ARCHITECTURE FOR SURVIVABLE SYSTEMS PROCESSING (ASSP)

Technology Benefits for

OPEN SYSTEM INTERCONNECTS

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RICHARD J. WOOD
RL/OCTS
ASSP Program Manager

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1.0 INTRODUCTION

The Architecture for Survivable Systems Processing (ASSP) program is a two phase program whose objective is the derivation, specification, development and validation of an open system architecture capable of supporting advanced processing needs of space, ground, and launch vehicle applications.

The output of the first phase is a set of hardware and software standards and specifications defining this architecture at three distinct levels. The lowest level consists of the hardware bus(es), operating system, and software development environment. It facilitates the interoperability/interchangeability of heterogeneous processors for the processing subsystem. The middle level is the intraplatform networking of the subsystems such as the data processing subsystem with the communication and other subsystems, as shown in Figure 1-1. The sensor and signal processing subsystems, although frequently connected by point-to-point links, may also be candidates for networking technology. The top level is the interplatform networking between common platforms, and to platforms of other system elements. In most cases, existing standards will be adequate; specification of these standards is all that will be required. Where standards do not exist or are inadequate, specifications will be developed. These specifications will be approved by the government Technical Advisory Group (TAG) to insure non-parochial interests and eventual acceptance by appropriate standards committees. The first phase output will include breadboard implementations of ASSP specified interconnection technology. This breadboard will be implemented in flight deployable hardware, to demonstrate the architectures capabilities as defined in the SOW.

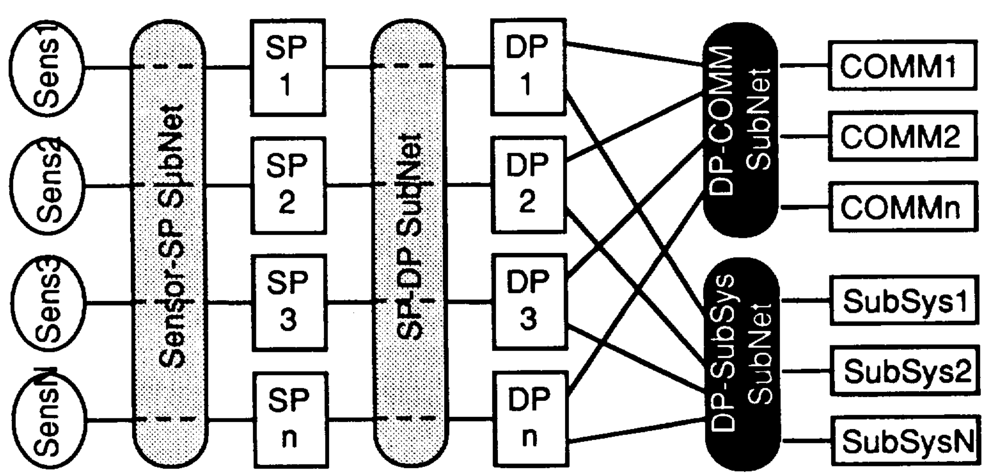


FIGURE 1-1: Application of Networks within a Surveillance Satellite

The second phase of the ASSP program will validate these standards and develop any technology necessary to achieve strategic hardness, packaging density, throughput requirements, and inter-operability/inter-changeability.

2.0 PROBLEM STATEMENT

The Follow - on Early Warning System (FEWS) and Brilliant Eyes (BE) are some of several specific programs whose requirements are being used to drive the ASSP program. They were selected because of stressing operational requirements, that will need:

1. **Interplatform communication standards** between satellites from different contractors and ground stations.
2. **Backplane and intrasatellite network standards** to minimize breakage during Block to Block transitions as the processing loads shifts from ground to space.
3. **Interplatform communication standards** between Satellite constellations (BE, FEWS, DSP-upgrades etc. terminal defense systems (GSTS, THAAD, E^2I, etc.), and the ground stations during EOAC and GPALS. Figure 2-1 summarizes the benefits of ASSP in this context.

The selection of standard intrasatellite network architectures can minimize the re-design of the interfaces between subsystems during block upgrades, Similarly the selection of a standard backplane can simplify upgrading from Block to Block. For example, a 16-bit processor can be replaced with a 32-bit processor that both interface to the same backplane, yielding an order of magnitude improvement in throughput with minimal impact on other board designs. Finally, the selection of a standard operating system interface will allow applications software developed to be reused ensuring cost effective transitions.

The selection of interplatform communication standards mitigates the risk that Satellite constellations can interchange handoff messages with interceptor systems, and deliver summary messages direct-to-users.

3.0 ASSP NETWORKING SOLUTIONS

The International Standards Organization (ISO) developed the Open Systems Interconnect (OSI) standard in response to the growing need in the commercial community for interoperability among different computer vendors. That same need is now manifesting itself in the defense community. ASSP was conceived with the idea of taking advantage of the significant commercial investment in OSI technology, while also bridging the differences in networking requirements between the commercial and defense communities. BE and FEWS are examples of programs that have portability, upgradeability, and interoperability requirements that can be met through the work being performed on the ASSP program. This section will provide a brief overview of the state-of-the-art commercial OSI technology and how ASSP is utilizing that to solve problems for programs like Integrated Satellite Control Systems (ISCS), Common Communications Components (COM^3), and Corporate Information Management (CIM)

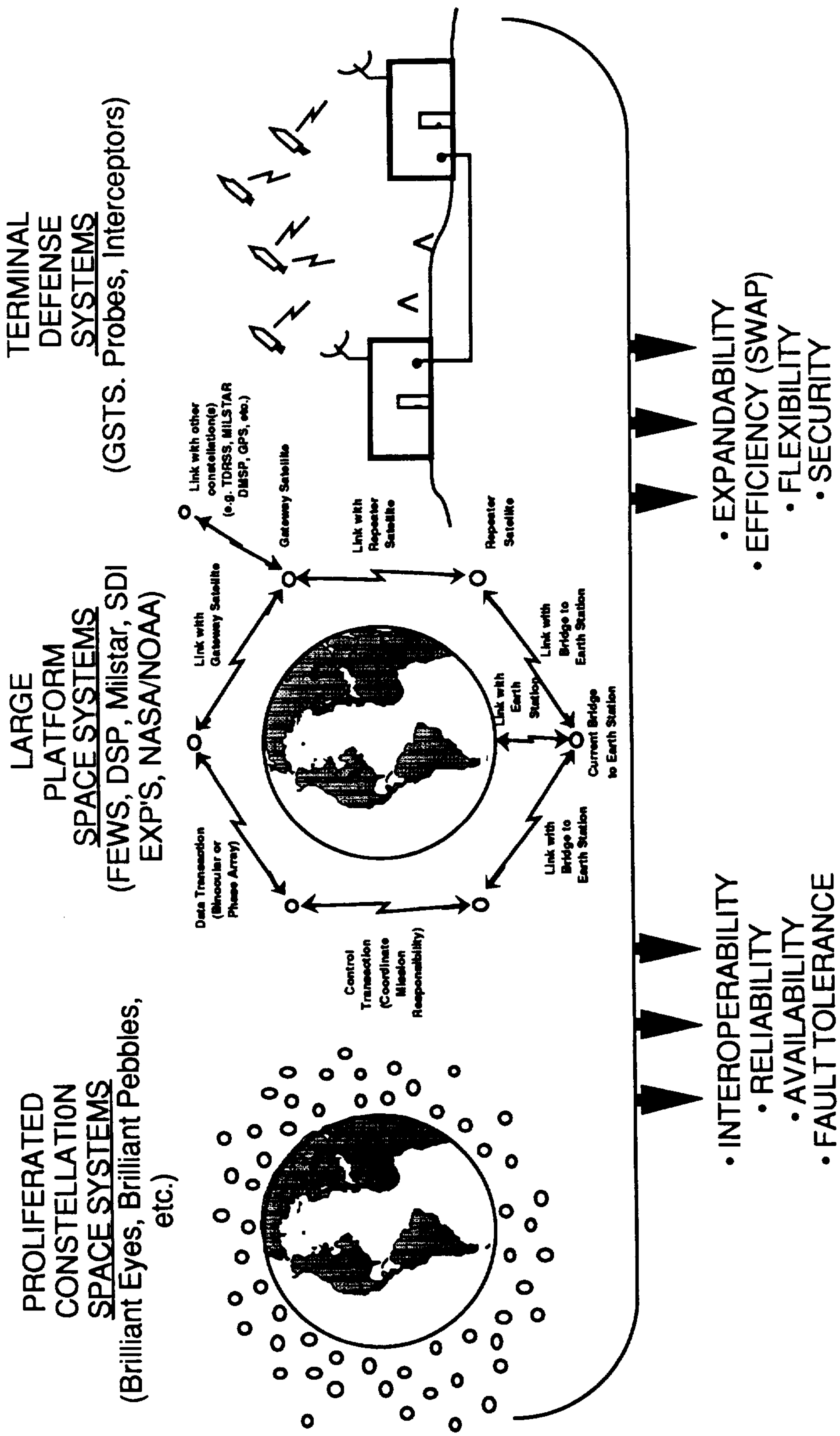


FIGURE 2-1: ASSP User Community

Figure 3-1 shows the layers that make up the OSI Reference Model. This model is based upon the well-known principle of "information hiding". To reduce design complexity and promote portability and interoperability the OSI Reference Model uses layers, where each layer builds upon the services/functions offered by its predecessor. The purpose of each layer is to offer specific services to the higher layers, shielding those layers from the implementation details of how the service is implemented. Thus, by standardizing only the interface between layers, and not the implementation, implementations can change without having to modify higher layers. For example, the Network Layer is primarily concerned with routing messages between processors. If the routing scheme were to change, the Transport Layer and all higher layers are shielded from this change - requiring little or no modification to their implementation. This is a powerful concept that allows much easier insertion of new communication technologies with minimal cost and schedule impact.

The challenge facing the military community is how to take advantage of this networking standard and the significant commercial investment in associated technologies. Most of the commercial use of the OSI standard is in Local Area Networks (LANs) on the manufacturing floor or in the office. Although the defense community can make use of this work (and is), the real need is for the use of standards in embedded systems. The embedded environment offers much more stringent communication requirements than the corresponding manufacturing or office environments. In addition, high throughput density and reliability requirements, and the emergence of advanced backplanes, combine to cause networking concepts to be applied at the backplane as well as the traditional LAN level. Very high speed, efficient communications are required in an environment that places severe restrictions on size, weight, and power. Thus, communication protocols must be specified/developed that are not computer and/or memory intensive. ASSP's mission is to provide a suite of protocols that satisfy the OSI standard and meet the requirements of the embedded environment.

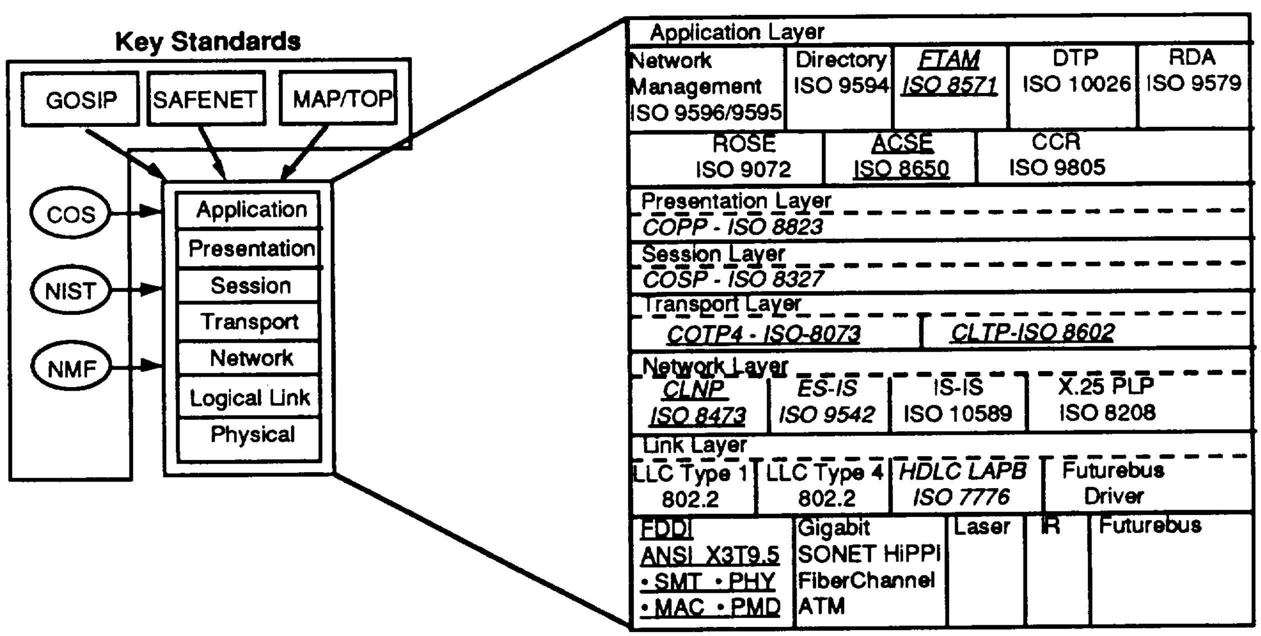
Layer No.	Name	Protocol
7	Application	Supplies user services, application-specific standards
6	Presentation	Provides code conversion, data reformatting
5	Session	Coordinates interactions between end application processes
4	Transport	Ensures end-to-end data integrity and quality of service
3	Network	Switches and routes information
2	Data Link	Transfers information to other end of physical channel; controls media access
1	Physical	Transmits bit stream over the medium

FIGURE 3-1: ISO/OSI Reference Model

3.1 Application Through Network Layers

The Application Layer through the Network Layer provide communication services accessible by application programs. These layers provide services such as guaranteed message delivery, checkpoint/rollback, security, encryption, data conversion, etc. The lower two layers (Data Link and Physical) are primarily concerned with managing the physical communication medium (twisted pair copper wire, coaxial cable, fiber optics, parallel backplanes, RF links, etc.) and are discussed separately in Section 3.2.

For each of the layers, the OSI Reference Model specifies numerous options. It recognizes that there is not one all encompassing set of network functionality that satisfies the communication needs of every user. Thus, for each of the OSI layers, there exist many protocols that provide all or part of the functionality specified by the OSI Reference Model. In addition, there exist standard "profiles" which specify a suite of protocols that provide a single OSI implementation. For example, the MAP and TOP profiles specify a standard OSI implementation (including specific options that are mandatory) for manufacturing and office environments. Each specifies protocols that provide functionality that best satisfies the needs of each environment. ASSP will develop a similar embedded systems OSI profile, where specific functionality is required for each layer in order to interoperate with other systems implementing the same profile. Existing commercial protocols will be used extensively in the creation of this embedded systems OSI profile. Figure 3.1-1 shows some of the sources we will draw upon as well as a tentative list of specific protocols that will make up the embedded systems OSI profile.



- Items in *italics* are part of the GOSIP standard
- Items underlined are part of the SAFENET-II standard

FIGURE 3.1-1: ASSP OSI Architecture

ASSP recognizes that not all applications need to start at the top of the OSI "stack" in order to send/receive messages. Therefore, options of implementing "short stacks" and/or "layer bypassing" will be provided. A "short stack" is one in which only the layers necessary to meet a specific application's communication requirements are present. Thus, the overhead associated with sending/receiving a message can be significantly reduced. The cost for this, of course, is in decreased reliability, functionality, and/or security for the transmitted/received message. However, in embedded systems, this is often an acceptable trade in order to increase communications throughput. "Layer bypassing" can be used to decrease the overhead associated with the transmission/reception of an individual message. With a full ASSP OSI stack present, an application can choose to send a message using the functions associated with specific layer(s). This is useful when only selected messages require faster transmission/reception, while others require the full functionality offered by the ASSP embedded systems profile.

Use of the embedded systems profile developed by ASSP will allow Platforms to meet portability, upgradeability, and interoperability requirements. Its use will allow satellites developed by different contractors to communicate with each other and common ground stations. The upper layers will provide standard functionality that will support this interoperation. Factors such as buffer overflow, message acknowledgement, lost packets, data conversion, etc., that previously fell into the O/S or applications' domain, are handled by the upper layers of the embedded systems profile. Many of the details of the communication links are hidden from application developers, thus each contractor has less complex (and therefore lower risk) software designs. An additional benefit is that specific satellites should be able to easily communicate with other systems (such as BE, FEWS, MILSATCOM, GBR, J-STARS) that also use the ASSP embedded systems profile.

In addition, use of the ASSP embedded systems profile will ease the portability/upgradeability problems like the BE contractor will face in moving from the Block 1 satellites to Block 2. Because applications are hidden from the details of communications and networking, new technologies can be easily inserted without affecting the applications. Only the implementation of the OSI layer(s) that is affected by such a technology insertion would change. Therefore, the risk of upgrading from Block 1 to Block 2 is significantly decreased by the use of the embedded systems profile developed by ASSP.

3.2 Link Layer and Physical Layer

The link and physical layers of data communications within satellite architectures could consist of the hardware required to implement interconnection within and between spacecraft, as well as of up/down link communications hardware. ASSP technology development will result in lower cost, shorter schedules, and improved performance. These benefits accrue from early definition, specification, and development of the principal hardware interfaces required for candidate designs. Four types of interface standards will be developed by ASSP which are projected for Spacecraft application: backplane, high-speed serial, R-F link, and sensor/signal processor interface. Application of these technologies are as follows: backplanes for Payload Data &/or Mission Data Processors; high-speed serial for Communications Subsystem, S/C Control Subnetworks, and S/C Management Subnetworks; radio-frequency for Cross-link and Up/Down link networks; and, sensor/signal processor interfaces for interface between Sensors and Signal Processors, or between Signal Processors and Data or Mission Processors.

Interconnection standards specification and technology development independent from system contractors is appropriate because an independent effort, such as ASSP, can address the needs of all system elements and ensure compatibility between BE, FEWS, and other GPALS elements. In addition, the independent specifications provided by ASSP will facilitate technology insertion and lower risk for individual projects.

First, ASSP will develop not just technology trades and roadmaps, but detailed specifications for a backplane, high-speed serial network, R-F network, and sensor/SP I/F's which are specific to space-based surveillance platforms. These specifications will include the following:

- **Physical Interfaces** - drivers/receivers, connectors, media characteristics, frequency and loading performance, etc.
- **Media Access Protocol** - encoding, clocking, arbitration, control/modes, handshake, error detection, etc.
- **Logical Link Services** - virtual channels, addressing, flow control, buffer management, burst and latency performance, multiprocessing and DMA support, error recovery, etc.

These specifications will constrain implementation of the interconnection hardware for the four target technology types (backplane, high-speed serial, etc.). The advantages of ASSP specifications will be that they will make maximum use of advanced "open", nonproprietary standards such as Futurebus+ and FDDI, and will extend them to accommodate size, weight , power, environment (including radiation), fault tolerance, and other requirements for space applications. This will allow maximum flexibility in prototyping and software development while providing highly capable technologies for space use.

Second, ASSP will develop components which fill technology gaps, and integrate these with other available components to build and validate integrated interconnection hardware for each of the four interconnection types. This includes hardware design instantiations of the backplane, high-speed serial network, R-F network, and sensor/SP interface specifications. Any new hardware designs will be done in VHDL and targetable to radiation-hardened VLSI libraries. Hardware for each interconnection type will be integrated and will include low-level communications management, buffering, control, protocol, error recovery, encoding, driving/receiving, connectors, and media, among other functions. Verification/validation of each interconnection network type will include demonstration of specific GPALS, FEWS threat detection and tracking applications. This will ensure the ability to handle the desired surveillance communication traffic at all interconnection levels.

Finally, in Phase II ASSP will update protocols and services, provide additional packaging density, and integrate strategically hardened prototype interconnections networks. These upgraded networks will be compatible with prior designs due to the open system development strategy of ASSP. Thus, transition to more stressing onboard processing for FEWS would be smoothly accommodated using ASSP technology and specifications.

4.0 OPERATING SYSTEM SOLUTIONS

Satellites developed and launched within the Integrated Satellite Control System (ISCS) directives will require the latest software technology to produce realtime, embedded software systems that will ensure performance, reliability and long operational life that will live up to the expectations of the proposed systems.

The ASSP program is the source for the requirements and specifications for such systems. By adopting an "open system" approach and striving to adapt from the best commercial, university, and government non-proprietary products, ASSP will specify an operating system based upon commercial standards, protocols and rules and DoD, NASA are in a position to profit.

Three major structural characteristics point up the utility of the ASSP Operating System (O/S): a standardized application programming interface (POSIX, ISO 9945-1 and ISO 9945-2), support for Ada applications executing in realtime, and portability of the O/S kernel that will ease the risk of hardware upgrade to higher performance processors. The following discusses each of these characteristics in detail.

The IEEE standards group has defined a Portable Operating System Interface, extended (POSIX) for the C language, that initially came out in 1988. It has been extended to cover realtime, multitasking, and the Ada language. This standard defines the function calls to the underlying operating system such that an application will get the same service on any host as long as the host O/S meets the same POSIX standard. The ASSP program is working with the IEEE standards groups to select the proper subset of these specifications that support the BE, FEWS class of problems. By writing the software following the POSIX standard, future upgrades will have minimum software risk.

The Department of Defense has defined Ada (DoD-STD–1815A) to be the high order software language for realtime, embedded systems. This is a large step along the way to having a repository of reusable realtime code. However, an additional step is needed; the application program interface to the operating system on the host computer must also be defined by an accepted standard. Otherwise, the reusable software is the oft-stated 95% complete with the other 5% costing the usual non-recurring.

The ASSP O/S has a layered structure (see Figure 4-1); the kernel layer touches and controls the host hardware, the service/policy layer is made up of the major functions (written in Ada packages) that are needed by the applications, and the applications layer has network and system management software in addition to the mission software written by the user. The service layer can be tailored to the needs of the applications, ensuring minimum data latency and the realtime performance required. The OSI stack for network communications is in the service layer and this standard set of protocols provides for interoperability among satellites in or out of their constellations.

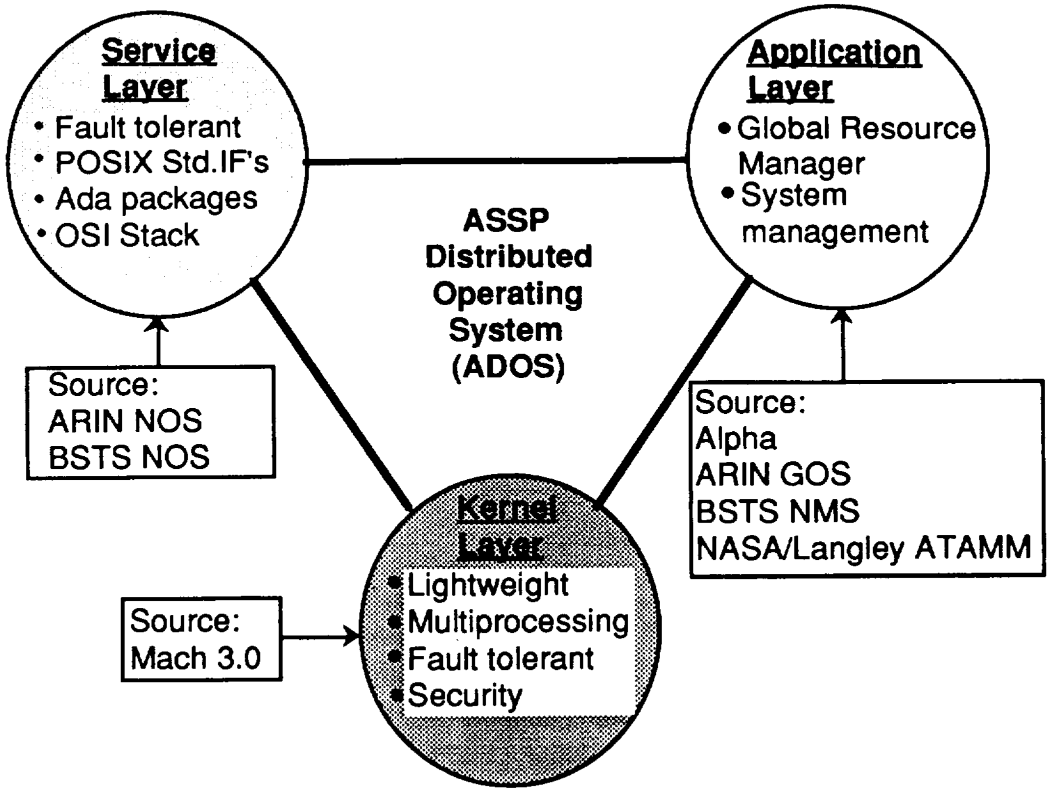


FIGURE 4-1: ASSP Operating System Diagram

The kernel layer of the ASSP O/S is very "lightweight," allocating all functions not absolutely required to control the hardware to the service layer. This contributes significantly to the portability of the kernel to other hosts. When higher performance hardware is required, the O/S can be ported to the new hardware, the Ada application software recompiled, and the upgraded system is ready for integration and test.

The ASSP program also includes fault tolerance in the O/S from the initial specifications to implementation. The system configuration design to meet the reliability and long life will be amply supported by the controlling software.

5.0 SOFTWARE DEVELOPMENT ENVIRONMENT

ASSP will develop a software development platform (SDP) that will support the development of distributed applications targeted for the ASSP environment. State-of-the-art Computer-Aided Software Engineering (CASE) tools will be provided to aid the developer in working with the ASSP O/S and embedded systems OSI profile. Central to the SDP will be the use of a common "software backplane" that provides a framework for building and managing an integrated software development environment.

Features include a common data repository, repository services, and a standard user interface. Since all data stored in the data repository can be accessed through standard interfaces provided by the software backplane, integration of commercially available tools and easy replacement/addition of new tools is supported. This is particularly important in support of upgradeability and lower life cycle cost for long-life programs. Given a 15-20 year program lifetime, it is vital that the SDP support the insertion of new tools/technologies. By conforming to standards in this area, the ASSP SDP insures that developers are not "stranded" in the development cycle using old/obsolete tools.

6.0 ASSP SYSTEM SIMULATION SOLUTIONS

One of the principal ASSP outputs is a global, all inclusive simulation of the interaction of surveillance communications subnetworks. This simulation will be used to verify protocols, fault tolerance, network capacity, etc. Communications interactions are probably the most fundamentally difficult processing problems to analyze without simulation.

Space based as well as ground application programs can benefit greatly from the ASSP simulation tool technology development. ASSP will provide model library, user interface, and inter-simulation data transfer enhancements to the most popular commercially supported communications simulations packages. The enhancements will be fully documented and supported so that contractors will have a user friendly, highly capable simulation available which already has detailed library models of all the relevant system interconnection components and protocols. Availability of the ASSP documented and verified simulation tool allows communications simulations performed by multiple contractors and/or by multiple system elements to be combined to form large multi-system simulations.

7.0 CONCLUSION

The ASSP program directly responds to common government/industry deficiencies in providing architecture profiles that can support and upgrade processing systems without major redesigns, and procurements. It responds as well to the directives and goals for Corporate Information Management (CIM), Modular Open System Architecture Standards (MOSAS) and the Common Communication Components (Com^3). This program provides capabilities to launch processing networks that are versatile, offer various levels of complexity and are capable of rapid upgrades in mission profiles, hardware, and operating systems. The capability to incorporate commercial hardware breakthroughs along with their respective software support in a very short time frame and with a minimum of redesign//retooling provides significant Life Cycle Cost (LCC) savings and is most beneficial and advantageous to the DoD.

Feasibility demonstrations with preliminary System/Segment Design Documentation deliverables are scheduled at the completion of Phase 1a (FY92). Phase 1b and Phase 2 can be regarded as options to be exercised as directed by the ASSP Program Office.