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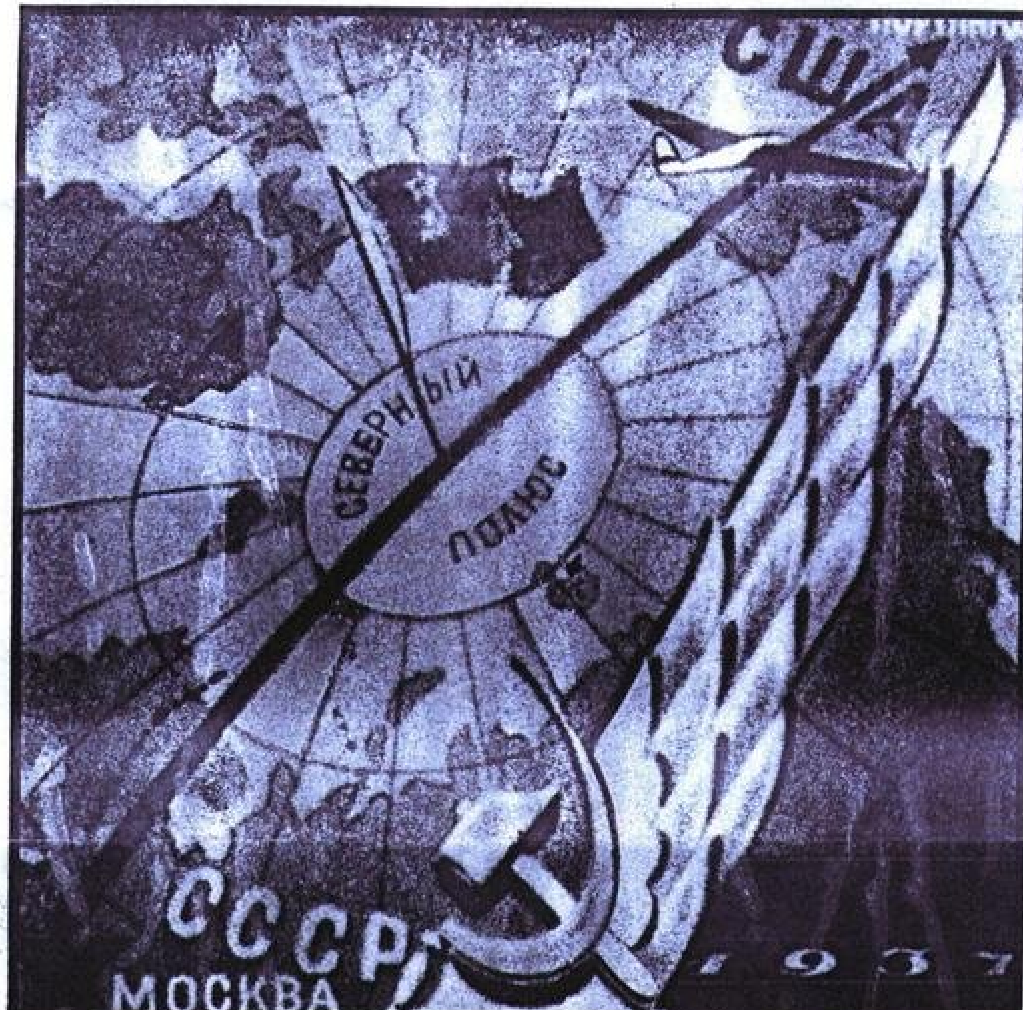

В память первого советского трансокеанского полета

AIR TRAFFIC CONTROL EXPERIENCE

By R. J. Hansen

Hansen is the manager of the Sperry Univac Transportation Systems Engineering Group. The group is composed of Concepts, Communication, Development and Implementation departments. He is responsible for system design, system integration and system and project management of current Automated Radar Terminal System (ARTS III) and ARTS III Enhancements.

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BY R. J. HANSEN, GROUP MANAGER, TRANSPORTATION SYSTEMS

Introduction

Since 1958, Sperry Univac has been an active leader in developing and implementing commercial air traffic control systems by successfully using general-purpose digital data processing systems.

A similar system concept has been successful in the airlines data management field. Sperry Univac's leadership in this related field is the subject of a companion paper.

Successful use of data processing systems in automating commercial air traffic control is assured by strict adherence to the following basic principles:

- Understanding the system application requirements.
- Using proven hardware, system, and software techniques.
- Have data processing system (DPS) respond to input and output of peripheral subsystems.
- Simplifying system design and scope as much as possible.
- Testing and checking progress of development often.
- Staging implementation.
- Providing and encouraging adequate training.
- Planning and preparing for installation.
- Placing extra effort on integration, checkout, and acceptance.

Sperry Univac's experience in automation of air traffic control is described in this paper. The application of real-time system principles to the ARTS III ATC program is also discussed.

Enroute ATC Experience

Sperry Univac's first experience in U.S. air traffic control began in 1958 with the United States' Federal Aviation Administration (FAA).

The system was developed to print flight strips at five of the new Air Route Traffic Control Centers (ARTCC) built during the late 1950's at New York, Cleveland, Boston, Washington, D.C., and Indianapolis.

The computer systems in these centers are basically similar.

The Sperry Univac File Computer performs four functions to relieve air controllers of considerable computational and clerical work.

They receive and store flight plans, compute estimated times of arrival, assemble and printout flight progress strips for display at control sectors, and transmit flight plan information to other FAA control centers.

The Sperry Univac system in Cleveland consists of a central computer, a general storage system of six drums with a total capacity of 1,080,000 characters, and an input/output system.

As many as 10 drums can be attached to the central computer to provide maximum storage of up to 1,800,000 alphanumeric characters. Input/output equipment provided with the Cleveland system includes high-speed paper tape, inquiry typewriter, magnetic tape, and a high-speed printer from which flight-progress strips are displayed in two colors. The colors can be used to distinguish flights by their route direction.

Each of these major FAA centers controls hundreds of flights each day. A large volume of incoming information is normally processed, since each route has several check points at which pilots transmit their positions.

This procedure results in at least as many calculations for each incoming flight as there are check points. Under these conditions, it would be time-consuming and inefficient for a controller to handle several flights at once since a computer performs more reliably and at higher speeds.

Traffic control along major air routes can be demanding, particularly in poor weather. Controlling a great variety of aircraft over such busy terminal areas as New York, Washington or Atlanta is especially difficult.

The task is almost beyond the capability of most human operators during "rush hour" periods and under low visibility conditions.

For this reason, the FAA studied the feasibility of automated systems such as the Sperry Univac 1218 ARTS (Automated Radar Terminal System) system at Atlanta.

The first enroute tracking system application was in 1964 at Indianapolis, Indiana, in a system called SPAN (Stored Program Alpha Numeric). ARTS components from the Atlanta terminal application were adapted to this long range system.

After successful system acceptance by the FAA and nearly one year of operational evaluation, the system was moved to New York. The NYCBAN (New York Center Beacon Alpha Numeric) system was successfully moved, installed and integrated by an experienced Sperry Univac team in 1966.

Sperry Univac is currently under contract to modify ARTS III for application to the Anchorage, Alaska, ARTCC.

This system will interface between FAA enroute radar production common digitizers (PCD) output and the NAS (National Air Space) plan view display subsystem. The system includes radar and beacon tracking on a 200-mile maximum range.

System acceptance by the FAA is scheduled for early 1975.

Terminal air traffic control

Terminal air traffic control facilities rely upon primary and secondary surveillance radar as the principal source of aircraft position information.

Secondary surveillance (beacon) radar, in addition to providing aircraft position, is capable of obtaining identity and altitude information from a beacon transponder in the aircraft.

The basic problem is presenting data from radar and beacon sensors to the air traffic controller in such a manner that he can most easily use it for the control of aircraft.

The conventional plan-position indicator (PPI) radar display technique had serious shortcomings, particularly in areas of high traffic density. Radar information was presented to the controller as a pattern of unidentified video blips on the face of a cathode ray tube.

Arts I and Arts Ia

The FAA recognized the need to alleviate this problem.

In 1963, after considerable research and study, the FAA developed a computerized system that would augment the radar and beacon video on a controller's console with the display of alphanumeric flight data automatically associated with the proper video returns.

This capability was "added to" the existing capabilities. It did not replace those displays and procedures which were developed by tried-and-proven methods through the years.

In 1964, a system was installed to evaluate the alphanumeric feature, and the feasibility of the technique was demonstrated.

The test system underwent field appraisal by the FAA and subsequently went into operational use. It was called Automated Radar Terminal System I (ARTS I).

In 1966, an expanded version, called ARTS Ia, was installed in the New York Common IFR Room at Kennedy International Airport. Both ARTS I and ARTS Ia systems have since been in continuous operation.

These systems provide automatic and continuous association, on a controller display, between the data pertinent to a controlled aircraft and its radar video.

The system tracks targets detected by both primary and beacon radar. ARTS Ia operates in a multi-airport complex and receives target reports from two primary radars and associated beacon radars.

In both systems, track position is indicated by a symbol, which appears directly on the controller's radar display.

In addition to the symbol, the aircraft identification is displayed in unmistakable association with the proper radar blip.

In summary, these systems perform the tasks required to maintain the association between the data on a controller aircraft and its radar blip.

They provide the capability for automatic transfer of information required for coordination between controllers and reduce the need for verbal communication.

In each system, a controller normally views track data only for those tracks under his control. However, he has the ability to display another controller's track data.

This capability is used to great advantage in radar hand-offs within the facility.

The systems also provide the ground facility for effective utilization of the beacon system Mode C altitude reporting capability.

Sperry Univac provided the data processing systems, programming, integration, and checkout for both of these systems under contract to the FAA.

ARTS III System

Successful experience with the ARTS I and ARTS Ia systems permitted the FAA to proceed with confidence in implementing automation at more than 60 medium-to-large terminal sites.

In February 1969, the FAA awarded a contract for implementation of a beacon-only tracking system called Automated Radar Terminal System III (ARTS III). All systems were installed and operational by 1973 under a prime contract to Sperry Univac.

ARTS III simplifies the acquisition and maintenance of beacon identification; displays beacon-derived altitude data; simplifies intra-facility and inter-facility coordination procedures; and reduces the communications work load.

The result is more efficient usage of terminal air space and ATC personnel, and enhanced system safety. The system design of ARTS III was strongly influenced by the terminal area ATC automation experience gained by the FAA in the evaluation and operation of the ARTS I and ARTS Ia systems.

One of the requirements of ARTS III was that hardware and software components be modular in design. This permits the functional capability and traffic-handling capacity of the automated system to be tailored to the requirements of each individual terminal area.

It also permits future expansion of the Beacon Tracking Level system functions and capacities in a cost-effective manner by adding modules without replacement of previously installed equipment.

System modularity results in commonality of hardware, which also simplifies logistics, training, and maintenance requirements.

ARTS III implementation

The actual implementation of over 60 ARTS III systems into airports throughout the United States was one of the most important and successful phases of the ARTS III program.

At virtually every site where the customer-prepared facilities were ready, the turn-key date was on or ahead of schedule.

Furthermore, the transfer of responsibility for the system from Sperry Univac to the customer was efficiently implemented through timely coordination of the services described as follows.

Training

The Sperry Univac Education Department developed the necessary maintenance, systems, and software courses and training materials. Then, they trained a corps of instructors from the FAA Academy.

Training consisted of classroom instruction and laboratory "hands-on" experience on the first ARTS III systems, which were undergoing factory operational systems test in a non-operational environment.

These instructors returned to the FAA Academy and (with the assistance of Sperry Univac instructors as consultants and technical monitors) trained the first classes of FAA operations and maintenance personnel.

The first ARTS III system was delivered to the FAA Academy concurrently with initiation of the first classes and was used for laboratory training.

The Sperry Univac training program enabled the FAA to be almost completely self-sufficient both in their own training operations and in the maintenance and support of ARTS III before acceptance of the first operational system at Chicago.

Site preparation

Smooth integration of ARTS III systems into existing and new FAA facilities was guaranteed by efforts of the Sperry Univac Installation Design group.

Representatives of this group visited typical sites to examine facility structures and make all necessary measurements needed for installation drawings.

From the information gathered, the Installation Design group prepared and submitted to the FAA a typical installation plan, which contained all the physical, electrical, environmental, and interface characteristics necessary for the FAA to prepare a detailed preliminary installation plan for each site, which was then reviewed and approved by Sperry Univac eight months prior to equipment delivery.

During this eight-month period the FAA completed actual site preparation. Meanwhile, Sperry Univac manufactured all system interconnect cables to proper lengths and arranged for any special equipment required for equipment move-in and placement.

Shortly before equipment delivery, a representative of the Installation Design group made a final site inspection to ensure that all necessary preparations had been made to guarantee a smooth system integration.

Installation and checkout

The Sperry Univac Field Engineering group was responsible for installation, checkout, and demonstration of initial operating capability of the ARTS III systems.

A typical installation and checkout cycle began with the shipment of the equipment from Sperry Univac and subcontractors to the site.

Sperry Univac was respon ble for coordinating t shipments and arranging 1 move-in and placement of t equipment.

Most installations requir sequential phases of instal tion and checkout involvi removal of existing subs tems and replacement wi new ARTS III subsystems.

This was necessary to ensu continuous operational cap bility of the site. System i tegrity was ensured by pr grammed and non-pr grammed acceptance tests each unit as it was installed

The final turn-key test co sisted of a comprehensi Site Operation System Te which demonstrated all t operational capabilities of t system. A complete descri tion of on-site testing is i cluded in the "Performan Assurance" section of th paper.

Three features of the install tion and checkout effort co tributed to the smooth tran fer of responsibility for t system from Sperry Univ to the FAA at the completi of the Site Operational Sy tem Test:

1) FAA maintenance an support personnel o served and assiste Sperry Univac field e gineers during all phase of the installation an checkout. The FAA pe sonnel were continuousl informed of the purpos of every action, adjus ment, and test pe formed to alleviate an apprehension about a suming responsibility fo a new, state-of-the-a system.

2) FAA personnel were allowed to use the system for air-traffic controller training on a non-interference basis with the installation and checkout effort.

3) FAA maintenance personnel were given on-the-job training by Sperry Univac field engineers on diagnostic program usage, fault isolation, and equipment adjustments which added to, and reinforced, the training they received at the FAA Academy.

After the FAA accepted each ARTS III system, they continued on-the-job training for a period of time to refine their skills in the maintenance and usage of the system, and to develop confidence.

During this period, air traffic was controlled by pre-ARTS III methods, which served as a back-up mode of operation.

When the site attained full capability and confidence, it was certified and commissioned, and the automated air traffic control capabilities of the system were put into operational use.

Logistics and support services

Turn-key acceptance of an ARTS III system did not end Sperry Univac's involvement or concern with the successful operation of that system. Customer satisfaction with Sperry Univac's products was assured by the following:

- □ Warranty — Timely repair and/or replacement of failed replaceable modules
- □ Follow-on Maintenance — On-site maintenance support at several sites where FAA schedule problems prevent having a full crew of maintenance and support personnel at time of turnkey
- □ On-call Maintenance — Engineering support within 24 hours of a call for emergency aid in solving difficult systems problems
- □ Product Support — Design deficiency corrections instituted when encountered, and product improvement features designed at customer expense when requested by the customer
- □ Spares Provisioning — Recommendations on spares provisioning at site level and depot level; provided spares as requested by the customer.

ARTS III performance assurance

Performance testing of Sperry Univac ARTS III systems was accomplished at three different levels: hardware, software, and system.

The formal acceptance took place at the successful completion of the system test, performed at the customer site, called "turn-key."

The hardware testing consisted of the component tests, design qualification test, factory acceptance tests, type tests, and programmed operational functional appraisal tests.

Component tests consisted of incoming inspection of parts, vendor surveillance, and unit testing of basic components and subassemblies.

Design qualification tests consisted of a series of tests performed one time only on the equipment to prove design concepts which would remain constant as long as the design remains unchanged.

Many of the design qualification tests were identical to production tests. Others were more comprehensive and were conducted only on the first unit, subsystem, or system produced, and were not repeated during production testing.

The factory acceptance tests were special test programs, which support quality assurance functions of inspections, tests, and checkout on the factory test floor for Sperry Univac hardware.

These tests consisted of two phases: the first was the manual (non-programmed) test using electronic measuring devices while inspecting the product for workmanship and varying controls, voltage levels, switch key settings, and indicators.

The second phase used a program and step-by-step procedures to exercise all circuits and to verify proper operation.

The type or environmental test was performed on the first equipment group and several additional samples throughout the production run.

The tests were conducted in a test chamber under various specified environmental conditions while programmed functional tests were cycled.

The Oklahoma City, Detroit, and Dulles systems were subjected to environmental tests. Because of the size of the systems, the equipment was divided into two groups.

The first group was run in the test chamber while the second group was operated at room conditions. Then the two groups were switched and the tests repeated.

The environmental test for each system required approximately two weeks.

The programmed operational functional appraisal (POFA) tests were automated programmed tests that used the computer as a test vehicle to evaluate peripheral equipment performance.

These tests were designed to verify that the equipment can properly perform the functions defined by the design specifications.

For off-the-shelf hardware, reliability figures were available from previous tests.

For the new design equipment, a reliability test was conducted to verify the mean-time-between-failures (MTBF) requirement.

To demonstrate the specified mean uptime of 830 hours, a minimum of 35 days of continuous operation without error would have been required. Instead, the dual-beacon Washington system was operated as the equivalent of two reliability model systems, so that the total running time was accelerated by a factor of two.

Maintainability test requirements were met by keeping records of test failures and calculating the "mean-time-to-repair" of those failures, and by a maintainability demonstration in which simulated failures were diagnosed and repaired. During this demonstration, the diagnostic test programs and procedures were also demonstrated.

The operational program was tested during the operational system test.

The support software, such as assemblers, compilers, and utility programs, were demonstrated to verify proper operation.

The purpose of the operational system test (OST) was to verify that both the operational program and equipment comply with the customer's specifications.

To prove this compliance, it was necessary to prepare a test plan outlining the functions that were to be tested and the method to be used to test the functions.

The test plan was reviewed with the customer, and discussed at meetings, to obtain concurrence.

The approved final test plan served as a basis for writing the test programs and operating procedures. The procedures were then submitted and meetings held to discuss the procedures.

As soon as the operational program debugging had been nearly completed, the system test program and procedure debugging was started. During this period several hardware, software, and procedural problems were solved.

Once the test programs and procedures were debugged and the equipment and operational software were functioning properly, a preliminary operational system test was conducted to assure that the system was ready for formal acceptance test.

Sperry Univac then organized and conducted the formal test, which was witnessed by the customer.

Preliminary acceptance was accomplished in the factory with final acceptance at the site for the first six systems. The remaining systems were accepted on-site only.

Sperry Univac has a philosophy of testing at each level so that most problems are found and solved prior to final acceptance of the system. This assures a smooth transition between system design and final acceptance by the customer.

ARTS III expansion

Sperry Univac is developing system improvements under contract to the FAA, which will take advantage of the module expandability of ARTS III.

The schedule for actual implementation of each improvement depends upon completion of development, operational need, and availability of funding.

The following improvements have been made, or are in the development or planning stages:

- ☐ Primary radar tracking.
- ☐ Fail-soft and fail-safe system configurations.

- □ Conflict detection and resolution.
- □ Multi-sensor tracking.
- □ Automatic VFR voice advisories.
- □ All-digital displays.

Summary of experience

Sperry Univac is continuing to work closely with the FAA in expansion of the U.S. Air Traffic Control system.

The system, data processing, programming and support expertise built up over the past fifteen years have made Sperry Univac second to none in successful automated air traffic control systems, systems design, programming, testing, and implementation.

Sperry Univac is also active in international air traffic control, such as the application of ARTS III to Japanese terminal areas, currently in process.

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