Systems Integration

of the

777 Airplane Information Management System (AIMS)

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ABSTRACT

The systems integration of the 777 Airplane Information Management System (AIMS), both within the AIMS system and with the other systems on the airplane, represented the most complex system integration effort ever undertaken at Honeywell Air Transport Systems Division. The technological innovations in the AIMS design, coupled with an aggressive program schedule, were major factors in the AIMS challenge. Honeywell and Boeing had to work closely together to complete the design and development of AIMS in a time frame that supported the 777 Early ETOPS goal. With teams from the two companies working as one unit, redundant activities were eliminated, technical and program problems were identified and solved rapidly, and schedule time was saved by both teams helping with tasks that were traditionally considered to be the other team's job.

OVERVIEW

The Integrated Modular Avionics (IMA) architecture implemented by the 777 Airplane Information Management System (AIMS) represents a radical departure from the federated LRU architecture that exists on most commercial transports today. The design, development, integration, and testing of this system would have been a major accomplishment even on a traditional new airplane development program. Two complicating factors on the 777 program were the plan to receive ETOPS (Extended Twin Operations) approval immediately after initial type certification, and the desire to provide an airplane to the airlines that was service-ready at initial certification. To reach a high level of system maturity in time to support the ETOPS mission, Honeywell and Boeing developed a much closer and open approach of working together. This approach was used not only at the program management level, but also to resolve design issues, integrate AIMS lab facilities in both Phoenix and Seattle, support flight tests, and jointly perform system verification.

This approach was a huge success. It enabled the Honeywell-Boeing AIMS team to accomplish far more than what could have been done using a traditional airframer/supplier relationship. This paper will examine, in more detail, some of the key areas where Honeywell and Boeing worked together to make AIMS a reality, specifically: system design, system integration, system verification, and program management. In order to more fully understand and appreciate this discussion, an architectural overview of AIMS follows.

SUMMARY OF AIMS ARCHITECTURE

The philosophy behind the AIMS architecture is to provide a host platform where avionics applications (e.g., Flight Management, Displays) can share common platform resources. A block diagram of the AIMS architecture is in Figure 1 (on next page). The heart of the

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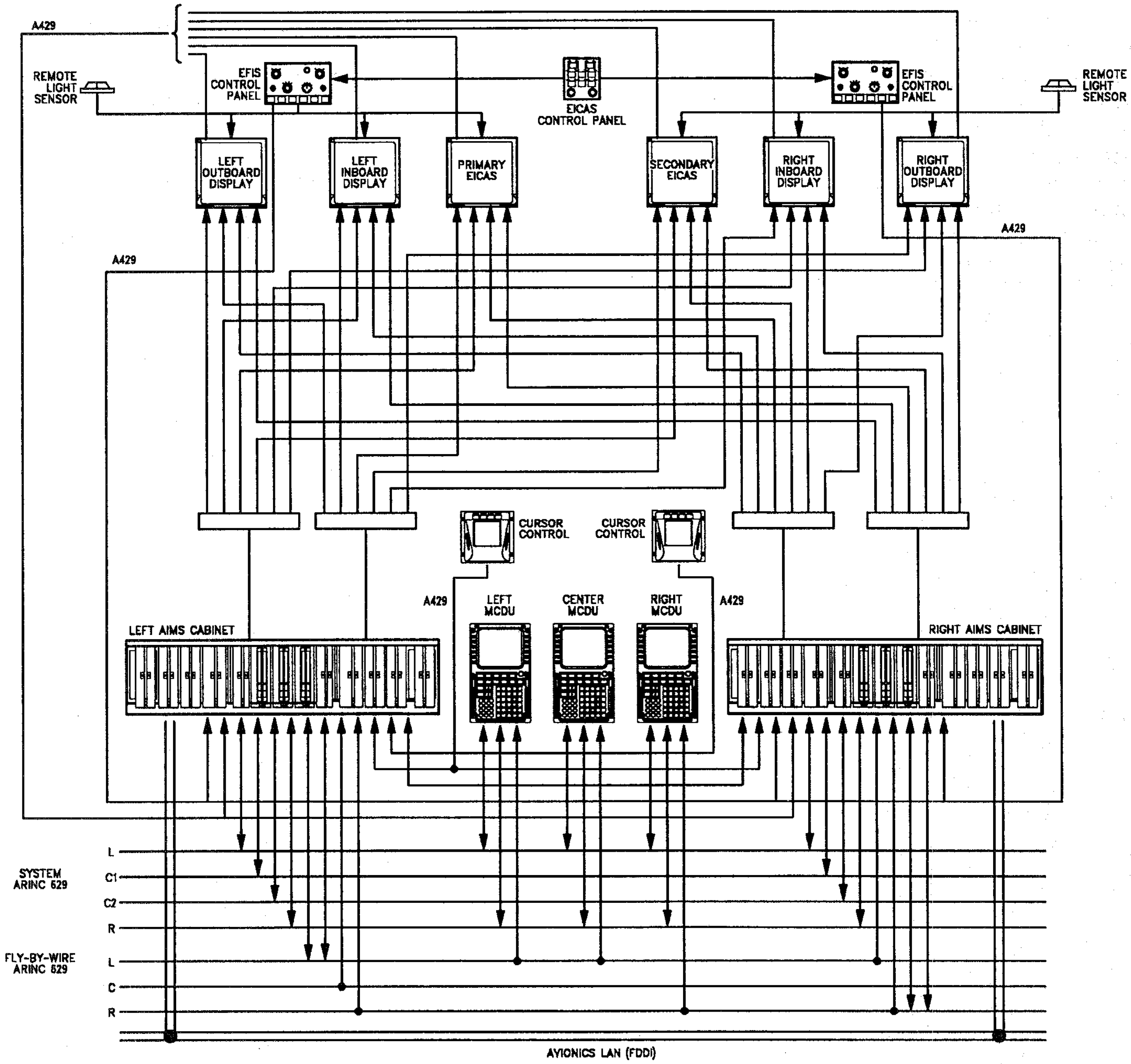

Fig. 1. AIMS Baseline Architecture

AIMS system consists of dual cabinets in the electronics bay that each contain 4 core processor modules (CPMs) and 4 input/output modules (IOMs), with space reserved in the cabinet to add one CPM and two IOMs to accommodate future growth. The shared platform resources provided by AIMS are:

- common processor, power supply, and mechanical housing;
- common input/output ports, power supply, and mechanical housing;
- common backplane bus (SAFEbus™) to move data between CPMs and between CPMs and IOMs; and
- common operating system, built-in test (BIT) and utility software.

Instead of an individual application residing in a separate LRU, applications are grouped together on CPMs. The IOMs transmit data from the CPMs to other systems on the airplane, and receive data from these other systems for use by the CPM applications. A high-speed backplane bus, called SAFEbus™, provides a 60 Mbit/second data pipe between any of the CPMs and IOMs in a cabinet. Communication between AIMS cabinets is through four ARINC 629 serial busses.

The robust partitioning provided by the architecture allows applications to use common resources without any adverse interactions. This is achieved through a combination of memory management and deterministic scheduling of application software execution. Memory is

allocated before run time, and only one application partition is given write-access to any given page of memory. Scheduling of processor resources for each application is also done before run time, and is controlled by a set of tables loaded onto each CPM and IOM in the cabinet. This set of tables operates synchronously, and controls application scheduling on the CPMs as well as data movement between modules across the SAFEbus™.

Hardware fault detection and isolation is achieved via a lock-step design on the CPMs, IOMs, and the SAFEbus™. Each machine cycle on the CPMs and IOMs is performed in lock-step by two separate processing channels, and comparison hardware ensures that each channel is performing identically. If a miscompare occurs, the system will attempt retries where possible before invoking the fault handling and logging software in the operating system. The SAFEbus™ has four redundant data channels that are compared in real time to detect and isolate bus faults.

AIMS is designed to be fault-tolerant such that the aircraft can be dispatched for 10 days without maintenance at 99% probability of success. The applications hosted on AIMS are listed below, along with the number of redundant copies of each application per shipset in parentheses:

- Displays [4];
- Flight Management/Thrust Management [2];
- Central Maintenance [2];
- Data Communication Management [2];
- Flight Deck Communication [2];
- Airplane Condition Monitoring [1];
- Digital Flight Data Acquisition [2]; and
- Data Conversion Gateway [4].

All of the IOMs in the two AIMS cabinets are identical. The CPMs have common hardware for processor, memory, power, and SAFEbus™ interface, but have the capability to include a custom I/O card to provide specific hardware for an application "client." The client hardware in AIMS includes the displays graphics generator, the Data Communications Management fiber optic interface, the Digital Flight Data Acquisition interface to the data recorder, ACARS modem interface, and the Airplane Condition Monitoring memory.

The other flight deck hardware elements that make up the AIMS system are:

- Flat Panel Display Units [6];
- Control and Display Units [3];
- EFIS Display Control Panels [2];
- Display Select Panel [1];
- Cursor Control Devices [2]; and
- Display Remote Light Sensors [2].

SYSTEM DESIGN AND DEVELOPMENT

The AIMS team began the program in October 1990 with some monumental design challenges in front of them. Since the architecture was so different, many new designs were required; CPM, IOM, SAFEbus™ and its interfacing hardware, and Flat Panel Displays are major examples. Boeing and Honeywell worked together on the Specification Control Drawings (SCDs) for AIMS (18 in all) to define the system level requirements. A highlight of this activity occurred in May of 1991, when as many as 65 Honeywell engineers went to Seattle to support a three-week push for the initial SCD release. System requirements were freely challenged by engineers at both companies. This process helped ensure that the requirements that drove the system design were necessary and of high-value.

System interface definition and control posed a major challenge, since AIMS interfaces with the majority of avionics systems on the 777. Boeing developed an electronic Interface Control Document (ICD) to define and control system interfaces at the airplane level. Honeywell developed a complementary Data Capture Tool (DCT) that took in the electronic airplane ICD information that related to AIMS. DCT then allowed AIMS engineers to electronically tag each ICD data item that was set or used by their application, and also provided for the entry of system requirements for application memory and processor throughput. This DCT database became the input for the SAFEbus™ Scheduler Tool. This tool generates the set of SAFEbus™ tables which are loaded onto each CPM and IOM to control the movement of data within the cabinet and to control the scheduling of each application's actual run time on the CPM.

Managing the allocation of cabinet resources (processor throughput, memory, and bus bandwidth) was a big task, and a very dynamic one. Some of the applications were new designs and had no historical resource data to use as a starting baseline. Many applications saw their initial estimates grow once detailed system design began. A central systems integration group had responsibility for working together with the application functions to establish memory, throughput, and bandwidth budgets for each application, and to manage to these budgets throughout the design phase. This activity kept a constant focus on resource-efficient design, and in some cases caused the Honeywell/Boeing team to change the AIMS system requirements to allow functions to fit within their resource allocation.

SYSTEM INTEGRATION

The need to begin application and system integration before the actual airborne hardware could be completed required "simulation" CPMs and IOMs to be developed for use in both Honeywell and Boeing lab

facilities. These modules did not have the throughput or fault containment that the airborne hardware had, but enabled initial application integration to begin seven months before the flight hardware was available. They also provided proof-of-concept validation for many new aspects of the system, such as SAFEbus™, partitioning, and application design.

A schedule for AIMS software loads was defined early in the program to allow AIMS functionality to be developed in a logical progression which supported Boeing factory and flight test needs. Application teams performed software builds (compile/link) privately to integrate their application to a level that would support AIMS level integration. A central Software Integration Team had responsibility for generating the AIMS level software builds on specific dates. Using a central software build team ensured that AIMS level builds had compatible interfaces and functionality between applications.

Lab integration in Phoenix included Boeing on-site personnel that worked with each application team. Integration was also facilitated by a central platform test team made up of both Honeywell and Boeing engineers. This team worked with application engineers to troubleshoot problems with the platform or the application-platform interface, and was crucial during both the simulation hardware and flight hardware integration phases.

Lab integration in Seattle began immediately after the first delivery of simulation hardware and application software, and included Honeywell on-site engineers. A major contributor toward well-coordinated integration testing was the daily integration teleconference between Seattle and Phoenix. This allowed the integration performed in both facilities to be complementary, and minimized redundant testing. It also allowed problems discovered in one facility to be quickly communicated to the other, so that time wasn't wasted investigating problems twice. Boeing integration of AIMS applications took place on Boeing test benches, while initial airplane-level integration was performed using Boeing's 777 Systems Integration Lab (SIL). The SIL contained actual 777 avionics equipment, complete with airplane-level electrical and power interface connections. The use of this facility reduced the amount of on-airplane testing that would have otherwise been required, since it allowed actual system-to-system interfaces to be exercised before going to the airplane.

On-airplane testing took place first in the 777 factory, with AIMS as a central component in the airplane build, test, and troubleshooting process. The AIMS Central Maintenance Computing System allowed Boeing factory personnel to test the other avionics systems on the airplane, while the AIMS Displays System provided maintenance pages which gave a dynamic, graphic indication on the flight deck displays of the data values of the interface signals between AIMS and the other airplane systems. Honeywell rotated Phoenix integration engineers to Seattle for 2 month on-site assignments to support the integration and use of AIMS in the factory. After first flight, Honeywell and Boeing worked together to support a very aggressive flight test schedule, with as many as 6 airplanes flying at any one time. Flight test status and problems were communicated daily from Seattle using electronic mail. This not only proved to be an effective method of initial problem reporting, but was well-received by the hundreds of engineers in Phoenix and Seattle working on AIMS as a way to keep abreast of the status of the 777 flight test program.

SYSTEM VERIFICATION

AIMS contained more than 600K lines of software, so the verification effort was enormous compared to past programs at Honeywell. Honeywell and Boeing engineers working in Phoenix and Seattle participated in the formal verification effort, which included test planning as well as actual test development and execution. By doing joint test planning, Honeywell and Boeing were able to minimize test redundancy and complete system testing in time to support the initial type certification in April of 1995. A test coordination team consisting of engineers and managers from both companies was formed early in the test phase of the program. This team used regular teleconferences (daily during the last months of the program) to remove obstacles from the test process, facilitate the shifting of test resources, and exchange application and overall AIMS test status.

As with the system integration phase, the test phase utilized lab resources from both companies. A great deal of application testing was performed using a mainframe computer-based simulation test bed. Test benches at both companies, populated with real and simulated AIMS hardware, gave application teams the capability to integrate their own functions and to do some low-level integration with other applications. Honeywell designed and built two full flight deck simulation facilities to allow integration and verification testing of the entire shipset of AIMS equipment. These two facilities and the Boeing SIL were also used to run a series of flight and maintenance operational tests. These tests exercised AIMS in the same way as an airline flight or maintenance crew, and helped to validate the AIMS design requirements.

PROGRAM MANAGEMENT

It was recognized early in the program that there was a need for exchanging information between Phoenix and Seattle. An electronic link between Seattle and the Honeywell mainframe computer allowed electronic mail to be exchanged between companies, and this feature was extensively used throughout the program for informal communications. To facilitate the exchange and retrieval of formal communications, Honeywell developed a tool for

managing coordination memos and action items. The system was hosted on the Honeywell mainframe, and was therefore accessible to both companies. Coordination memos and action items could be drafted, sent, sorted, and printed by personnel from Honeywell and Boeing. The on-line accessibility of the tool made formal communication and action tracking efficient.

A single problem reporting and change control database system was used on the program, and was accessible by both Boeing and Honeywell engineers. This saved time over past programs where separate problem reporting systems were used, since it cut down on the number of redundant problem reports written, and eliminated the problems with losing problem reports or inaccurate translation of problems between reporting systems.

The concept of honest status sharing was used from the beginning on the program between both companies. Although some traditional techniques were used to manage the AIMS program (e.g., weekly status faxes and monthly program status reviews), program problems were attacked in a positive way by the Honeywell-Boeing team. Blame was never a focus; coming up with positive actions to fix problems was emphasized throughout the program. This open approach to program management allowed problems to surface and be solved before they could have major negative impact on the program. Taking this approach not only resulted in program success, but it forged working relationships between Honeywell and Boeing that were based on trust and honesty.

SUMMARY

The teaming approach used by Honeywell and Boeing on the 777 AIMS project was instrumental in the success of the program. System design, integration, verification, and program management activities were conducted in an atmosphere of open communication and with a desire by both companies to do whatever was required to get the job done. The result of this commitment to teaming is not only a state-of-the-art avionics system on the world's newest transport airplane. It is a model for a better way to develop avionics systems in the future.

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