An Application of Aerospace Technology and Systems to Commercial Aviation

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AN APPLICATION OF AEROSPACE TECHNOLOGY AND SYSTEMS TO COMMERCIAL AVIATION

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Introduction

During the Fifth Space Congress, I discussed the upcoming "Information Explosion" era, in which satellite systems would provide communications, navigation, weather prediction, information search and retrieval, and air traffic control. Compared to sending men to the moon, the use of satellites for this purpose is an example of applying aerospace technology, separately and distinctively, to existing problems.

In solving these problems, we are compounding a more traditional problem: the addition of more equipments to the user vehicle for each "Information Function" added. This was a common practice in the Ground Space/Satellite Communications field until the Air Force recognized the need for the Space Ground Link Subsystem (SGLS), and integrated Telemetry, Tracking and Command (TT&C) communication system. Although the integrated information system was recognized for the ground, spacecraft vehicles still do not have integrated TT&C systems.

It was argued that it was not economical to apply the systems approach to the spacecraft vehicle because of its limited quantity, cost of its initial development and its delivery requirements; however, the systems approach is applicable to commercial aviation because they will be the large user in the "Information Explosion" era. New information function requirements are being identified every day and new equipments are constantly being added and will soon snowball. A systems approach which will reduce the total number of equipments is not being applied because it is traditionally argued in the commercial aviation field that:

1. Billions of dollars have already been invested in equipment and facilities.
2. It takes years of coordination and standardization within ATA, ARINC, IATA, FAA, and ICAO to get equipment specified and adopted.
3. Large original expenditures are required to develop new equipment. In the past, the commercial aviation equipment suppliers capitalized on military R&D expenditures.

Times have changed. Commercial aviation is growing rapidly and the inventory of new aircraft planned will easily supplant the aircraft in existence. Unless a systems approach to the information transfer problem is adopted, we will continue to have growth in the annual budgets of the airlines. More dollars will have to be provided for more equipments, maintenance, spares, and time and energy required for the operation of the equipments. The cost involved in building and operating the large number of aircraft contemplated (see Table 1) dwarf the original expenditures required to develop a new commercial avionics system. A new system which could be cost effective in the expansion of functions, phase-over, installation, maintenance and operation thereof, will be discussed in this paper after examining the trends, problems and interim solutions being offered.

New Information Functions to be Added

An anti-collision system providing information for commercial and general aviation aircraft is vital to the enhancement of air safety in view of the great growth projected for air traffic. It has been recognized that mid-air collisions occur due to errors in existing ground control systems and, in some cases, due to the non-existence of control facilities in remote or transoceanic regions. Therefore, it is desirable to place equipment aboard the aircraft to fill their gaps and reduce the probability of mid-air collisions. This is particularly necessary for airlines where the fatality rate for even one collision is large. For this reason, the airline industry has indicated their intention to equip their aircraft with a Collision Avoidance System (CAS). Standards for such a system were developed by the Air Transport Association in a series of meetings of a Technical Working Group which includes avionics companies. The conclusions of this group were stated as the policy and functional requirements of the airlines industry in a document entitled

The requirements are summarized below:

1. Detect all aircraft which represent a potential danger.

2. Evaluate the hazards presented by these aircraft.

3. Determine if a maneuver is required.

4. Indicate the evasive maneuver required in time to maintain safe operation.

The system requires RF and video sections, data processing, computation, clocks, displays and upper and lower antennas. It is a time-frequency carrier system. The addition of options such as diversity reception and altitude rate require additional building blocks.

Another related functional information requirement is Pilot Warning Indication (PWI) such as the infra-red PWI being sponsored by NASA. This non-cooperative detector and indicator of nearing aircraft detects the high intensity flash of the XENON light beacon (to be required by the FAA for visual conspicuity) on other aircraft. The detector has 360° coverage in 30° sectors and serves to warn the pilot to look for another aircraft in a particular direction. Evaluation and escape are visual. Relative altitude could be obtained by encoding the aircraft altitude into the light flashes. Tests have shown the detection range to be about 10 miles on a clear day and 5 miles in haze. The further reduction in heavier weather is of no great concern because a PWI is useful only if the pilot can see the other aircraft and evaluate the indicated threat. In such weather the aircraft must fly IFR and depend on ground control for separation.

As we further develop the aerospace technology for CAS/PWI we find that engineers soon start looking at its use for solving other problems and the system starts changing. More displays, communication channels, and processing equipment start being added and the system grows in size and complexity. Figure 1 illustrates that CAS systems could be used for rescue beacons, obstruction avoidance, air traffic control, altitude transponding, etc.

The potential rewards or losses entailed in the multibillion dollar investments in new aircraft and terminal facilities will hinge on the ability to operate them at increasingly lowered visibilities, and in dense air-traffic environments. They are now approaching potentially unacceptable levels and the impact of one electronic information element, the landing system, on safety and air traffic capacity has yet to be fully recognized. The present ILS approach (direct signal to a cooperative receiver and pilot display) is better than the World War II GCA concept; however, the ILS was and still is a radio approach concept fully depending on having sufficient visual range and time to correct visual radio-induced path errors; and the ability to return to a normal visual landing pattern just as if the visibility were perfect. Table 2 shows landing requirements today, which entails six internationally ICAO accepted standards for the ILS—see-to-land visual concept.

There is a large investment in VHF/ UHF ILS equipment today and the real issue is how far can the existing equipment be extended to cover the new landing categories. Every indication is appearing that this will not be possible unless ILS is combined with other information systems to take care of all of the associative problems of low visibility landing. As an example, the significance of the landing system with respect to the total flow of air traffic in a given terminal area is often overlooked. A cumulative reduction in actual landings per hour due to the lack of a number of runways simultaneously in use is a real limit to airline capability and growth.

In the future, precision surface-radar surveillance systems, such as ASDE (Airport Surface Detection Equipment), as well as the possibility of TRACE (Traffic Routing and Control Equipment) will be added for feeding radar traffic information and establishing the spacing between landing aircraft. The current limitations of the IFR/ATC and the UHF/VHF landing system mask the identifying need for ASDE and TRACE to become part of a total Integrated Landing System (ILS). Even though the low visibility landing problem is improved through the use of radar observation, the limitation in communications to the pilot will require a new, modern, and more flexible (microwave) ILS with the ability to provide rapidly up-dated information to improve air-to-air and surface-to-surface spacing.
The present avionics system of the 747 reflects a number of significant predictions of what satellite information systems they expect to include. Our question has to be - Are they the right ones and are other systems going to be available? The aircraft will carry duplicate VHF communication sets, as well as having provisions for HF communications. The former are directed toward eventual use for long range satellite communications in addition to shorter range terminal area communications. Boeing is also provisioning the aircraft with a company-designed omni-directional VHF antenna, which provided good results in NASA tests with the ATS-B satellite. Wiring for the remainder of the airborne portion of the satellite communications relay link is also included in the aircraft. VHF satellite receivers are being produced by avionics companies in the anticipation that each transport may carry two or three VHF sets as standard installation. A dual satellite communication system called (SATCOM) is being planned to provide this information via VHF; however, USAF is involved in a program called TACSATCOM with equipments operating in the SHF and UHF region. The basis for the difference in the experiment lies primarily in the opportunity afforded the airlines to use their existing radios for multifunction purposes; however, one should consider that going higher in frequency for satellite communications offers many more benefits in RFI, spectrum utilization, bandwidth, etc., that could economically more than justify the change to a new family of equipments. In addition, Boeing is reserving space for a digital air-to-ground communications link, but its engineers suggest its development will be dependent on the emergence of satellite airline communications. The Radio Technical Commission for Aeronautics (RTCA SC110/111 Committee) has issued standards for a "Universal Air-Ground Digital Communications System." Three propagation modes will be used in the VHF portion of the radio spectrum for air-ground digital communications. These modes are established as: (a) line of sight, (b) tropo-scatter, and (c) satellite relay. Various different digital communications systems will have to be provided, however, it is expected that they will be integrated around a common form of VHF modulation.

Satellite systems are also being considered as a solution for the navigation and traffic control requirements of civil aircraft traveling over international waters. The final report of the AD Hoc Joint Navigation Satellite Committee (JNSC) summarizes these needs as: (a) more efficient air traffic control or coordination system over the North Atlantic available within a few years, (b) independent aircraft position fix capability by Air Traffic Control Centers and, (c) improved communications between shore-based stations and vehicles over ocean areas. The major elements of any new system will include the satellites, the user equipments, and the ground stations. There are apparently two schools of thought in the commercial navigation satellite field. Some activities believe that the NAV/TC (Navigation/Traffic Control) user equipment must rely as little as possible on other aircraft instrumentation and provide very reliable accurate navigation and time data. Others look at a navigation satellite system as a means of updating the primary inertial or doppler navigation system. Honeywell designed a system called the Updated Geo Navigator around a satellite system which was found incapable of providing continuous position fixes. As a result, the system must now operate as a dead reckoning navigation aid between such fixes. A fast moving platform, such as an aircraft needs information on the vehicle's velocity for accurate position fixes; this information is readily available only if the aircraft is equipped with an inertial or doppler system. Therefore, the use of the Honeywell system appeared best suited as a means of updating the primary navigation systems. Predictions are made that this system may be integrated some day into inertial-satellite navigation systems which would be competitive with gimbaled, pure inertial systems. The Updated Geo Navigation system now consists of a receiver, digital computer, control display and power supply.

Other candidate NAV/TC systems based on different satellite configurations, being studied are: (a) two baseline interferometer, (b) spinning interferometer, (c) swept beam fans, (d) synthetic interferometers, (e) pulse ranging, (f) time ranging, and (g) hyperbolic ranging. Each system requires a trade-off of not only the number and complexity of the satellites, but the user equipment requirements such as: power, antennas, and compatibility with existing equipment.

One study concluded that L-Band transmission offered the best user equipment when implemented with satellite phased array antennas. Such a conclusion ignores existing avionics equipment which uses VHF. Some agencies insist
on VHF and ignore its disadvantages, such as its bandwidth limitation for future growth, and its requirements for large satellite and user antennas.

With all the new information being made available through CAS, automatic landing, communications satellite, digital data links, and navigation satellite, a fresh look at a wider band communication system is needed and we cannot be constrained by compatibility with equipment and practices in existence.

The Problem and Offered Interim Solutions

Problem

As shown previously, new equipments are being added to service mission areas such as Air Traffic Control, Collision Avoidance, Airport High Density Traffic Handling, Transocean Navigation, and Landing. Instead of looking at the CNI (Communications, Navigation and Identification) system as one information system, the history of electronics for CNI has resulted in each system having its own transmitter and/or receivers, antennas, building/shelters, operating and/or maintenance personnel and logistic requirements. Present plans for the 747 include the customary assortment of equipment, in duplicate and triplicate, to provide for improved reliability. These include dual installations of, VOR/ILS receivers, DME transponders with dual situation indicators, coupled with two radio altimeters having two independent outputs. Triplicate VHF sets and HF equipment are also contemplated. The net result of all these changes are: (a) spectrum crowding, (b) too many equipments, (c) RFI problems, and (d) too many ground and satellite environments. An example of the present spectrum utilization is shown in Table 3.

The addition of air-to-ground digital communications, radar altimeters (4300 MHz), landing signals, and the possibilities of incorporating new navigation systems such as Decca and Omega (10-200 KHz) or satellite communications can broaden the frequency range of CNI systems so that equipments will operate from 10 KHz to 4300 MHz. Figure 2 shows the antenna locations planned for the Boeing 2707 supersonic transport. Adding more antennas for the new information functions just compounds the RFI, space, temperature and installation problem. This complexity is increased by interfacing problems related to wiring, function control devices and other "black-boxes" required to allow the primary elements to operate as a system.

System Solutions Being Offered

Combinations of new functions and the close interrelationships of traditional capabilities are evolving a new character for the commercial avionics system. "Integrated Avionics" has drawn a lot of interest over the past few years and is expected to draw more in the future. First, we must define "integrated avionics" in a system sense. Three definitions which have been used are discussed below.

Definition 1 - In this definition of "Integrated Avionics," integrated circuits are connected internally as a system to reduce the size of individual block boxes. Although air transport equipment is beginning to utilize microcircuitry, its advantages are principally enhanced by reliability and lower power consumption rather than by any appreciable size reduction. The Collins Radio Model 618 M-2B VHF transceiver employs microcircuitry and silicon solid-state devices mounted on metal core planar boards in its construction. The transceiver is packaged in a 1/2 ATR short case, similar in size to the earlier 618 M-1 larger solid state model, though weight saving in the new model is nearly 2 pounds. The new model is interchangeable with earlier Collins equipment and all ARINC 546 transceivers. Along with the reduction of size in these systems, new applications are added. The solid state equipment packaging permits the use of dual NAV/COM sets, and also improves the compactness of control boxes which provide integrated information functional groupings such as navigation and communications tuning on the same panel. The Collins Radio 331N-3D combines these operations and a DME function switch on one panel.

Definition 2 - Here, "Integrated Avionics" is the integration of functions in a group of functional black boxes that may or may not use integrated circuits. Two examples follow: (1) reduce the duplication and number of separate equipments by either replacing various different communications black boxes on an aircraft with one black box doing all these functions, or combining their individual functions in separate black boxes for some form of improvement; and (2) integrating, in some form normally done by a data processor, separate black boxes with different functions - Communication, Navigation, and Identification. Figure 3 illustrates this concept. The RCA AVN-210 Integrated Navigation System shown in Figure 4 is an example of this approach. Many new aircraft for years to come will benefit from this combined VOR/LOC, Marker Beacon, VHF and Glide Scope System.
Bendix advertises a line of integrated flight control and navigation systems such as (AHRS) Altitude and Heading Reference System, to be used with a microelectronic map computer. An Integrated Vertical Navigation System (VERNAV) that computes pilot programmed ascent and descent flight patterns is also part of these integrated systems.

Definition 3 - This definition involves specifically designing the complete avionics package in a fashion such that functions are combined by including in the integration, the vehicle, the mission, and the information requirements necessary to perform the mission. Integrated circuits should be used and the system should be under the control of some central data processing complex. An approach to designing such a system will be discussed in depth in the next section of this article and examples will be given here of "interim trend" type of systems. This new system will be called the "Integrated Information Processing System."

To put a stop to the proliferation of transmitter, receiver, and antenna designs, the Air Force's "Space Ground Link Subsystem" (SGLS), like NASA's unified S-band system, integrated on one or two channels most of the tracking, telemetry, and command functions of manned spacecraft communications. Designed by TRW, the SGLS equipment makes extensive use of microcircuits and is modular and expandable to meet changing requirements. In the design of such a system, the information to be transmitted was determined and an Integrated RF transmission system was developed. Figure 5 indicates the system for both ground and spacecraft.

Two years ago, during the 4th Space Congress, the RCA MINCOMS (Multiplexed Interior Communications System) developed for the US Navy was discussed as a means of integration for aircraft and space vehicles. Multiplex entertainment and passenger service systems are now appearing in the designs of the Boeing 747, the Lockheed L-1001, McDonnell Douglas DC-10, and the supersonic transport. Multiplexing provides a means of simultaneously transmitting signals between a number of terminals on an airplane and combining different kinds of signals (voice, video, synchro, and analog low level signals) with different routings into a common transmission line that connects all the terminals. Figures 6 and 7 show such an arrangement. In a multi-jet airplane, multiplexing can eliminate tens of miles of wire and many multipin cable connectors, and reduce the weight by more than 1000 pounds. The terminals can be instrument transducers, crew controls, indicators, communications and other avionics equipment, and special or general purpose computers. Its justification for commercial air transport has had to await the maturing of integrated circuits and circuit array technologies.

The development of multiplexing integrated circuit technology and increasing complexity of new aircraft has initiated the development of aircraft integrated data systems for obtaining, recording and evaluating in-flight data for operation and maintenance scheduling and analysis. Figure 8 shows an Aircraft Integrated Data System (AIDS) for monitoring and evaluating all aircraft systems. In the RCA system, an integrated circuit signal conditioner is physically connected to each data point sensor, thereby eliminating the need to switch signal conditioners among the main aircraft's operating circuits. This provides several benefits:

1. Improved isolation for aircraft circuits.
2. Flexibility and adaptability for handling additional types of sensors.
3. Increased number of sensors can be polled in a given sampling period.

In the RCA system, analysis can be performed either by an on-board computer, by a ground based computer through data link, or by using a recorder to log the data for post-flight evaluation.

In flight analysis of aircraft systems for the identification of faulty lowest replaceable units will be used on aircraft engaged in critical military missions where maintenance requirements must be predicted before the aircraft lands. The first commercial aviation systems will utilize on-board data collection for later analysis by a ground computer system. As the systems grow, there will be a trend toward in-flight real-time data analysis in commercial aviation.
The Integrated Information Processing System

Present development programs, including the interim solutions discussed, will continue the proliferation if nothing else is accomplished in a coordinated fashion. Complete and unrestricted proliferation of both air and ground systems must be replaced by an efficient integrated information system for global communications and navigation embodying the functional integration of Communication, Navigation, and Identification. We must conclude that, if in 1920 we had the technologies and systems available to industry today, we would not have proceeded in the same manner. Maximum use of satellites, broadband RF, new signal processing techniques, phased array antennas, electrically tuned preselection, and LSI synthesizers would occur. In the design of such a system, several ground rules must be stated:

1. Spectrum utilization must be improved.
2. Airborne equipment must be simplified.
3. Ground complex simplification must occur.
4. A standardized system must be adopted.
5. Improved CNI performance is needed for the post-1975 period.
6. Capabilities must be within the system for all flight phases of the mission.
7. Added system performance, due to radar and satellite system data availability, must be capable of being accepted.
8. Better general available performance is needed.
9. Promising new concepts and technology must be used.
10. Enhanced cost effectiveness would result if equipment is removed each time a new function is added.

Figure 9 indicates the direction in which we should be heading. An integrated information system, providing a world-wide capability, would have two modes: (1) a remote mode which is a satellite-based system capable of providing global navigation and communications, and (2) a direct mode for ground/air, air/air communications and for ground-based navigation. The direct mode would be required to handle the large capacity needed for CNI purposes, particularly in those portions of the flight profile at or near air terminals. The elements of such a system are shown in Figure 10. The satellite mode would employ a constellation of synchronous satellites, capable of providing position determination from range difference measurements beyond line-of-sight communications and system precise timing. Such a system could be militarily compatible except for AN complexity additions.

Approach

A task flow chart indicating a methodology of designing such a system is shown in Figure 11. Complete missions of aircraft known today as well as future requirements have to be studied, including phases such as take-off, terminal area control, enroute navigation (land and sea), collision avoidance and landing. A time line analysis of the functions must be performed within and without the aircraft to ensure mission accomplishment and safe return of the aircraft and pilot. These analyses must be expressed in the form of time-based charts of the total workload so that each of the functional information areas are specified and the need for display and control are identified. The divergence of aircraft requirements are also studied from a point of view of size and mission, civil versus military, and foreign and domestic requirements. Current and future communications and navigation equipments and systems are studied for compatibility with major ground systems such as ATC and other aircraft systems such as flight control and inertial navigation. Part of the investigative technique is the selection of optimum air traffic control, navigation, identification procedures and techniques. The integration of the information system with other onboard equipment (radar, altimeter) and satellite and ground sensor systems is a most necessary consideration.

The evolution of platforms for experiment and operational employment, as shown in Figure 12, must be taken into consideration for specific controlled
environments. Such a system is realizable because of the available technologies to accommodate these platforms when they appear. After the conclusion of such a study, a set of preliminary informational functional requirements, as shown in Table 4, can be obtained.

The next step in the process should be the design of the "information pipe" (similar to a SGLS concept), which is a candidate waveform design which will be synthesized to integrate the various functions of direct and remote (satellite) communications, navigation, IFF, instrument landing altimetry, and collision avoidance. Examples of modulation techniques that could be used are:

- PN - Pseudo-noise
- FH - Frequency hopping
- GPN - Gated pseudo-noise
- FH/PN - Hybrid combination of frequency hopping and pseudo-noise
- GPN/MF - Gated pseudo-noise with matched filter

Before waveform designs are postulated, it is necessary to determine the most up to date projection of technological constraints on the generation, transmission, reception and detection of these waveforms. This will allow initial rejection of any design which exceeds the projected growth of technology. As an example, the projected technology of delay line matched filters and pseudo-noise correlators are explored to determine maximum keying rates which can be processed so that waveform designs can be limited to this maximum. Table 5 shows an analysis of various modulation techniques against certain criteria. Other criteria such as sensitivity to user motion (doppler), satellite power utilization, spectral efficiency are added in more exhaustive analyses. Design studies of these "information pipes" for this type of problem have been performed by many avionic companies and are proprietary.

Conclusion

From such efforts evolve new user terminals, such as Figure 13, which will cause changes in aircraft avionic systems. The "equipment less aircraft" of the future will have data circulated around the aircraft in processed language which will be fed through new types of conversion equipment (conversion by need at the right mission time) to a computer which will control the use, display and timing of the data. Such a system will minimize the diagnostic test equipment needed. All information will be distributed in the minimum number of coaxial paths and new equipments could be plugged in as subscriber terminals to withdraw the information. The airlines and the FAA have the most opportune advantage in implementing the required aircraft and ground network because they can control their own operating environment. Phase-over can be accomplished gradually by integrating new ground terminals into existing stations, equipping new aircraft with the new system and allowing older aircraft to use the previous systems until obsolescence occurs.
<table>
<thead>
<tr>
<th>Year</th>
<th>Commercial Fixed Wing Aircraft (US Production)</th>
<th>Fixed Wing Carriers in Service (US Non-US)</th>
<th>Executive Jets</th>
<th>Heavy Twins</th>
<th>Light Twins</th>
<th>Heavy Singles</th>
<th>Light Singles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>162</td>
<td>2272</td>
<td>1400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>162</td>
<td>2388</td>
<td>300</td>
<td>750</td>
<td>1800</td>
<td>4900</td>
<td>9,900</td>
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<tr>
<td>1969</td>
<td>205</td>
<td>2583</td>
<td>363</td>
<td>827</td>
<td>1984</td>
<td>5395</td>
<td>10,790</td>
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<tr>
<td>1970</td>
<td>245</td>
<td>2730</td>
<td>1550</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td>230</td>
<td>2860</td>
<td>300</td>
<td>750</td>
<td>1800</td>
<td>4900</td>
<td>9,900</td>
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<tr>
<td>1972</td>
<td>230</td>
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<td>1650</td>
<td>395</td>
<td>903</td>
<td>2166</td>
<td>5885</td>
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<tr>
<td>1973</td>
<td>215</td>
<td>3170</td>
<td>1700</td>
<td>419</td>
<td>958</td>
<td>2298</td>
<td>6241</td>
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<tr>
<td>1974</td>
<td>220</td>
<td>3320</td>
<td>1750</td>
<td>456</td>
<td>1046</td>
<td>2508</td>
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<td>1976</td>
<td>245</td>
<td>3570</td>
<td>1850</td>
<td>510</td>
<td>1189</td>
<td>2850</td>
<td>7727</td>
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<td>1977</td>
<td>260</td>
<td>3660</td>
<td>1900</td>
<td>582</td>
<td>1249</td>
<td>2994</td>
<td>8116</td>
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<tr>
<td>1978</td>
<td>280</td>
<td>3750</td>
<td>1950</td>
<td>561</td>
<td>1312</td>
<td>3166</td>
<td>8524</td>
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<tr>
<td>1979</td>
<td>300</td>
<td>3860</td>
<td>2000</td>
<td>600</td>
<td>1392</td>
<td>3337</td>
<td>9038</td>
</tr>
</tbody>
</table>

Table 1 - Aircraft Production Projections

### Table 2 - ICAO Low-Visibility-Landing ILS Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Runway visual range, RVR (ft)</th>
<th>Decision height, DH (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2400</td>
<td>200</td>
</tr>
<tr>
<td>II-A</td>
<td>1600</td>
<td>150</td>
</tr>
<tr>
<td>II-B</td>
<td>1200</td>
<td>100&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>III-A</td>
<td>700</td>
<td>--</td>
</tr>
<tr>
<td>III-B</td>
<td>150</td>
<td>--</td>
</tr>
<tr>
<td>III-C</td>
<td>zero</td>
<td>--</td>
</tr>
</tbody>
</table>

<sup>a</sup> Height (above runway elevation) below which a pilot must not descend if he has not obtained adequate visual references before approaching this point. He must execute a missed-approach procedure at this point or be assured he has adequate references to land by visual means.

<sup>b</sup>Sometimes called CAT II.

### Table 3 - Partial Requirements

<table>
<thead>
<tr>
<th>Mission</th>
<th>Function</th>
<th>Frequency-Range (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>Navigation</td>
<td>0.2-0.4</td>
</tr>
<tr>
<td>Loran</td>
<td>Navigation</td>
<td>1.7-2.0</td>
</tr>
<tr>
<td>HF</td>
<td>Communication</td>
<td>2-30</td>
</tr>
<tr>
<td>VHF-M</td>
<td>Communication</td>
<td>30-70</td>
</tr>
<tr>
<td>Marker Beacon</td>
<td>Navigation</td>
<td>75</td>
</tr>
<tr>
<td>ILS-Localizer</td>
<td>Navigation</td>
<td>108-110</td>
</tr>
<tr>
<td>VOR</td>
<td>Navigation</td>
<td>110-118</td>
</tr>
<tr>
<td>AM Civil</td>
<td>Communication</td>
<td>118-136</td>
</tr>
<tr>
<td>ILS Glide Slope</td>
<td>Navigation</td>
<td>330-335</td>
</tr>
<tr>
<td>ILS Receiver</td>
<td>Navigation</td>
<td>978-1213</td>
</tr>
<tr>
<td>ATC Transponder</td>
<td>Navigation</td>
<td>1030-1090</td>
</tr>
<tr>
<td>IRE Transponder</td>
<td>Navigation</td>
<td>1041-1150</td>
</tr>
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</table>

Table 3 - Partial Requirements
<table>
<thead>
<tr>
<th>Function</th>
<th>Direct Mode</th>
<th>Remote Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMMUNICATION</strong></td>
<td>Typical Aircraft: Simplex operation of one 2 kHz b/s vocoder channel, 15 dB processing gain, 10^-5 ber, Coverage to horizon.</td>
<td>Typical Aircraft: Passive monitoring of 3 or 4 NAV satellites continuously transmitting reference signals, Satellites from more than one constellation may be in view at one time.</td>
</tr>
<tr>
<td><strong>Guard Channel Monitor</strong></td>
<td>Continuous receive voice or data on one all-call channel.</td>
<td>Same</td>
</tr>
<tr>
<td><strong>Data Link and Landing</strong></td>
<td>Simplex operation of one 2 kHz b/s data channel. Within a channel, messages will be time-division multiplexed using address header, either personal or position.</td>
<td>Same</td>
</tr>
<tr>
<td><strong>En Route Navigation (Long Range)</strong></td>
<td>LORAN-A,-C, OMEGA</td>
<td>N.A.</td>
</tr>
<tr>
<td></td>
<td>Passive or active monitoring of ground based equipment for position determination.</td>
<td>N.A.</td>
</tr>
<tr>
<td><strong>Navigation (Short Range)</strong></td>
<td>TACAN, VORTAC, DME, OMEGA</td>
<td>N.A.</td>
</tr>
<tr>
<td></td>
<td>Radar</td>
<td>N.A.</td>
</tr>
<tr>
<td><strong>Identification</strong></td>
<td>Radar Identification: Active determination of height above terrain using reflected signal.</td>
<td>Passive</td>
</tr>
<tr>
<td><strong>Collision Avoidance</strong></td>
<td>Transmission of GAS message on a GAS channel(s). One way or reply to interrogations received. Must be continuous with rep rate 1 sec or less. Preferably altitude discrimination prior to reply. Preferably civilian compatibility.</td>
<td>N.A.</td>
</tr>
<tr>
<td><strong>IFF</strong></td>
<td>Similar to GAS but without altitude discrimination. Civilian compatibility but must be secure for military. Could operate as a digital data link but must have random access in all-call channel.</td>
<td>N.A.</td>
</tr>
<tr>
<td><strong>CAS</strong></td>
<td>Same as GAS</td>
<td>Same as data link</td>
</tr>
</tbody>
</table>

Table 4 - Preliminary Information Functional Requirements

<table>
<thead>
<tr>
<th>Modulation Techniques</th>
<th>Rapid Synchronization</th>
<th>Wide Dynamic Range</th>
<th>Accurate Time</th>
<th>Accurate Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>PN</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>FH</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>FH/PN or FH/PN</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>GPN</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>GPN/MF</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 5 - Signal Modulation Comparison
Figure 1 - Growth Functions of Collision Avoidance Type System
MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT USE IC'S

NAVIGATION SYSTEM

MAY OR MAY NOT USE IC'S

IDENTIFICATION SYSTEM

MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT USE IC'S

COMMUNICATION SYSTEM

MAY OR MAY NOT BE UNDER DATA PROCESSOR CONTROL. INTEGRATION CAN SAVE BY NOT DUPLICATING POWER SUPPLIES, COMMON FUNCTIONS, ETC.

CONTROL

DATA PROCESSOR

DISPLAY

BLACK BOXES

Figure 3 - Definition 2 System Integration

Figure 2 - Antennas for Boeing 2707
Figure 4 - RCA AVN-210 Integrated Navigation System

Figure 5 - SGLS Concept
Figure 6 - 747 Floor Plan

Figure 7 - Schematic of 747 Multiplexed Entertainment System
ACQUISITION UNIT

ACQUISITION UNIT

ACQUISITION UNIT

ACQUISITION UNIT

CENTRAL ELECTRONICS UNIT

5 MINUTE LOOP RECORDER AND PLAYBACK

INCREMENTAL RECORDER

TAPE CARTRIDGE

TO GROUND DATA PROCESSING EQUIPMENT

Figure 8 - Aircraft Monitoring and Evaluation
INTEGRATED CONSOLE
CONVERSION EQUIPMENT
COMPUTER
PROCESSOR
RECEIVER/TRANSMITTER

INFORMATION DISTRIBUTION SYSTEM

SKIN TYPE ANTENNAS

GROUND STATION

Figure 9 - Equipment/Less Aircraft Concept (Future Avionid System)

Figure 10 - Elements of Information System
Figure 11 - Mission Requirements Methodology
Figure 12 - Evolution of Platforms
Figure 13 - General Block Diagram of Information User Terminal