# COMMERCIAL AIRCRAFT TECHNOLOGY APPLICABLE TO THE SPACE SHUTTLE

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## INTRODUCTION

Before beginning the technical discussion let me state briefly why Pan American World Airways is sufficiently interested in the Space Shuttle to spend corporate funds on it. Our ultimate interest in the Space Shuttle is in its potential as a commercial space vehicle for use in both space travel to earth orbit and point-to-point transportation on the earth. These applications, we see in the 1985-2000 time frame. In the meantime, we are interested in providing services to the Government in the design, engineering, test and evaluation areas with the objective of operating and maintaining the space shuttle system under Government contract to NASA or the Air Force after the system becomes operational.

In line with these objectives, a Pan Am Task Group has been working on the Space Shuttle for over a year. We are teamed with McDonnel Douglas on Phase B Studies and in a Cargo Handling Study. McDonnell has given Pan American extensive tasks in the Phase B study in the areas of launch operations, mission planning, flight operations, maintainability, maintenance and turnaround time and manpower estimates. In addition, Pan American is providing consulting services on maintenance and maintainability to Aeroject General on the Phase B Main Propulsion System contract.

In the discussion to follow the word technology is used in the general sense (i.e., technology is the application of scientific knowledge to practical purposes in a particular field ). Commercial aircraft technology is the application of scientific knowledge to practical purposes in commercial aircraft. From the commercial aviation vantage point, one visualizes the space shuttle as evolving from a series of increasing complex aircraft systems - the DC-3, the DC-8, the B707, the B747, the DC-10 the SST. Since the basic requirements of the space shuttle system are substantially equivalent to those of advanced aircraft systems: high performance, reusable systems, emphasis on safety, operational flexibility, low costs, routine and economic maintenance to allow reasonable turnaround time, it makes good sense to examine commercial aircraft technology for potential application to the space shuttle. We are in a position to discuss this subject since Pan American World Airways has been actively engaged in the problem of reducing maintenance and operations costs on reusable space vehicles, airplanes, for over forty years and has made significant progress in this area.

The subject is too broad for comprehensive coverage in the time and space allowed. The commercial aircraft technology to be discussed will be limited to those topics which will have been developed by 1975. The space shuttle must be based on tried and true technology - those things we know will work, i.e., give the desired performance and have high reliability within minimum cost of operation.

Topics such as satellite navigation, satellite traffic control and avionics beyond the Super Sonic Transport (SST) will not be included.

## OPERATIONS AND SAFETY

Of special importance to this discussion is the relationship of costs of operations and safety to the commercial aircraft technology. While always striving for increased performance - thereby providing faster service and more comfortable service, there are two overriding driving forces to commercial aircraft technology - they are costs of operations and safety.

The basic premise of all airline operations is safety. Safety is not negotiable. Airplanes must always be airworthy--that is axiomatic. They are always 100% safe.

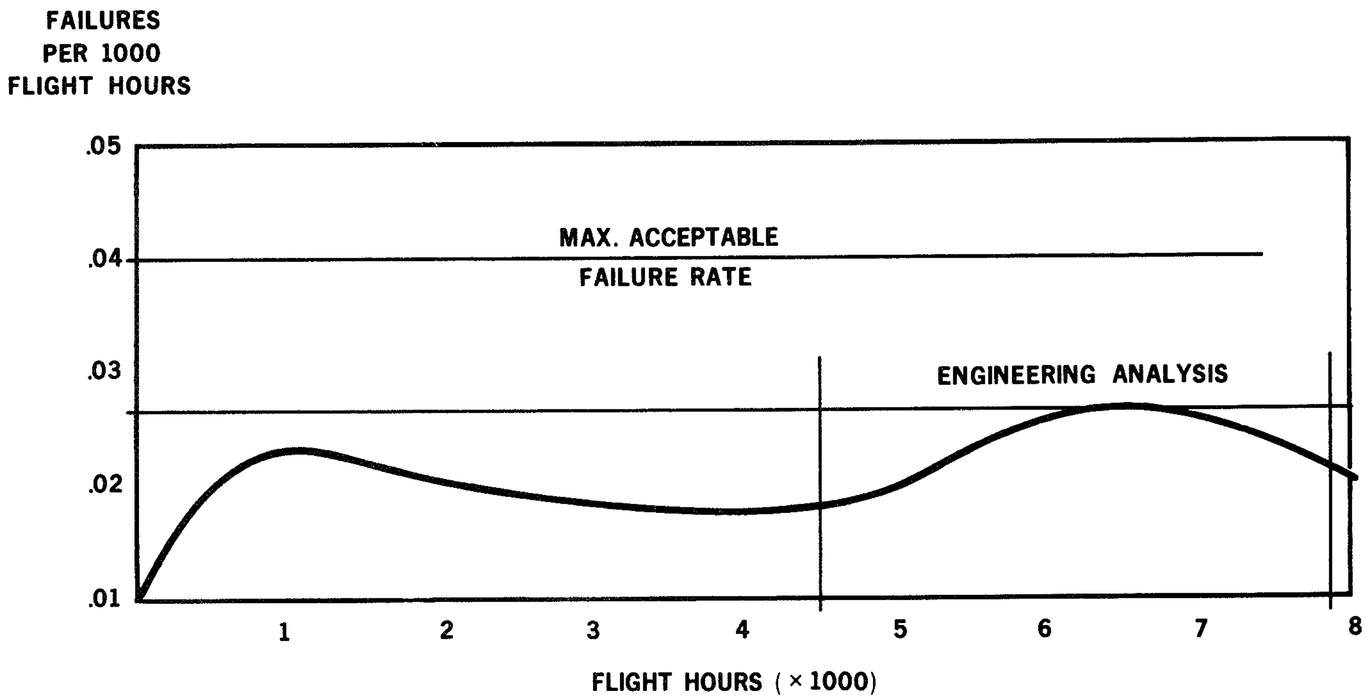
However, the achievement of 100% safety does not necessarily require that vehicles operate with no failure of any kind. Designing and operating a no-fail vehicle would be extremely expensive, if not impractical. Safe operation with imperfect parts can be and is achieved simply by designing the vehicle to accept failures. Not only do airlines complete flights after failures have occurred, but we often dispatch aircraft with systems or components inoperative. Dispatch with inoperative parts can, of course, be done only if sufficient redundancy is designed into the system to permit completion of the mission even after additional multiple failures in flight.

To achieve the required safety and to keep operating costs within acceptable bounds commercial airlines have made significant technological advances in the maintenance area and in the maintainability area. The following comments are pertinent in the maintenance area.

Experience has shown that routine overhaul or check out of components or systems on an arbitrarily established time basis brings about an expensive maintenance program which is not justified by corresponding increases in safety or reliability. On the contrary, we have found that disturbing systems or components that are operating satisfactorily decreases overall system reliability. When a system or a component fails to meet established performance limits, the fault is rectified. Redundancy insures safe operation in the interim. We are convinced that--other than routine replacement of expendables, lubrication, replacement of time limited components and correction of faults--the best maintenance policy is a "good leaving alone." This has led Pan Am to an "on-condition" maintenance policy.

If a component shows a normal life curve with an inflection, the component may or may not be time limited at the inflection point depending on the maximum acceptable unreliability. An engineering analysis of the reason for failure at the inflection point is always initiated.

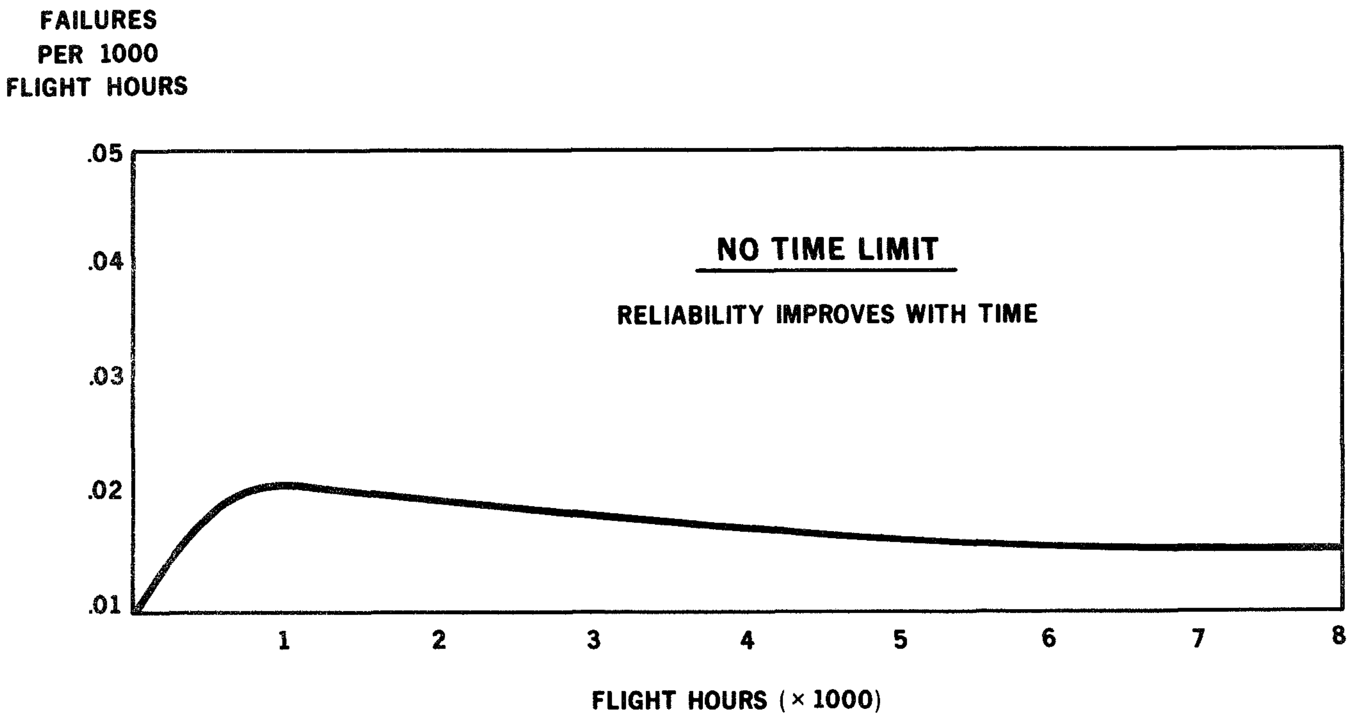
# NORMAL FAILURE WITH INFLECTION



Some components are time limited; some are not. If a component shows a wearout trend, we determine the maximum acceptable degree of unreliability and establish a time limit at this point.

Most components in fact do not show a wearout trend, rather they manifest their reliability in the way illustrated on the normal failure pattern.

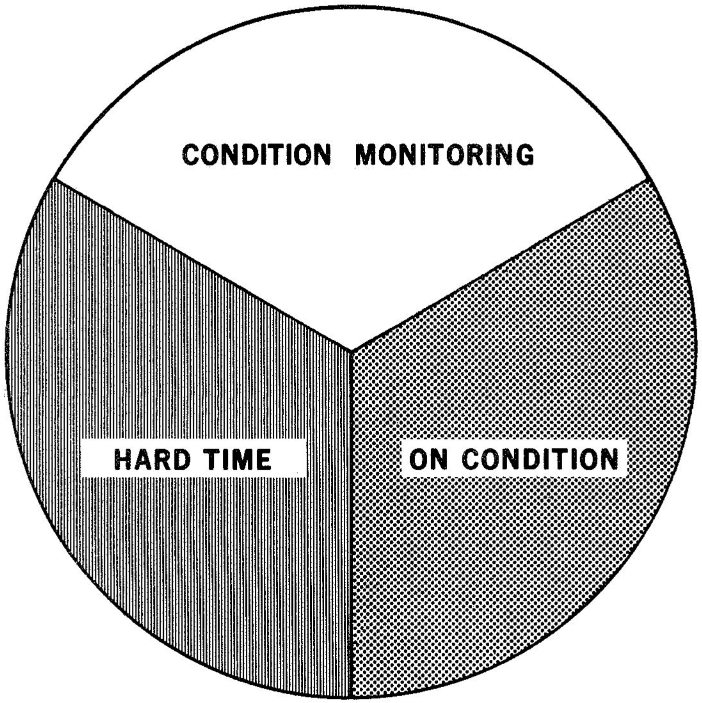
# NORMAL FAILURE PATTERN



The condition of systems and subsystems are monitored in various ways (to be discussed later). When the performance or reliability of a system becomes questionable, it is put "on condition" and it is put under special surveillance.

"On condition" means that the condition is monitored, and as long as the condition is satisfactory to complete the next mission or series of missions, the system or component is left alone. Do we ever fly it until it fails? Yes, if there is sufficient redundance to assure airworthiness--sufficient redundancy to permit additional failures and continuation of the mission with complete safety and if it is advantageous economically to let it fail.

# CURRENT LARGE AIR TRANSPORT MAINTENANCE PHILOSOPHY



The condition of units may be monitored in various ways. When an airplane is landed and the pilot reports that the electronic systems he used were accurate throughout the flight, and if the systems are not disturbed prior to the next flight, it is highly probable that these systems will work satisfactorily on the next flight. In fact, their satisfactory operation is much more probable under these conditions than when the systems are disturbed by the installation of new components.

When a system is not used on a flight and therefore the pilot cannot comment on the condition, the systems require a self-test feature to assure satisfactory operation on the next flight.

Some other items--for example, turbine blade condition or structure cannot be adequately checked by self-test features or by the crew. In these cases we rely on inspcetors and their inspection techniques to assure satisfactory condition to complete the next flight.

Are we only concerned about the next flight? From a safety standpoint, yes. From a practical economic standpoint, no.

I have stated that it is logical to accept a failure in a system. We will correct the fault in due time. We would, of course, prefer to correct the fault at a scheduled maintenance period. To assist in this area the installation of systems such as AIDS (Airborn Integrated Data System) which will predict out of tolerance conditions in some cases, detect trends, and ennunciate to the crew will be valuable.



## ON CONDITION MAINTENANCE

1. ON CONDITION INSPECTION TECHNIQUES:

   A. PERIODIC OPERATIONAL CHECK AGAINST A "STANDARD".

   B. CREW LOGBOOK.

   C. INSPECTORS.

2. CONDITION MONITORING RELIES ON AIDS CONCEPT – PRIMARY MAINTENANCE CONTROL IS RELATED TO GATHERING AND ANALYSIS OF DATA.

In commercial airlines, operating patterns define the scheduled maintenance program. We buy airplanes to fly them, not to fix them. Hence scheduled maintenance programs must be designed to mesh with the flight scheduling requirements.

In designing the program, efficiency requires routine work be equalized among services as regards elapsed time requirements, overall manpower requirements, and specialty manpower requirements. This doesn't necessarily mean that a service done every 300 hours must be the same size as a 1,200-hour service, but that all 300-hour services be similar. Non-routine work must be predicted and sufficient time allocated for its completion.

Our B727 operates under a maintenance program consisting of only two service sizes. One is an annual interior refurbishing and modification service. The other, a scheduled maintenance service. This service, lasting eight hours block to block, is accomplished after each 325 hours of aircraft operation (approximately monthly). While it is improbable that any two services have identical work content, each service takes eight hours and requires (statistically) 8.17 manhours of radio work, 14.15 manhours of hydraulic work, 7.48 manhours of electrical work, etc. Services are end-to-end to get maximum utilization out of our working force. This aircraft is never overhauled.

Our average labor expenditure at this service is 260 manhours. Our average cost per service is $3,328 which includes all materials and labor, but excludes labor burden. This figure incidentally represents .07% of the purchase price of a B727.



The direct maintenance cost per flight hour is $129.31 (i.e., annual direct maintenance cost divided by total flight hours per year).

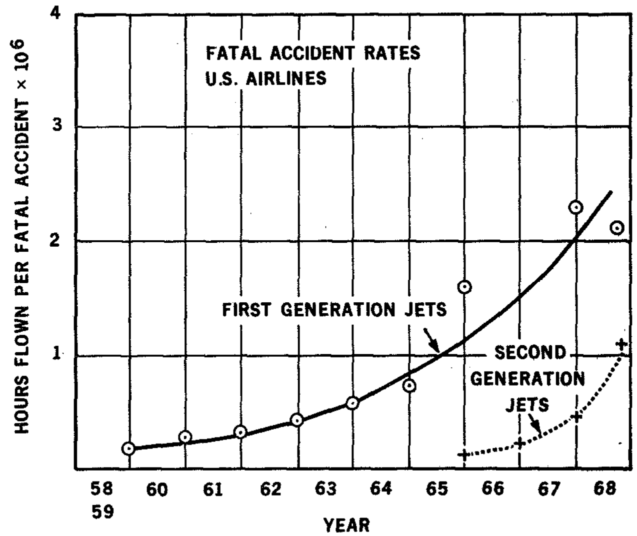
## TOTAL DIRECT MAINTENANCE COST
B-727-21

| | |
|---|---|
| DIRECT MAINTENANCE COST PER HOUR: | $ 129.31 |
| AVERAGE FLIGHT TIME: | 1 HOUR |
| DIRECT MAINTENANCE COST PER FLIGHT: | $ 129.31 |

The term "100% safety" has been used often, but, of course, there is a degree of risk in operating any vehicle. Currently, the American Airline Industry is experiencing 1,200,000 flights per fatal accident. You will notice, however, that fatal accidents occur more frequently in the early years of operation of a new technology aircraft. This is to be expected as 90% of all fatal accidents are "operational" in nature and the rate of accidents will normally be inversely proportional to flight and ground crew time on the aircraft.

# FLIGHTS PER FATAL ACCIDENT 1.2 x $10^6$

(1965 - 1968)



## MAINTAINABILITY

Maintainability is that part of technology that is concerned with the ease with which an operation can be sustained or restored and is substantially determined by design. Hence, maintainability attributes must be sustained into the product, beginning with its conception and throughout its development.

Maintainability goals for commercial aircraft are:

(1) to reduce the frequency and extent of scheduled maintenance,

(2) to eliminate, wherever possible, those inspections and maintenance operations that do not effect airworthiness,

(3) to develop and apply maintenance methods that will detect degradation of component performance, impending malfunctions and wear.

(4) tc adopt a maximum use maintenance plan for component replacement.

(5) to incorporate service-proven design features that permit the most rapid restoration for revenue use.

As an important part of the maintainability study, all components will be reviewed to determine whether a failure would cause a mission delay or abort. In general, the following rules are used:

1. Design the system so that the vehicle can be dispatched with that component inoperative.

2. Provide additional redundancy for components that can cause mission abort.

3. If the vehicle cannot be dispatched with the component inoperative, make the item readily replaceable. Time for trouble shooting and replacing must be less than fifteen minutes or the failure is considered a delay item.

A review of reliability data based on unscheduled removals shows that many components are removed for trouble, checked out on the bench and no discrepancy found. These findings require on-board instrumentation which provides fault analysis.

# MAINTAINABILITY

DESIGNING SO THAT MAINTENANCE REQUIREMENTS ARE MINIMIZED.

1. SIMPLICITY AND ISOLATION
2. RELIABILITY
3. PREDICTION OF IMPENDING FAILURES
4. DESIGN TO MINIMIZE CONNECTIONS
5. DESIGN FOR PROPER ROUTING, FLEXIBILITY, AND SUPPORT OF WIRE BUNDLES, TUBING, DUCTS AND CABLES
6. SELECT MATERIALS TO MEET CONDITIONS.

DESIGNING TO MAKE MAINTENANCE EASY AND ECONOMICAL.

1. STRUCTURE INSPECTION PLAN
2. MINIMIZE IMPROPER REMOVALS BY RAPID, ACCURATE FAULT ISOLATION
3. EASY ACCESS, REMOVAL AND REPLACEMENT.

DESIGNING TO MINIMIZE DELAYS AND PROVIDE ALTERNATE MEANS OF SYSTEM OPERATION.

1. DISPATCH WITH EQUIPMENT INOPERATIVE
2. POSTPONABLE MAINTENANCE
3. QUICK REPAIR WITH SCHEDULED GROUND TIME
4. SERVICE LIMITS WHICH ARE LESS RESTRICTIVE THAN DESIGN OR OVERHAUL LIMITS.

## PROJECT MANAGEMENT TECHNOLOGY

Airlines have developed advanced techniques for the procurement of complicated aircraft systems. Pan American was the first airline to purchase aircraft to the buyer's specifications and have on several occasions provided the catalyst to chrystalize development of new aircraft systems. For example, the commitment of 269 million dollars by Pan Am to the purchase the first generation of airline jets and the billion dollar order for Boeing 747 were necessary in each case to put Boeing into production and to assure the development of these aircraft. In this financial posture, the airline can actively participate in the planning and design of the aircraft. Of particular importance is the opportunity to provide inputs to the design which reflect airline operations and maintenance philosophy. Optimum operational systems and maintainability must be built into the design from the preliminary definition phase.

Philosophy with respect to the mean time between failure (MTBF) and inventory of spare parts which was generated within Pan Am, is both technically and economically interesting. For example, the MTBF for a system is guaranteed by the manufacturer of the system. In the event the system does not achieve its guaranteed rate during actual operation, the manufacturer, under some contracts, is required to furnish additional hardware with the original MTBF. Where the manufacturer has been over zealous in his salesmanship, this cost runs into the millions of dollars. Airlines are attempting to make this type of agreement cover most systems. Similarly, in the inventory of spare parts, the airline usually has an agreement in which the manufacturer specifies the type and number of spare parts that are required. The operator then buys exactly what the manufacturer has stipulated with the contractual agreement that the excess will be repurchased if the manufacturer has over-estimated the inventory required.



### Economic Models

For planning purposes, economic models have been developed to simulate the operations of an airline to assist in decisions to purchase new aircraft like the SST (or a cargo version of the B747). Such a model relates the factors (a) traffic model, (b) airplane characteristics of price, performance, and operating expenses, (c) route characteristics for the airline structure, (d) passenger and cargo revenue, (e) passenger preference as related to fare levels, flight frequency and trip times, and (f) a level of operation for the airplane mix which will provide an adequate level of service and a satisfactory return on the airline investment.

A similar model is used on an operational basis for developing airline schedules and routes and to measure cost effectiveness.

# PROJECT MANAGEMENT TECHNOLOGY

1. PARTICIPATE IN THE PLANNING AND DESIGN OF AIR-CRAFT.
2. RELIABILITY AND INVENTORY OF SPARE PARTS PHILOSOPHY.
3. ECONOMIC MODELS.
4. DESIGN REVIEW.
5. ACCEPTANCE TESTS.

# MAINTENANCE CONTROL SYSTEM (MCS)

I would like to spend the time allotted to computer technology to Pan American's Maintenance Control Program. This program has been under development since 1968 and plans call for it to be operational in 1972. Cost savings of $5 million per year to Pan American are estimated from the use of this program. It is basically a management information system which incorporates maintenance programming and control functions into an integrated operation. A.I.L., a division of Culter-Hammer, provided technical consulting services to Pan American in the feasibility studies.

All of Pan American's maintenance requirements through 1980 have been considered in the design of the program. The program will give all levels of management, an adequate amount of information and control of the maintenance operations.

The system has been designed in a functional manner. This was done in order to construct a control process which would insure a fully integrated cost effective system. The three basic functional areas chosen were forecasting, scheduling and monitoring.

In broad terms, the system would begin to function upon the receipt of a new flight timetable. Management control over the maintenance processes would follow through the three main functional areas.

From data contained in the timetable, information is generated with respect to assignment of aircraft to flights, times into and out of maintenance, and provisioning requirements for main base and line stations. Based upon the new operating plan, past performance histories and aircraft, material and resource status, a capability is developed to forecast every phase of operations and maintenance.

Forecasts are used to schedule maintenance work. Also, new data is accumulated to revise perfomance history. This could be defined as a control function.

Performance history and forecasts serve as a base for the determination of the adequacy of operations and inventories. This provides guidelines for perfomance evaluation.

To integrate these fundamental functional areas into a total system, 12 subsystems were designed. These serve as the core of MCS.

In arriving at the subsystems, such factors as aircraft, manpower, materials and flow of work were descirbed in detail. These descriptions were applied as the platform on which the framework of the 12 subsystems was constructed. The subsystems and the major areas each involves are:

Aircraft routing and service forcasting (forecasting and scheduling).

Diagnostics (monitoring).

Provisioning (forecasting).

Manpower and shop load (forecasting).

Modification (monitoring, scheduling and forecasting).

Parts identification (monitoring and scheduling).

Ground support equipment maintenance (scheduling).

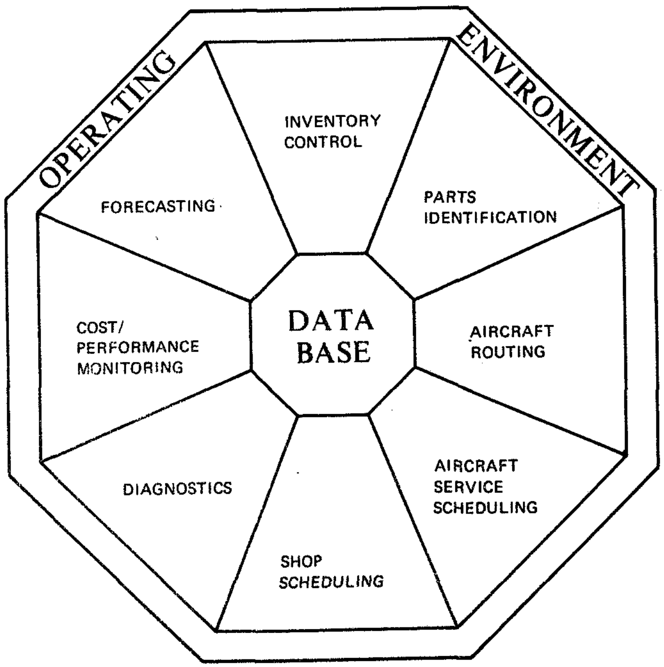
Aircraft service work planning and control (scheduling).

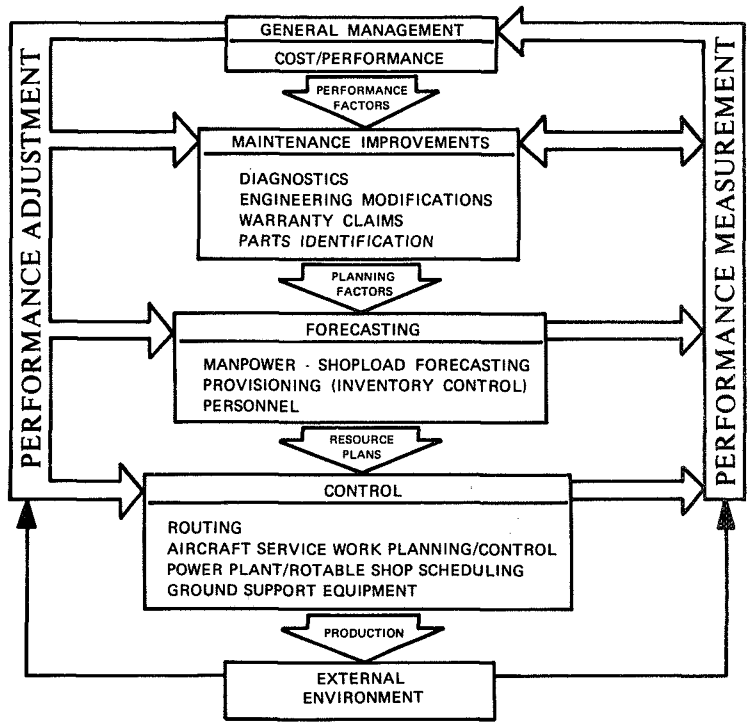
Personnel (forecasting, scheduling and monitoring).

Powerplant/sop production (scheduling).

Warranty claims (forecasting, scheduling and monitoring).

Cost/performance (monitoring). This function combines the monitoring of all subsystems to establish an evaluation capability.


OPERATING ENVIRONMENT
DATA BASE
INVENTORY CONTROL
PARTS IDENTIFICATION
AIRCRAFT ROUTING
AIRCRAFT SERVICE SCHEDULING
SHOP SCHEDULING
DIAGNOSTICS
COST/ PERFORMANCE MONITORING
FORECASTING


GENERAL MANAGEMENT
COST/PERFORMANCE
PERFORMANCE FACTORS
MAINTENANCE IMPROVEMENTS
DIAGNOSTICS
ENGINEERING MODIFICATIONS
WARRANTY CLAIMS
PARTS IDENTIFICATION
PLANNING FACTORS
FORECASTING
MANPOWER - SHOPLOAD FORECASTING
PROVISIONING (INVENTORY CONTROL)
PERSONNEL
RESOURCE PLANS
CONTROL
ROUTING
AIRCRAFT SERVICE WORK PLANNING/CONTROL
POWER PLANT/ROTABLE SHOP SCHEDULING
GROUND SUPPORT EQUIPMENT
PRODUCTION
EXTERNAL ENVIRONMENT
PERFORMANCE ADJUSTMENT
PERFORMANCE MEASUREMENT

# AVIONICS

The first step in avionic procurement and development within Pan Am has always been an assessment of the mission. The major mission of most avionics systems is to assist in providing for the safe and expenditious conduct of the aircraft from its origin to its destination within the air traffic control environment. During system planning and design, there is a continual effort to reduce crew and ATC controller workloads to improve the safety and efficiency of the operation. The mission must be accomplished reliably and in a cost effective manner.

Airline efficiency was dramatically influenced by avionics in the 60's. The ability to land a jet aircraft under adverse weather conditions, reduction in crew complement, and reduction in crew workload, are major advances which have been made through judicious avionics system planning. In late 60's after delivery of majority of 707 fleet and before introduction of all weather program to obtain approval to operate in Category I and II condition, diversions ran about 2 1/2%. After approval, they were reduced to less than 3/4% with large savings in operational costs. The B747, which contains triple inertial navigation systems, Category II landing capability expandable to Category III, satellite communications provisions, and greatly improved instrumentation, is an excellent example of this planning.

We feel that a considerable amount of airline avionics design philosophy is applicable to the space shuttle operation, particularly with regard to the safe and successful conduct of the mission. Within Pan Am, there has always been an emphasis on reliability and maintainability in systems selected for installation. Normally, maximum reliability is achieved through redundancy rather than accepting an increase in system complexity. Over the past 15 years, there has been a significant increase in reliability and at the same time reduction in the size, and weight, of aircraft systems with the advent of solid state and integrated circuitry. Two systems, VOR and ILS, which required a total of four boxes, were integrated into a single 1/2 ATR system with an attendant reduction in volume. Reliability of the system has improved about four-fold.

The airlines have moved cautiously toward system integration. Where integration of certain systems which perform closely related functions appeared to be attractive, this has been done as in the case of VOR/ILS and the B747 autopilot/flight director system. There are, however, several advantages to maintaining separate boxes designed to perform specific functions. Industry competition is encouraged; many manufacturers who would not otherwise have produced certain hardware elect to do so. The ability to reasonably improve maintainability, reliability, and system capability is directly affected. A manufacturer can make significant advances in all of these areas with advanced versions or modifications to first generation hardware often with considerable ease and minimum cost. This subject needs detailed review for possible application to the space shuttle.

Several recent efforts and other major projects presently in progress have and will directly affect avionics technology applications for the airline and space shuttle operations. Following is a brief summary of these projects:

## Inflight Information System

To improve operating efficiency, Pan Am is planning the development of an inflight information system. The system will employ wide use of airborne and ground computers, data, and voice to provide a real-time information flow between aircraft and the ground. The system will collect, analyze, transmit, store, receive, and present information required by: air traffic control, the flight crew, and company offices.

It is planned that services provided to company offices and flight crews will include the following:

Company Operations:

- Flight Following
- Operational Messages
- Flight Performance Analysis
- Abnormal Aircraft Operations

Company Maintenance

- Engine Performance Analysis
- System Degradation and Analysis
- Advance Information to Line Stations of system or Engine Faults
- Abnormal Aircraft Operation (overspeeds, hard landings, etc.)

Company Traffic Department

Passenger Handling Requirements

A. Medical Information
B. Connecting Flights
C. Hotel Accommodations

Company Accounting Department

- Aircraft Ground and Flight Operating Time
- Crew Flight Time

Some of the technology required to develop the system exist however, a number of new developments will be required. Two of the most important elements of the total system are an air-ground data link and satellite communications.

# FLIGHT INFORMATION SYSTEM

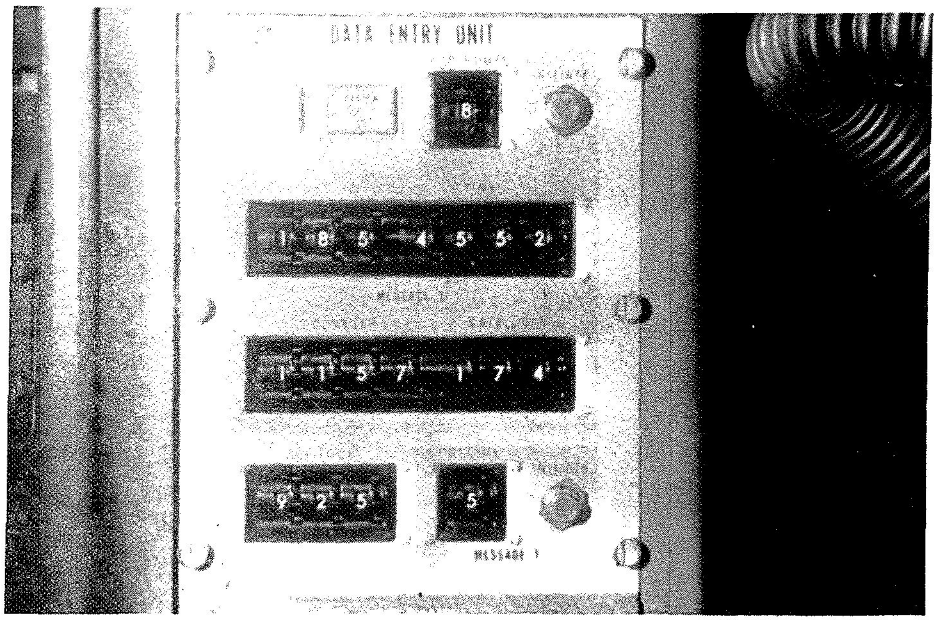
COLLECT, ANALYZE, TRANSMIT, STORE, RECEIVE AND PRESENT INFORMATION REQUIRED BY:

- AIR TRAFFIC CONTROL AND ADVISORY SERVICES
- FLIGHT CREW
- FLIGHT OPERATIONS
- MAINTENANCE
- MANAGEMENT

## DATA LINK

Beginning next month, air-ground operational trials of prototype hardware designed to a draft industry characteristic will be flight-tested between the West Coast and Honolulu. The airborne hardware, consisting of a 1 ATR unit and control panel, will respond to a ground interrogation with aircraft identification, position (latitude and longitude from the inertial navigation system), altitude, and a pilot inserted coded message. Aeronautical Radio, Inc., is providing the ground radio terminal, consisting of an extended range VHF station covering the eastern one-third of the route and a computer processor which will poll aircraft and process and switch received messages to airline offices or the FAA for flight following.

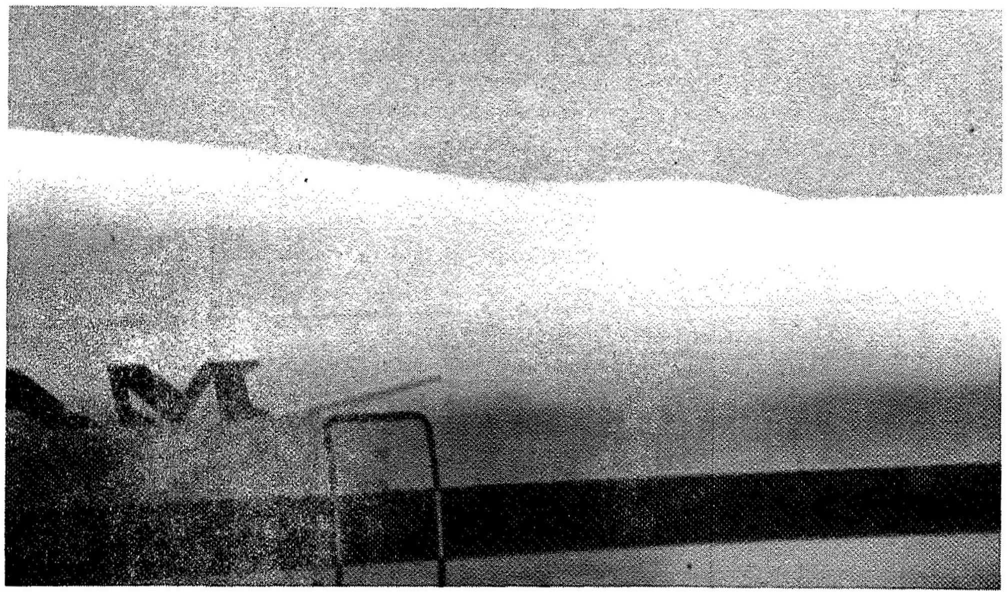
The purpose of the trial is to confirm technical desisions and demonstrate operational utility. It is expected that production airborne hardware will be available in late 1971.



# SATELLITE COMMUNICATIONS

The feasibility of air-ground VHF communications via synchronous satellite has been demonstrated. The NASA ATS-1 and ATS-3 have been used by the industry to develop production airborne hardware. Two U. S. manufacturers presently produce the VHF transceiver hardware capable of satellite communications that have been purchased by several airlines. The B747 aircraft has wiring provisions for satellite communications, including antenna.

COMSAT presently has a proposal for consideration by the airline industry and the FAA for preoperational VHF satellite service and L-Band experimentation. The VHF system would provide operational experience by serving airline company offices using both voice and data link as well as providing direct pilot-to-controller communications for air traffic control. At the same time, comparison tests would be conducted between VHF and L-Band.

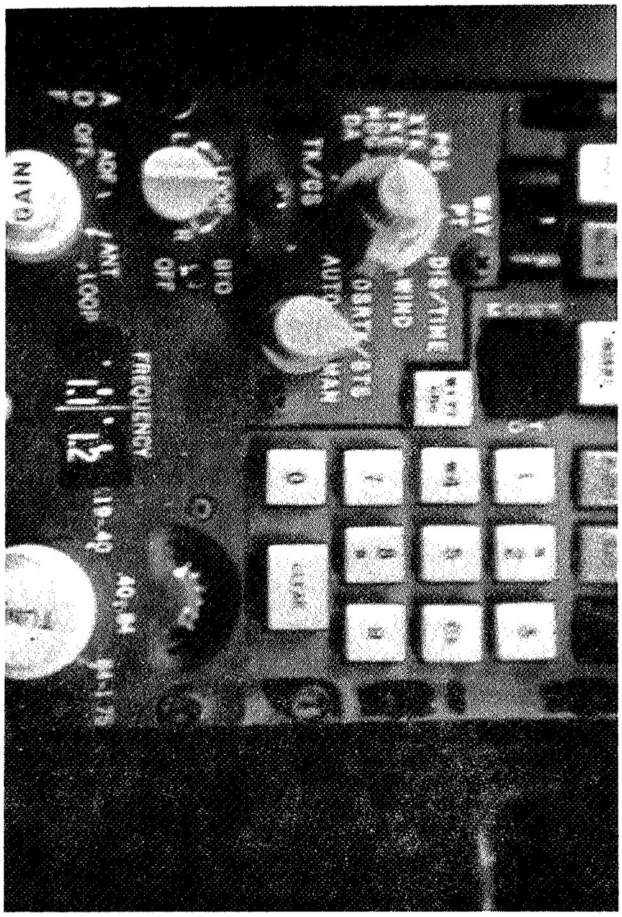


## INTERTIAL NAVIGATION

The B747 was the first commercial aircraft to be delivered with an operational inertial navigation system. Pan Am aircraft are equipped with three Carousel IV systems built by AC Electronics. Total value of the installation is about $400,000 per aircraft. Only two systems are required for dispatch of the aircraft, and one serves as a spare to ensure reliable on-time performance.

Inflight MTBF of the unit to date has been approximately 2500 hours; 95 percent accuracy is 1.85 nm/hr; CEP is 0.55 nm/hr. Pilots have been highly receptive to this greatly improved method of long-range navigation. An important feature that has caused this acceptance has been the development of an excellent pilot-to-machine interface in the cockpit.

The airline is now focusing attention on reliability improvement and improved maintenance training for the Carousel IV. Data collected in this program should be of value in determining operational costs and maintenance procedures for the space shuttle system.


GAIN
FREQUENCY
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LOOP
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DA
DIS/TIME
WIND
AUTO
MAN

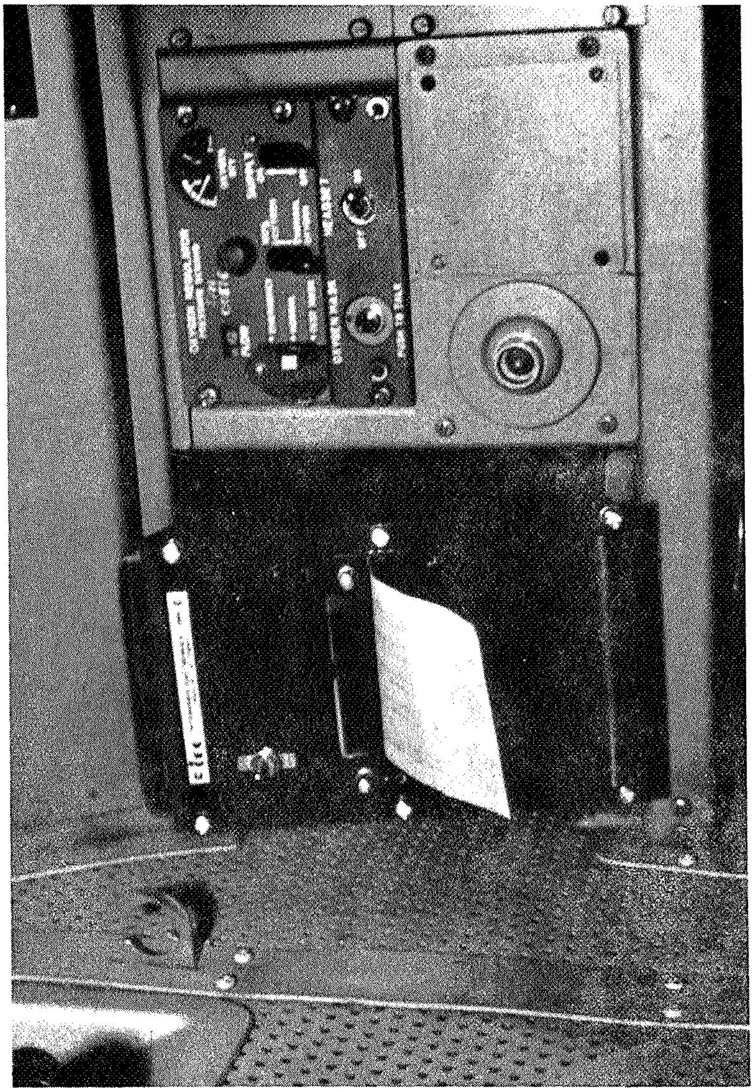
# AIRBORNE INTEGRATED DATA SYSTEM (AIDS)

This term has been generally applied to the acquisition and recording of maintenance data from on board systems. Illustration shows the basic structure of one possible configuration for the system. Pan Am has taken the view that maximum processing of data should be done on board and that the crew should be advised in real-time of the performance of the monitored systems. This prevents the delay and work necessary to process data at a later date after on board recording of large amounts of data.

Processing capability will be required to analyze data for tolerance and trend, reject redundant data, and alert the crew when tolerances are exceeded. To help achieve this goal, fault detection and analysis capability has been built integral with a number of systems, such as the radio altimeter, VOR/ILS receiver, HF transmitter/antenna couplers, DME, INS ATC transponders, electrical generating systems, etc. Pan Am favors fault detection to at least the line replaceable unit where practicable. When an abnormal situation is detected or anticipated, it is planned that most of the information will be provided via data link to the aircraft destination in advance of the arrival of the aircraft to allow expeditious corrective action.

Pan Am has just completed flight test of an airborne engine monitoring system which used engine data on a B707 aircraft to compute solutions to engine performance equations for comparison with stored values to determine trends in engine performance. Exception data was provided to the crew on a 600 word per minute printer. The system will soon by flight tested aboard a B747 aircraft.

An industry characteristic developed by the Airline Electronic Engineering Committee has recently been completed covering an airborne data acquisition system and flight data recorder which will be utilized by the airlines to satisfy pending FAA requirements for expanded flight data recording. Provisions have been made in the characteristic for providing data to an airborne AIDS processor and data link.


OXYGEN REGULATOR
FLOW
SUPPLY
OXYGEN MASK
HEADSET
PUSH TO TALK

## AUTOMATIC LANDING SYSTEM

Over 80 per cent of U. S. jet transports are qualified for Category 2 landings. Pan Am's entire fleet has been qualified. The Category 2 airport qualification program is far behind. For more that 20 years, it has been possible to make R & D demonstrations of automatic landings. The problem has been to translate this capability to a day-to-day operation using skills and maintenance practices found in an airline environment. The airlines have arrived at that point where automatic landings can be made practical on a line operation. Pan Am has made considerably more than a thousand automatic landings of which 500 were on scheduled passenger operation. Pilot acceptance and enthusiasm are good.

The basic mode of Category 3a operations will be automatic to touchdown. Redundant operational flight control capability (two operational landing systems making a fail-operational landing system) at least down to the predetermined alert height is required. The 747 has two independent automatic/manned landing systems with integrated flight directors, plus about half of the components needed for a third independent system. Pan Am will probably seek 3a approval by providing a monitored automatic landing system plus an independent manual landing channel or expand the existing compliment of equipment to include three independent automatic systems. The SST and the Concorde will be certified for Category 3 operation.



In addition to overcoming low ceiling problems, the airlines believe that a safer operation and landings with less wear and tear on the aircraft can be made by automation of this function. Airlines believe that a safe, efficient and highly reliable operation can be conducted under Category 3 conditions.

The new Navy automatic landing system, AN/SPN-42, which has been made operational on McDonnell Douglas F-4 fighters for fully automatic all-weather landings may be of interest to the space shuttle. It is all digital. It takes the opposite approach from most land-based automatic landing systems currently being developed, where the steering and throttle commands are generated within an airborne computer. The Navy also used the C-Scan System (AIL) which has two microwave transmitters and two separate azimuth and elevation scanning antennas to transmit coded pulses to the aircraft. These are processed and used to drive the heads-up display on conventional ILS cross pointer. The system can be employed from 20 miles out and it guides the aircraft to capture by the SPN-42. Estimated touchdown dispersion with the system is 15 feet laterally and 40 feet longitudinally.

## COCKPIT DESIGN AND DISPLAYS

Major interest in this area is directed toward simplifying the task of the crew and reducing the crew workload. Some of the most promising prospects present pictorial displays to the crew associated with flight management systems. Examples of these displays are:

- Cathode ray-tube for the electronic attitude director indicator. The display, at top center will have four modes: taxi, takeoff/appraoch, cruise and attitude. The tube will present, either by television or digital or symbolic displays, such items as speed error, radar altitude, flight path angle, flight path acceleration and attitude. The tube will also serve as visual display for the aircraft's instrument landing system. When in taxi mode, a television picture will present that operation.

- Large moving map for the inertial navigation system. The display could be directly underneath the electronic attitude director indicator for both the captain and first officer. The moving map will show desired course and actual position. It will also have the capability of providing short-term prediction of probable ground track of up to one minute.

- Multi-function screen for alpha-numeric, symbolic or graphic data presentation such as rate of climb profile and vertical navigation.

The crew would sketch desired climb profile on a scaled grid on the display. The system would provide real-time pictures of actual vertical position in relation to desired position. Similarly, other vertical navigation problems could be monitored on the display along with such items as fuel management.

Another cockpit change that crews will find is the lack of a control column - yoke or wheel - for roll and pitch. In its place will be a pair of control handles permitting an unblocked view of main panel for the electronic attitude direction indicator and area navigation displays.

Subsonic aircraft in airline service do not have the total capability afforded the supersonic transport by these advanced systems, but they will have much of it by 1975. Several of the main components are already in advanced stages of development. Electronic attitude director indicators have been used extensively in military aviation and a cathode ray-tube area navigation pictorial display was tested in a Boeing 727 last year. An electronic attitude indicator system has been tested in the Boeing prototype 707, and has been considered for the Lockheed L-1011.

## ADVANCED SIMULATORS AND CREW TRAINING

Significant advancement in the state of the art in simulators is taking place. Advanced simulators generate as many as three different synthetic pictures simultaneously and include radar as well as direct viewing. They include capability for normal landing, takeoff, emergency landing and takeoff, aborts, unusual and routine maneuvering, fueling, and reconnaissance. Simulation techniques are also being used as visual environmental simulation system to aid in design and evaluation of new aircraft control systems and the evaluation of new image generation concepts. Computer image generation techniques are being applied to the development of the electron attitude director indicator.

The computer generated visual imagery, both the "out of the window" display and the radar landmass simulation use digital data stored in the computer to describe terrain and cultural features in three dimensions and in color. No physical models or films are employed as data sources.

Change of altitude, perspective and relative motion of runways, buildings and other aircraft respond instantly to simulated motion of the pilot's own aircraft. Perspective of the runway and near by buildings changed with lateral positioning of the aircraft.

In commercial airlines, flight training is the extension and laboratory application of ground school training. The basic objectives are to provide crew with essential information and knowledge needed and usefil to operate the aircraft under: (a) normal condition, (b) abnormal conditions, and (c) emergency conditions (meaning a condition in which safety is threatened until corrected or contained).



Pan American training is based on the specific behavioral objectives (SBO) concept. It is intended that such training will be accomplished in a positive manner. In so doing, it is intended to: (a) cover essentials for safe and successful operations under the conditions noted above; (b) establish and demonstrate basic knowledge and technical operational competence prior to aircraft operation; (c) concentrate flight operation to fundamental and important aircraft differences which have bearing on ground and flight management of the aircraft; (d) during the entire training process,teach to provide specific airmen knowledge and know-how required to establish competence and verification thereof, with a design to retain proper elements of personal confidence.

NOTE: Pan American airmen are all swept wing turbojet qualified. The transition training to B747 in this case will be built on their experience and benefited by state-of-the-art improvements in the training area and the aircraft itself.

The SBO training concept will be optimized through coordination and control of all inputs and their consistent treatment in the aircraft operating manual which will be used as a ground school and flight training textbook, and the SBO applications in the laboratory aspects of training on the cockpit procedures trainer, the simulator and the aircraft.

Pan American flight training for the B747 is being carried out at Roswell, New Mexico. The most effort is exerted on touch and go landings on facilities with a 13,000-foot runway. A typical course involves several hours of classroom work, including cockpit familiarization in a cardboard mockup and about eight hours of flying, a two-hour rating flight and a two hour oral examination completes the training. The amount of training is not set, but varies with the proficiency of the individual.

# CARGO HANDLING

Pan Am air freight facility at New York's Kennedy International Airport is designed to handle one billion pounds of cargo per year.

Three handling systems form backbone of Pan Am Cargo Terminal. The combination of three mechanical cargo processing systems form the backbone of the air freight terminal. The three systems are: a package conveyor arrangement, an automatic tow cart network, and an AirPak pallet system.

Applying unique techniques to processing flights in mass volume, the three systems are linked to an electronic computer network. It is estimated that this combination permits a reduction in ground handling time for individual shipments by as much as 80 per cent.

Using AirPak, up to 13 pallets, each 88 inches by 125 inches, may be loaded on Pan Am's all-cargo jets in a few minutes.

When a package is delivered to the terminal for export, it is first necessary to obtain pertinent data on the shipment, not already contained on the waybill. This information includes the height of the package, the width, length, actual volume, cubed volume and weight in pounds or kilos, and is obtained in two basic ways. This information is obtained using two separate and different electronic measuring systems.

The Caprocon system utilizes an electronic photo unit to determine much of the readout information. The Data-Cube System obtains the same readout information through a sonic beam unit.

Each unit is also capable of sending information directly to the cargo inventory computer system. Depending on size and weight, individual packages arriving at the terminal for export are placed in one of the three automated handling systems.

The first system is called the Package Conveyor System. Employing powered and gravity conveyors, the package conveyor or Rapistan system, handles both import and export shipments.

Packages smaller than eight inches long, eight inches wide, and four inches high are stored in a small package area.

When placed in the package conveyor system, the package moves to a sorting station where it is coded by destination or flight. From the sorting station it is dispatched by conveyor to any one of 120 gravity flow rack storage lanes elevated 12 feet above the terminal floor. Each lane represents a particular destination or flight.

For aircraft loading, cargo is retrieved from the package conveyor system by triggering an escapement release. This permits the cargo to move out of its lane by gravity and then by conveyor to a check station. There it is dispatched by conveyor to either the shuttle platform for transfer to the passenger jet; to the AirPak pallet buildup area; or to one of the loading fingers for placement in the belly compartment of an all-cargo aircraft.

The second system is called the Towline Cart System. A floor-level towline cart arrangement is generally used when a package is too large for the package conveyor system.

The third cargo handling arrangement is the AirPak pallet system. Cargo exported via the AirPak pallet system is usually assembled on pallets at the terminal. However, completely loaded pallets may be received at the terminal via highway truck.

Essentially, cargo arrives in the pallet make-up area from either the tow cart system or the package conveyor network. When the pallets are made up, they are raised to an upper level where all storage and aircraft loading activities take place. Average pallet make-up time is 30 minutes.

Completed pallets are stored in any of 51 holding stations prior to being loaded on the aircraft. The loading system is designed to permit placing in pallets in an aircraft in a 20-minute period.

An electronic computer system, the most extensive of its kind ever developed, is the nerve center for the automated air freight terminal. Working in harmony with the three mechanical ground handling systems, the computerized facility permits the airline to reduce handling time on individual shipments.

The main computers, located in the Pan Am Building, are linked to electronic equipment in cargo terminal by high speed telephone lines. Primary aim of the computer/handling system network is to speed the flow of freight through the terminal by providing instant readout on freight inventory, handling of reservations, and simplifying the dispatch and tracing of cargo movements.

Backbone of the system is an IBM 7080 computer and an IBM 7750 programmed transmission control unit. Located in the Pan Am Building, this equipment is linked by high speed telephone lines to two Bunker Ramo control units at the cargo terminal. The Bunker Ramo control units in turn are connected to some 26 input/output sets which are strategically placed throughout the terminal.

A shipment of cargo arrives at the terminal for export overseas. As the freight is unloaded from the truck and placed on one of the three mechanical handling systems, information regarding the shipment is typed into a input/output set. The operator views what he is typing on a minature television screen.

Included in the basic information record are the date and time of cargo receipt, airwaybill number, destination, number of pieces in the shipment, weight of the total shipment, cube of the total shipment in cubic feet, a description of the contents and where the cargo will be stored in the terminal. In addition, other data such as special handling instructions for animals and perishables may be recorded. If the freight is placed in a tow cart, the number of the tow cart is recorded, as is the number of a pallet if the shipment is palletized.

This information is relayed in seconds by the input/output set to a central control unit in the terminal, and then via high speed telephone lines to the computer complex in the Pan Am Building. Here the information is stored. When it is time to begin assembling freight for a flight, cargo load control personnel utilize either an IBM high speed printer or a teletype unit to retrieve information from the computer in the Pan Am Building.

From the computer a list of cargo holding reserved space for a particular flight is first obtained, including the information on each piece of freight which was initially fed into the computer. Cargo load control next requests a listing of all of the cargo for the flight destination. The information received from the computer by load control lists the order in which the cargo was delivered to the freight terminal and other pertinent data, including the location of the cargo in the terminal.

The load list is received from the computer in only a few minutes. This information in turn is dispatched to the various areas of the terminal where the cargo is stored. The individual freight pieces are then moved via the three handling systems to the loading area.

Some of the freight will proceed to the pallet make-up area, some directly to the loading finger for placement in the belly compartment of the freighter, while complete pallets are moved directly to the aircraft for loading.

Under this procedure, cargo load control, with the information obtained from the computer, is able to quickly decide on the best combination of space utilization for the flight and request a final manifest from the computer.

On the import side, as soon as a freighter arrives at the terminal, the cargo manifest is entered into the computer via an input/output unit. Then as the cargo is unloaded, each piece is again recorded in the computer via a separate input/output unit. In this way the manifest is checked against the actual cargo received with the computer pointing out any errors.

Thus, the computer retains complete storage of all pertinent data.

In addition to speeding the flow of cargo through the terminal by retaining all of the information on the individual cargo movements, the computer provides Pan Am with a vast source of record data.

For example, a shipper may call the cargo telephone sales department in the Pan Am Building and request information regarding his shipment. By utilizing any of five input/output units the cargo sales agent can retrieve the entire record of the shipment and relay this information to the shipper in a matter of minutes.

Reservations for cargo space, of course, are able to be confirmed in a matter of seconds with the computer.

## SUMMARY

Certain topics in commercial aircraft technology with potential application to the space shuttle have been briefly reviewed. It can be concluded that much commercial aircraft technology available in 1975 will be directly applicable. This includes maintainability, maintenance, avionics, management techniques and operations. We strongly recommend (1) that airline management, engineering, maintenance and operations techniques be used in the procurement, design, test and operation of the space shuttle; (2) insofar as possible only technology available in 1975 time frame - so called - off the shelf technology be used in the space shuttle.

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