commerce permits the military to exploit the massive investment being made for commerce, manufacturing, education, and entertainment. This investment will continue to drive progress, and the benefits are available to all: commerce, the military, our friends, and our adversaries. While the Air Force cannot push progress in general software infrastructure capabilities beyond those boundaries, it must assure that its acquisition regulations permit it to remain current with the state-of-the-art.

This brief monograph will focus on issues where there are specific Air Force and DoD opportunities or issues. For a broad outline of status and plans for DoD software we refer to the proceedings of the July 17, 1995 workshop on "Defense Software Research, Development, and Demonstration: Capitalizing on Continued Growth in Private Sector Investment", by a panel of the National Academy of Engineering. That report draws in turn on the draft DoD Technology Plan for Software, developed by Barry Boehm et al., and on the analysis by the Defense Science Board Task Force on Military Software.

11.1 Definitions

Software infrastructure comprises the operating systems, communications, networking, input/output software, the file systems and databases, as well as many of the tools that are now expected to be delivered with a computer system. The scope of infrastructure software is increasing rapidly. As researchers or developers sense that some application function is repeated in several instances, it will be implemented as a sharable tool or service. If the tool or service is effective it will be marketed and in time displace functions previously bound to particular applications.

The type of tool will differ depending on the type of computer system. Mainframe computers will be equipped with transaction management systems for commercial processing, mini-computers for process control will have real-time data-acquisition and control software, engineering workstations will have support for shared access to design drawings and files, multimedia systems will have image-processing software, and personal computers will have word-processing, graphics software, and spreadsheets.

Services will be offered over the ubiquitous networks. Services include passive services, such as databases and other information resources which can be accessed by customers and their programs, as well as active services, such as software agents which will carry out tasks as searching and retrieval for specified types of data. Added-value services have an economic value, and are typically provided by commercial or publicly supported institutions. Mediators are processing services on the network which can access, transform, aggregate, and integrate data to provide information tuned to a specific type of customer, domain, or application type. Mediators provide added value, and are associated with an expert or an institution which takes responsibility for the content and quality of the result.

Software languages and their compilers are also part of the infrastructure, but have a reduced role today for the DoD compared with the days when DoD software was written in hundreds of languages and dialects with little concern for commonalty with non-DoD practices. Today few principle languages remain, and they all have a specific niche:

1. FORTRAN for scientific computation and sensor data processing.
2. Ada for embedded and secure software modules.
3. LISP for artificial intelligence programs, especially their initial demonstrations.
4. C and C++ for systems and general purpose software.
5. Higher-order languages, which typically generate intermediate code in one of the languages listed above.

For the modern, distributed software systems the principal concern is the interoperation of software modules, often written in different languages and operating on distinct hardware platforms. While development and maintenance tactics will differ for different languages, the resulting software code can be indistinguishable.

11.2 Status of Software and Software Acquisition in the Air Force and DoD

Infrastructure software, as enumerated above, is making rapid progress in functionality, performance, and interoperability, driven by intense market pressures. It is not feasible for the DoD to advance the broad front of this arena beyond what becomes available Commercial-Off-The-Shelf (COTS), although there will be pockets where DoD investment can exert crucial leverage. There are invariably intersections where competitive pressures have a negative effect, for instance where vendors benefit from limiting interoperation with their competitors.

It will be difficult for the DoD to keep up institutionally with COTS infrastructure advances if traditional policies of global computer system acquisition, preceded by large scale evaluation and vetting, are followed. A careful, but slow process of determining equipment standards guarantees obsolescence. Two factors come into play here. The obvious one is the delay. By the time the DoD procurement system selects, approves and obtains new equipment, it is obsolete, relatively costly, and hard to maintain. It is rare that DoD computing equipment is less than 3 years old in terms of design, and will therefore necessarily be well behind the state-of-the-art. Having obsolete equipment means that modern software and existing infrastructure products are hard to use. Savings due to spending less on acquisition of hardware and software infrastructure induce major costs in applications and their maintenance, which would be avoided if systems were state-of-the-art.

The second factor is less obvious. Selling equipment to the DoD removes vendors from commercial realism and has caused their eventual demise. The DoD and Air Force acquisition focus must shift to defining standards for interoperation (as TCP/IP), and letting military units buy the best and most modern hardware and software that complies with those interface standards. Today the individual soldier often has a better personal laptop than the equipment provided by the DoD. There are numerous anecdotes from Desert Storm that illustrate individual initiatives where personal equipment provided solutions.

11.3 Projection for Investment

Not all applications needed by the Air Force will be satisfied by the commercial world. But even DoD specific software can benefit from using the best tools available. Using modern tools also helps in tapping the existing talent pool of software specialists, and reduces training costs. Given the rapid progress of the computer industry in providing infrastructure improvements and the widespread familiarity of recruits and contractors with computing, assessments of software investment are essential.

11.3.1 Progress Due to Commercial Interests

We focus on infrastructure software here: the operating systems and the basic network services that connect the computer systems.

Commercial interests are causing a rapid convergence to a smaller number of distinct software systems. While there were once dozens of mainframe operating systems controlling large computers, hundreds of intermediate systems, and a diversity of small systems, we can project that ongoing commercial investment will be limited to three to five families of basic operating systems, all available on multiple vendor platforms. We posit that there will be one operating system for mainframe computation, likely based on IBM practice, one for a family of intermediate systems, clustered around a standard operating system architecture based on UNIX or Windows NT, and perhaps two or three families of systems on personal computers. It is not unlikely that this number will reduce further, although there will continue to be vendor-specific versions. There will also be broad use of standards among those systems, for instance SQL to enable UNIX-systems to access mainframe databases, and CORBA to enable personal computers to access object-structured resources kept on UNIX-based servers.

These interoperability standards will continue to grow in breadth and capabilities, since, for each vendor, maximizing access to resources of others is crucial for winning market share. Similarly, features made available in one system will be rapidly replicated and superseded by features provided by a competitor. Specifically the arena of multi-media will continue to see rapid change, since the spread of visual information to millions of sites, driven by the entertainment industry, will motivate investment to lower cost and enhance capabilities. Even though the pace of change may slow down somewhat, there is little doubt that throughout the next 25 years the commercially available software infrastructure will provide the foundation for most DoD and Air Force systems. Even mission-critical applications will be supported in this manner, although the systems they acquire may be vetted for security and trustworthiness, causing DoD to lag behind the curve with respect to features and cost-performance ratios. This lag should be minimized, so that the differential of SW availability and its capability to exploit modern hardware does not lag excessively behind that of adversaries, who have fewer constraints.

Legacy systems will continue to exist beyond their economic lifetime because of conversion costs, but where the systems have to interoperate they will be wrapped to conform to existing standards.

11.3.2 Capabilities Appropriate for Government Support Funding

A concern for the national effectiveness of broad-based software systems is the developing of common and sharable systems, and the standards that enable interoperation, to avoid excessive dominance of a few vendors. This would lead to a concomitant isolation of computational communities and specializations, say operations researchers and knowledge engineers.

Vendor competitiveness motivates uni-directional compatibility, but of broader concern is bi-directional interoperation, so that users, and specifically DoD customers, retain the flexibility to change platforms and use systems that are composed with hardware and software obtained from multiple vendors, including competitors. Standards, and verification of conformance with standards, are tasks that should be supported by government, to assure fair and early dissemination of sharable technology. Such standards should focus in *interfaces*, not on equipment of software, so that best possible equipment can be obtained within interface constraints.

Infrastructure standards to consider include:

1. Operating system services as micro-kernels and POSIX
2. Base communications, as TCP/IP and successors
3. Database access, as SQL, RDA and successors
4. Object-oriented and multi-media access, as CORBA, MPEG, and successors
5. Knowledge transfer, as KIF and successors
6. Multi-representation interoperation, as OLE, KQML and successors

DoD can protect its interests by requiring its contractors to use standards rather than proprietary solutions whenever feasible, encouraging developers to use the most recent and emerging standards, and supporting researchers' participation and travel to the standards developing committees, so that the compromises of the vendors will be mitigated by forward-looking participants.

Within the US government NIST has the primary role for standards, including software standards, but has rarely been able to be proactive. There is hence a role for DoD research agencies to support standards activities that can accelerate the adoption and availability of sharable technology of interest to the military from commercial vendors. Examples of such involvement are the ARPA CSTO support of an operating systems micro-kernel, which can enable the transition of modern operating system technology into multiple vendors' military embedded systems, and the ARPA knowledge-sharing initiative, to assure interoperation and easy employment of artificial intelligence technologies into DoD information systems.

These subsystems, integrated into the commercially available infrastructure, will provide the sharable basis for future military information and control systems, and assure that software systems developed for the Air Force and other branches of the military can be flexibly and rapidly deployed. They will displace the bottom layer of the traditional stovepipes that characterize DoD system architectures. They will also provide the infrastructure for interoperation of general software development and the global information systems that are higher in the information system food chain.

11.3.3 Capabilities Requiring Military Investment

On top of the considerable commercial and national infrastructure will be some requirements that require specific military investment if US SW technology is to be maximally effective and superior to the technology of adversaries. Specific capabilities include:

11.3.3.1 Real Time

Highly robust real-time software modules are needed for data fusion and transmission. Real-time constraints require an ability to shed load or modify processing tactics in order to satisfy hard-time constraints on result delivery or feedback initiation. As improved fusion algorithms are being developed there is a need to incorporate them rapidly into the system infrastructure. While high-rate performance requirements are also common to commercial real-time systems, there is less of a need in commerce to assemble specific systems as rapidly as the demands of newly emerging threats. In the commercial world real-time systems, such as those used in refineries, factories, or power plants, the systems are carefully designed and evolve as the facilities are upgraded. Filters exist to assure that no unexpected signals enter the real-time processing stream. These conditions cannot be counted on in military situations.

11.3.3.2 Integration Of Simulation Software Into Military Information Systems

The support of decision making requires simulation, but the commercial tools lag far behind those used for advanced military simulation for training and modeling. The current applicable commercial interoperation standards focus on components such as spreadsheets and graphics, and permit at most dynamic incorporation of spreadsheet results into textual documents. Standards such as CORBA permit access to general object-oriented data, but little flexibility is provided, so that simulation objects cannot be easily aggregated, or partitioned.

It is doubtful that commercial progress relevant to interoperable simulation will support military requirements, if the planned insertion of simulation into all phases of military systems acquisition, testing, deployment, training, planning, and plan execution proceeds at the pace envisaged. At the same time, conceptual and structural similarity with developing standards in the COTS world should be maintained, so that plug-and-play capabilities are maintained. The Air Force must not put itself in an isolated position.

11.4 Paying Attention

Organizationally, it will remain critical for the Air Force Labs, such as Rome Lab, to maintain close linkages with ongoing technology and continuously monitor the gap between the available and emerging commercial technology and military needs, identifying the high leverage items that warrant the attention and funding of the Air Force.