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**FAA Category III Instrument Landing
System: A Ground Equipment
Development Overview**

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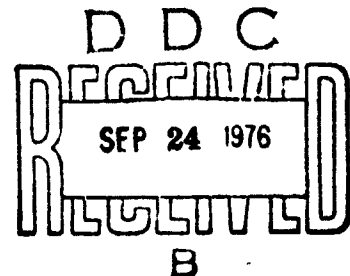
FAA CATEGORY III INSTRUMENT LANDING SYSTEM: A GROUND EQUIPMENT DEVELOPMENT OVERVIEW

Carl G. Peterson



August 1976

Final Report



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16. Abstract Federal Aviation Administration, Systems Research and Development Service VHF/UHF Category III Instrument Landing System development efforts have resulted in the establishment of operational Category IIIA ILS at various airports in the United States. Significant efforts and results are summarized. Major differences between the FAA Category III ILS and other types of ILS are pointed out. Reliability aspects, the Far Field Monitor, the Maintenance Monitor and the ILS Monitor Precision Calibrator as part of the Category III ILS development are presented. Existing lightning problems and efforts to resolve these are covered. Report serves to provide a broad single picture of SRDS interrelated Category III ILS development activities to date.			
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Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find
LENGTH			
mm	millimeters	0.04	inches
cm	centimeters	0.4	inches
m	meters	3.3	feet
km	kilometers	1.1	yards
		0.6	miles
AREA			
cm ²	square centimeters	0.16	square inches
m ²	square meters	1.2	square yards
km ²	square kilometers	0.4	square miles
ha	hectare (10,000 m ²)	2.5	acres
MASS (weight)			
g	grams	0.005	ounces
kg	kilograms	2.2	pounds
t	tonnes (1000 kg)	1.1	short tons
VOLUME			
ml	milliliters	0.03	fluid ounces
l	liters	2.1	pints
		1.06	quarts
		0.36	gallons
m ³	cubic meters	36	cubic feet
		1.3	cubic yards

TEMPERATURE (exact)

°C	Celsius temperature	°F (then add 32)	Fahrenheit temperature
-40	-40	-40	-40
-20	-20	-4	-4
0	0	32	32
20	20	68	68
40	40	104	104
60	60	140	140
80	80	176	176
100	100	212	212

1 in. = 2.54 cm (exact)

1 ft = 12 in. (exact)

1 yd = 3 ft (exact)

1 mi = 1.609 km (approx)

1 square inch = 6.45 cm² (approx)

1 square foot = 0.09 m² (approx)

1 square yard = 0.8 m² (approx)

1 square mile = 2.6 km² (approx)

1 acre = 0.4 ha (approx)

1 ounce = 28 g (approx)

1 pound = 0.45 kg (approx)

1 short ton (2000 lb) = 0.9 t (approx)

1 teaspoon = 5 ml (approx)

1 tablespoon = 15 ml (approx)

1 fluid ounce = 30 ml (approx)

1 cup = 0.24 l (approx)

1 pint = 0.47 l (approx)

1 quart = 0.95 l (approx)

1 gallon = 3.8 l (approx)

1 cubic foot = 0.03 m³ (approx)

1 cubic yard = 0.76 m³ (approx)

1 °F = 5/9 (after subtracting 32) °C (exact)

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Chapter 1

INTRODUCTION

Category III Instrument Landing Systems (ILS) of the conventional VHF/UHF type has been introduced for actual operation in the United States. Further implementation of several systems is anticipated within the near future. The Category III ILS represents the latest existing ground electronic guidance system designed to best meet demands for high dependability during aircraft approach and landing in very limited visibility.

The continued development of ILS over the years has made it possible for pilots during inclement weather to an every increasing extent depend on the ILS for safe and efficient guidance in airport approaches and landings. Categories of ILS operation as defined in the Aeronautical Telecommunications Annex 10 to the Convention of International Civil Aviation (ICAO Annex 10) are used to describe operation under different visibility conditions. Category IIIA operation represents at the present the minimum weather conditions during which commercial operations are possible. The ground equipment required for Category IIIA operation, including Category III ILS and certain runway lighting aids and RVR equipments will permit "hands-off" landing by a qualified aircraft crew in forward visibility down to 700 feet and no decision height. By comparison, a Category II system provides landing capability under minima not lower than a 100 foot decision height and forward visibility down to 1200 feet.

Although the nominal radiated signal characteristics are the same for Category I, II, or III, the difference in the ILS equipment itself corresponding to higher categories of service is represented by extension of guidance required along the runway itself and by refined accuracy and tighter tolerance capability in the ground equipment as described in the ICAO Annex 10.

Additionally, an outstanding characteristic of the Category III ILS is that the reliability and the availability of the system must be the best achievable in order not to compromise the ILS signal during the final phase of an aircraft Category III ILS approach. Usually, actual Category III conditions are relatively infrequent at most airports but the characteristics of the Category III ILS will enhance safety and availability for Category II and I ILS operation as well.

A complete Category III ILS consists typically of a VHF localizer with dual transmitters, a wide aperture antenna and redundant monitors, a UHF glide slope with dual transmitters and redundant

monitors, dual 75 MHz transmitters for the inner, middle and outer markers, plus remote control and monitor indicator equipment at the airport control tower.

The following pages in this report present a general overview and insight into the Category III ILS ground equipment which has been developed under a program of the Systems Research and Development Service of the Federal Aviation Administration and single out significant results obtained from the development. For additional detailed information attention is invited to the reference documents which cover specific details of the development effort and the technical aspects of the equipment itself.

Chapter 2

BACKGROUND

2.1 Early development efforts

The FAA first undertook development work of a Category III ILS in the early 60's. This development resulted in separate major equipment contributions by five different U. S. manufacturers and the furnished equipment was intended to be evaluated at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, as a system. The system was never fully completed, however, and consequently did not undergo a complete system evaluation. Specific problems included lack of main/standby equipment transfer capability within two seconds, as required, an unsuccessful and delayed localizer near field monitor development and general equipment instability and reliability shortcomings. A summary NAFEC letter report on the evaluation of the furnished equipment is included as Appendix B of this report.

Although the initial Category III ILS development was unsuccessful, continuing R&D work leading to improvements in ILS during the 1960's contributed to an improved base of knowledge for specifying performance requirements for a Category III ILS.

2.2 STAN 37/38

Concurrent with the U. S. effort at NAFEC, the United Kingdom had worked on the development of a Category III system which resulted in a system designated STAN 37/38. Later, an agreement was reached between the U. K. Board of Trade and the FAA for FAA to perform a jointly agreed evaluation plan of this system at NAFEC. The system was installed as an 85 foot antenna array localizer and an M-array glide slope. The evaluation plan included an evaluation of system performance against ICAO Annex 10 Category III ILS requirements but was primarily for the purpose of evaluating the integrity of localizer and glide slope executive monitor systems under conditions of transmitter antenna malfunctions and environmental factors, including overflights. Following the installation and evaluation efforts which were completed during the period from August 1969 through May 1971, the system was transferred and installed at the Dulles International Airport as a wide aperture 185 foot antenna localizer and a null reference glide slope for an operational evaluation which eventually resulted in an FAA purchase of the system and commissioning it as a Category III ILS. FAA reports FAA-RD-72-50 "Test and Evaluation of Category III ILS Ground Guidance Equipment

'STAN 37 Localizer Tests at NAFEC on R/W-4'" and FAA-RD-72-105 "Test and Evaluation of Category III ILS Ground Guidance Equipment 'STAN 38 Glide Slope Tests at NAFEC on Runway 4'" describe the evaluation and tests on the STAN 37/38 equipment.

An important conclusion from the NAFEC tests on the STAN 38 was a validation of the FAA practice of always requiring a separate glide slope clearance signal with the M-array.

2.3 Recent Category III ILS development

Although it would have been possible to implement nominal Category III ILS equipment in the U.S. by procuring additional STAN 37/38's and/or French equipment claimed suitable for Category III ILS, a decision was made in order not only to develop U. S. domestic capability, but also, to implement improvements over already existing system designs. The development effort was not required to be 100 percent new development as it was intended that advantage should be taken as much as possible of already existing modern solid state design, in major units such as transmitters, monitors, etc., and modify and assemble these as a system using appropriate redundancy to achieve the highest feasible system reliability and availability. The approach was taken as a practical compromise to save time as well as expense.

Texas Instruments, Incorporated (TI) was awarded a contract on June 30, 1971, to develop and furnish two Category III ILS (FAA MARK III ILS) and to install one of these at NAFEC. The contract was later amended to include the installation of the second system at the William B. Hartsfield Atlanta International Airport and to furnish a third system for installation at the San Francisco International Airport. The NAFEC system has undergone extensive evaluation at NAFEC since its installation including a localizer monitor integrity evaluation with antenna malfunctions by Ohio University in February 1973. The overall MARK III evaluation at NAFEC is being covered in a separate NAFEC report yet to be published. The Atlanta system was commissioned as Category III on November 28, 1974, and the NAFEC system on January 16, 1975, as Category I, however, although the MARK III by itself met Category III ILS requirements. The San Francisco system was installed during the summer of 1975 and later also commissioned.

In a related equipment development effort for test equipment, Cardion Electronics was awarded a contract at the end of 1971 to develop and deliver an ILS Monitor Precision Calibrator for use as Category III ILS test equipment.

In addition to the initial implementation of Category III ILS, modification of existing suitable Category II ILS was considered as an alternate means for achieving Category III ILS. The feasibility of this approach was demonstrated through a contract with TI to furnish and install a Category II to III ILS upgrade kit in the Category II ILS at NAFEC (TI type GRN-27) during the summer of 1974. The performance requirements of an ILS thus upgraded were nearly identical to those of the FAA MARK III ILS. A NAFEC report on the installation effort is included as APPENDIX C of this report.

As of the summer of 1975 the initial goal for the development, implementation and evaluation of a Category III ILS had been reached. Based on our experience with the system, however, and later developments, there are known areas where significant improvements for the present as well as future systems are possible. Efforts are continuing to bring about these improvements to enhance the safety, economy and performance of the VHF/UHF ILS in general which includes not only the Category III ILS but also Category I and II ILS as well.

Chapter 3

DISCUSSION

Except for unanticipated problems and delays associated with the field implementation of the first two MARK III ILS's, the original goals of the development effort have essentially been met. Engineering Requirement CAT III/II ILS Development FAA-ER-320-002 (see APPENDIX A) which was used for the development effort and the system equipment handbooks are referred to for specific details in the performance requirements and the technical description, respectively.

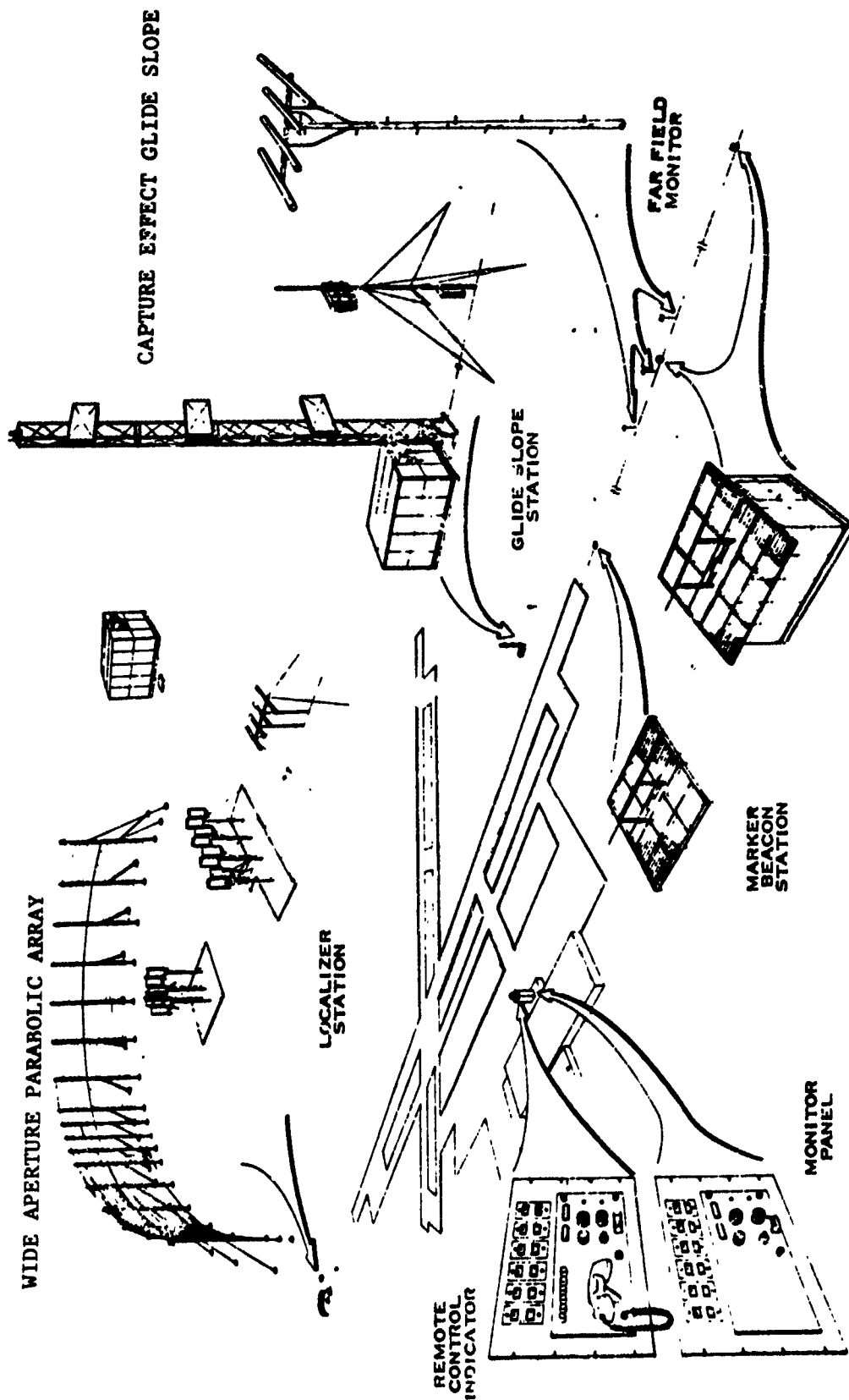
For a further insight into the equipment a comparative perspective of the MARK III ILS, the upgraded TI Category II ILS and other types of Category III ILS is presented below by identifying outstanding differences among these systems.

3.1 MARK III vs LS 371

Although the FAA MARK III ILS is basically of original French design as implemented in the Thomson CSF type LS 371, the French type Category III ILS, there are nevertheless a number of differences between the two systems which it was felt, should contribute to greater reliability for the U.S. system. For example, the MARK III ILS has triplicate localizer and glide slope clearance monitors while only single clearance monitors are used in the LS 371. Also, unlike the MARK III, the LS 371 has no standby transmitter course width monitor, no glide slope integral course monitor, no localizer identification monitor, no shelter temperature monitor, no glide slope antenna mast misalignment detector or localizer near field and far field course monitors. The LS 371 would not meet the FAA engineering requirement for continued normal operation during environmental extremes and a three hour commercial power failure. To insure monitor fail-safe operation an air traffic controller may remotely test the LS 371 monitors for fail safe operation just prior to authorizing a Category III ILS approach, but in the MARK III high fail-safe reliability is primarily insured through equipment design and scheduled maintenance without requiring this additional controller responsibility.

3.2 MARK III vs STAN 37/38

In comparison to the STAN 37/38 ILS which employs triplicate monitoring through separate inputs from internal, aperture and



FAA Mark III Instrument Landing System

near field monitors, the MARK III also uses triplicate monitoring but derives its monitor inputs from integral monitor probe pick-up elements located close to the antenna elements. Integral monitoring in the MARK III assures that equipment transfer and shutdowns are initiated by a monitor input signal closely analogous to an out-of-tolerance condition in the far field, avoids misleading near field effects and is not affected by overflight interference. The MARK III has additionally a near field plus a far field difference in depth modulation (ddm) monitor which will recognize far field disturbances in the approach area resulting in an out-of-tolerance course alignment and alert the controller by downgrading the Category III ILS status immediately or after a short delay, as desired, in the tower. If the out-of-tolerance condition persists for a period longer than normally caused by far field overflight interference, the MARK III far field monitor will shut down the localizer. The MARK III and the STAN 37/38 both require two-out-of-three identical monitors (i.e., such as identical course, width or clearance monitors) to alarm before executive action is initiated, but there is an obvious difference in the control logic in the MARK III compared to the STAN 37/38 (and also the LS 371). For example, the STAN 37/38 monitor system will cause transfer and/or shutdown with a single radio frequency (rf) level alarm on one monitor plus a ddm alarm on another monitor in the same group while the MARK III requires either two rf alarms or two ddm alarms from the same monitor group to cause executive action.

The STAN 37/38 employs mechanical transfer relays and mechanical modulators while the MARK III has no moving parts in the transmitter system and uses a solid state modulator which serves to reduce maintenance requirements. In comparing the antenna systems it can be observed that the wide aperture configuration for each produces comparable main beam widths; however, the STAN 37 localizer employs 24 dipole antenna elements versus only seven antenna elements for the MARK III parabolic array. The MARK III requires separate course and clearance carrier frequencies while the STAN 37 localizer generates course and clearance by means of 90/150 quadrature audiotone modulation of a single carrier. The MARK III provides satisfactory clearance to beyond $\pm 50^\circ$ from the courseline while the STAN 37 exhibits a sharp ddm reversal at approximately $\pm 41^\circ$ from the courseline. The operating environment for the STAN 37/38 is required to be within 0°C to $+30^\circ\text{C}$ while the corresponding requirement for the MARK III is from -10°C to $+50^\circ\text{C}$. A number of other differences exist but are perhaps of less significance. Having been developed and installed only relatively recently, the MARK III has been

subject to a number of initial system shakedown failures and only long term operation of both systems will establish the relative maintenance, operation and reliability merits of the two systems.

3.3 Mark III and GRN-27 (Category II) Comparison

The MARK III and the GRN-27 having both been manufactured by TI have a number of identical subassemblies. Except for the localizer antenna, discussed below, the essential difference between the two systems is a MARK III tighter tolerance monitor system and equipment redundancy designed to achieve greater overall operation reliability and availability. Obviously, a given MARK III would be expected to experience a greater total of individual component failures over a period of time as compared to a GRN-27 system; however, improved system reliability is assured by the fact that most individual MARK III single equipment failures are not likely to result in an erroneous radiated signal or a system shutdown. For example, in contrast to the Category II, a battery or battery charger failure, a dc/dc converter failure, a transmitter failure or a monitor peakdetector failure will not cause a significant interruption or a loss of the radiated signal. Unlike the Category II, the MARK III ILS has a continuously operating standby transmitter into a dummy load monitored and controlled by a set of single internal monitors, and if that transmitter is operating it is immediately available upon transfer. In order to display a Category III status indication on the indicator located in the tower both main and standby localizer and glide slope transmitters must be operating satisfactorily. The radiated clearance, course, course width, and identification parameters, as applicable, are each monitored by three monitors, at least two of which must indicate a fault condition for transfer or shutdown to take place. This arrangement not only prevents a single monitor from shutting down the transmitter due to a monitor failure but also prevents a single monitor from failing to shut down the transmitter if this monitor is not fail-safe and the other two are operating properly. Each monitor is provided with its own peakdetector. The GRN-27 ILS on the other hand employs dual monitors with a common peak detector for each set of course width, and clearance monitors.

The MARK III localizer antenna is the parabolic array with a 176 foot aperture. The reflector parabola is 18 foot high. Three course V-frame antennas located at the focal point radiate energy back towards the parabola which focuses the reflected energy into a very narrow horizontal and low vertical angle beam. Four separate clearance array elements radiate clearance for a coverage of more than $\pm 50^\circ$ about the localizer course centerline.

The installation of the parabolic array requires very precise placement and rather intricate adjustment and tuning but having been installed, the antenna apparently provides very stable performance. Early experience at Atlanta and NAFEC established the necessity of furnishing radomes for the radiating elements including the monitor proximity pickup elements in order to avoid degrading performance effects of rain and ice. If the traveling wave antenna had been sufficiently developed and tested at the time the Category III ILS development contract was signed it is possible that the MARK III could have been furnished with a traveling wave localizer antenna. The traveling wave antenna, used with the GRN-27, exhibits the obvious advantage of being a low profile antenna and is relatively easy to install and adjust; however, it requires additional power input furnished by a power amplifier in addition to the basic MARK III type transmitter to provide the comparable coverage of the parabolic array. Theoretically, the traveling wave antenna with the greater number of radiating elements and corresponding number of connectors is subject to a higher failure rate than the parabolic array. Transmission line open/short detectors and misalignment detectors unlike the traveling wave localizer antenna are not used with the parabolic antenna.

For Category III ILS application, with an upgraded GRN-27 localizer, the antenna array may consist of the basic Category II localizer two frequency 1B array, that is the 14 and 6 element arrays for course and clearance, respectively, to provide Category III course alignment and quality, or a 22 and 8 element array combination may be required depending on the siting conditions. The 22 element array would provide a narrow course beam comparable to that of the parabola, but is of course more complex than the 14 element array. Development efforts are underway to finalize a technique to combine the 14 and 6 arrays and the 22 and 8 arrays, respectively, into single 14 and 22 element arrays for the radiation of both course and clearance signals. Such arrays are expected to reduce the cost and complexity of the antenna system and improve the reliability of the traveling wave antenna array both for Category II and III ILS application. A possible further step toward localizer antenna reliability improvement may include the adoption of a so-called slotted cable localizer antenna presently under development by SRDS.

3.4 Category II to III ILS Upgrade Effort

As mentioned earlier, demonstration of the upgradability of a Category II to III ILS of the GRN-27 with a traveling wave antenna localizer has been made at NAFEC. It involves the procurement of a suitable upgrade kit developed by TI and following a pre-

determined step-by-step procedure to minimize the length of the installation effort. The upgrade effort includes a modification of all the ILS stations. Dual marker beacons in lieu of the existing single marker beacon is desirable to maintain good marker beacon availability. The tower equipment is replaced by new remote control indicators which differentiate between power failure alarms and monitor alarms and also provide an ILS status indicator. The far field monitor is replaced with an upgraded version consisting of two additional antennas, two additional receivers and three monitor channels instead of two. The localizer and glide slope transmitters, cabinets and antenna systems remain intact, but additional monitors, peakdetectors, dualization of batteries, power supplies and control unit boards replacement are required. The Category II antenna change over relays are replaced with solid state pin diode rf switches which provide nearly instantaneous transfer. Also, the present Category III ILS uses an overall heated box for its peak detectors rather than individually heated Category II peak detectors. As part of the upgrade effort replaced surplus equipment becomes available for the Category II ILS inventory.

Certain variations in the Category III ILS upgrade scheme are possible without greatly affecting the basic performance comparison of the upgraded ILS with the MARK III. The MARK III ILS monitor units are similar to the GRN-27 except for certain parts quality and tolerance designed for better performance stability in the MARK III and an output logic which allows for comparison of the status of the individual parameters of each monitor (ddm, rf and sdm), rather than the method of comparing the overall status alarm signal of each monitor unit. The former method as used in the MARK III, theoretically provides for greater system availability and reliability in the long run; however, increased equipment complexity and relative costs are also factors to be considered.

In the upgrade effort at NAFEC the former method was used for the localizer by replacing all the monitors, and the latter method for the glide slope by supplementing the existing monitors with the replaced monitors from the localizer.

Obviously, many other details must be considered beyond the broad outline given here, but the procedure developed for NAFEC is considered to be an efficient way to establish a Category III ILS where a GRN-27 type ILS is already in place. Recommissioning flight checks are required to set the monitor alarm limits but the transmitter system and antenna should not require readjustment. Other schemes for establishing Category III ILS include a replacement

with entirely prewired cabinets, entirely prewired shelters, or a completely new Category III ILS facility. The first two schemes would require additional station tune-up and alignment and the last one would require additional downtime but would be necessary if the existing facility is not a GRN-27 type.

3.5 MARK III ILS FMECA Study and Reliability Evaluation

The Category III ILS system reliability has been given uppermost attention in the design and implementation of the MARK III ILS. It is obviously impossible at the same time to design a practical and an absolutely "safe" system. For the development effort a reliability goal in the form of an absolute number was specified such that theoretically the electronic ground system should not contribute a significant factor to cause a Category III ILS approach and landing to be more risky than the average human experience in day-to-day activities. Since the ILS is only a link in the chain that represents all the conditions needed to insure successful execution of an all weather landing, the actual required reliability number (less than one ground system ILS operational failure during the critical phases of 10 million landings) may be considered somewhat arbitrary.

The stated reliability requirement for the MARK III ILS development was as follows: "That during the critical phase of a Category III Landing (any 10 and 5 second period for the localizer and glide slope, respectively) the probability of a potentially hazardous signal fault including loss of signal shall not exceed 1.0×10^{-7} ." For a Category III approach the assumption is that the ILS is fully operational in a Category III status, including active standby equipment, prior to the aircraft entering the critical phase as described. The theoretical determination of the reliability of the proposed TI design is described in the TI report No. FAA-RD-72-8 "FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA) of the Category III Instrument Landing System" the purpose of which was primarily to verify that the equipment design and system interface was such that the reliability requirement would be met in a total system configuration. In actuality, the theoretical design goal was not easily achieved but became possible with a reasonable effort which was really the intent of the development. The initial analysis revealed the need for a number of design modifications which when incorporated resulted in a system theoretical hazard probability to less than $.9 \times 10^{-7}$. The method of analysis could serve as an illustration of a technique to evaluate the comparative hazard probability of the performance of other systems. The FMECA study also produced a number of other results including identification of all hazardous failure modes, the effect of these failures and a quantitative rationale

for the frequency of "hidden" failure preventive maintenance checks to maintain the system reliability.

A similar FMECA study, Report No. FAA-RD-73-11, "Failure Modes and Criticality Analysis (FMECA) of Category III Instrument Landing Systems with Traveling-Wave Localizer Antenna", was performed to include the reliability impact on the system by the use of this antenna, which resulted in a somewhat lower reliability figure for this system due to a greater number of localizer antenna elements and the addition of the localizer transmitter power amplifiers. The analysis is reasonably representative although it does not cover certain changes or developments that have occurred since the report was written such as the replacement of the localizer near field monitor, the installation of the antenna array misalignment detector and the installation of antenna and monitor system rf transmission lines open/short detectors. (These open/short detectors were first installed in the upgraded ILS at NAFEC in May 1975 for evaluation.)

The Category III ILS development contract required an operational practical demonstration on the first two systems to verify that the specified reliability requirement had been met. Since it was impossible to demonstrate this directly within a reasonable period of time (about six months) on only two systems with any degree of confidence, an alternate method was chosen. The theoretical operational reliability had been derived from individual component failure rates, using the probabilities of single and multiple failures that could cause a total failure, given a fully operative Category III status at the beginning of any 10 or 5 second period. These basic component failure rates had been used in the calculation of the equipment Mean Time Between Failures (MTBF) which is in the order of 795 hours for the MARK III ILS localizer and glide slope considered together. (Although this equipment MTBF is comparatively lower than that of the GRN-27, the total system operational MTBF or potentially hazardous probability corresponding to an MTBF or approximately 26,000 hours, is primarily achieved through effective use of circuits and equipment redundancy.) By demonstrating the equipment MTBF and consequently the acceptability of the same component failure rate data from which the total system operational reliability figure was derived, the validity of this figure, $.9 \times 10^{-7}$, would be indirectly verified.

A reliability demonstration plan was prepared for the first two systems, not to exceed 5,000 hours of simultaneous operation. The actual testing was started on the Atlanta system in December 1973 and continued through June 1974 for a total of 4764 test hours. The NAFEC system was operated for 843.6 test hours, and was terminated on August 30, 1974, for lack of additional support funds which left the overall test result in a "no-decision" status according to the test plan predetermined acceptance criteria.

The results of the reliability demonstration test during the abbreviated time period are not outstanding, regardless of the relative number of failures considered "relevant" or "non-relevant" based on the specified test conditions. However, the formal evaluation did serve as a means for systematic analysis and careful documentation of actual in-the-field operation to justify any needed corrective design modification.

Eleven relevant failures were determined which did not allow final determination of reliability acceptability or rejection. A number of failures can be contributed to initial system "shake down" failures and are not likely to be repeated while others have resulted in equipment design modifications, such as for example the antenna radome installation. The most outstanding problem has been destructive effects as well as non-destructive operational interference due to lightning induced transients on the ILS interstation monitor and control lines. Some corrective measures have been taken to resolve the problem but it is still the object for a continuing effort (see below). Detailed results of the reliability demonstration test are furnished in the TI final report FAA-RD-74-180 "Instrument Landing System Category III" which is referred to for further reference.

The following is a somewhat arbitrary classification of the incidents experienced on the MARK III during the test period as derived from the TI report:

<u>Description of Problem</u>	<u>No. of Events</u>
Random component failures not listed below	5
Failure of operation, unknown cause, no component failure	5
Mechanical failure, solder, wire, etc., potential future problem eliminated	19
Failure due to lack of localizer antenna radomes, potential future problem eliminated	8

Failure due to improper tune-up and maintenance, potential future problem eliminated	90
Failure due to lightning	11
Fuse failures	4
Reset of circuit breaker required	9
Failure due to equipment other than TI	4
TOTAL	155

Thirteen of the above incidents led to total localizer or glide slope shutdown.

The Marker beacons in the first two MARK III ILS installations underwent a separate reliability test during the fall of 1974 designed to demonstrate an MTBF of 10,000 hours of each station. During this period an antenna design deficiency was determined and corrective action taken. The test resulted in a successful acceptance decision of the marker beacons.

3.6 Far Field Monitor

The MARK III ILS localizer Far Field Monitor referred to earlier is an integral part of the system and serves several functions. The final role and use of the Far Field Monitor have not been clearly established, but the development of this monitor has served to highlight and demonstrate certain capabilities.

Both the MARK III and the GRN-27 Category II ILS Far Field Monitor consist of VHF receiver and monitor channels, usually located in the vicinity of the middle marker on the runway centerline extended. They monitor the localizer course alignment for a zero difference in the 90 and 150 Hz modulation depths (ddm) and will cause the localizer to shut down in the event that the localizer course alignment as seen by the monitors should exceed and remain outside Category II tolerance, that is, beyond nominal ± 10.7 microamperes for at least 70 seconds. The monitor indicated ddm is also relayed to the localizer station on a landline as an analog dc voltage for a remote meter indication. This indication may be used as a maintenance tool to remotely check and adjust the far field localizer course alignment.

The MARK III ILS Far Field Monitor consists of triple monitors, each associated with its own VHF receiver and all located in the same shelter. The three receiver antennas are located along the runway centerline extended and separated by more or less arbitrary longitudinal distances to provide some space diversity. It is known that a localizer course interception of the centerline at a given check point does not guarantee the absence of deviations at other

points along the centerline. Space diversity with three monitors assures a better detection of these potential (static) course deviations. It is conceded that the distances between the antennas as installed probably do not represent the optimum separation for detecting reflections from reflecting surfaces on any given airport. Furthermore, the magnitude of a static or dynamic deviation seen by the monitor may not correspond to the absolute magnitudes of deviations experienced by an overflying aircraft on an ILS approach due to the difference of antenna location of the aircraft and the far field monitors. The Far Field Monitor will not detect a far field change of sideband only radiation affecting course width and clearance. At any rate, however, it is important that the monitor will detect dynamic and/or static changes of the localizer course alignment from any cause and provide a remote indication and/or executive action. Additional efforts will be required to develop a Far Field Monitor which ideally should indicate a true correlation with signals seen by approach aircraft on the approach path, and cause instantaneous executive action as warranted.

In addition to the shutdown capability function of the localizer based on a two out of three monitor vote, the MARK III Far Field Monitor will also provide an output function indicating an at least two out of three monitor channel determination of Category III course alignment (nominally within ± 8.6 micro-amperes.) This information is available at the remote control indicator in the tower as one condition (out of several others) which unless bypassed must be satisfied for the Remote Control Indicator equipment to display the Category III status indication. Normally, whenever an aircraft flies over the Far Field Monitor, the localizer signal as seen by the Far Field Monitor is temporarily disturbed causing an accompanying temporary down-grading of the ILS status in the tower and a temporary buzzer sound. Since this represents a nuisance during fair weather, a provision is available to the tower operator which allows him to easily mask up to 20 seconds any temporary loss of Category III course alignment information as furnished by the Far Field Monitor.

At the present time, it is possible to bypass the Far Field Monitor, thereby disabling the executive control of the localizer as well as the Category III course alignment indication to the tower without the tower having knowledge of the bypass. To the extent that the Far Field Monitor is required to verify the localizer alignment it appears corrective action is warranted. A relatively easy modification would insure that the Category III course alignment local indication to the tower would not be bypassed, even if the executive control function from the Far Field Monitor of the localizer is bypassed locally. The means exist in the tower equipment to ignore the Far Field Monitor indication if so desired.

A potentially desirable modification is for the addition of tower bypass capability of the Far Field Monitor shutdown function, to allow lower Category ILS service in the event of Far Field Monitor failure.

Another unique feature of the MARK III Far Field Monitor is the shutdown alert function. When activated, this function causes a 1900/2100 Hz tone modulation to be generated over the localizer transmitter. The tone is generated just prior to a likely shutdown of the localizer by an impending shutdown control signal to the localizer from the Far Field Monitor (or the near field monitor).

The purpose of the shutdown alert signal is to warn a pilot using the localizer that he may expect a shutdown of the localizer within five seconds so that he may abort his approach for safety reasons, if necessary. Although the 1900/2100 Hz signal produces a uniquely discordant sound, because of the rarity of its occurrence, its practical use may be questioned. A possible extended use of this capability would be to exercise it whenever the Far Field Monitor sees a significant disturbance.

3.7 Maintenance Monitor

A unique feature of the FAA MARK III ILS is the addition of the Maintenance Monitor which is a non-executive type monitor. Although the Maintenance Monitor is associated with the ILS equipment in the localizer, glide slope and localizer far field monitor as an ancillary system, the ILS operates independently of it, that is, a failure in the Maintenance Monitor itself is very unlikely to affect the ILS operation. Each local station operates within certain operational tolerances which, if exceeded, will immediately or eventually affect the availability and/or the integrity of the radiated signal. The primary function of the Maintenance Monitor is to relay detailed information to the remote control point on the status of the equipment operation in addition to the information already available from the Remote Control Indicator such as Main/Standby/OFF and general monitor alarm indications. The Maintenance Monitor information is relayed to the tower equipment maintenance room whenever a given monitored signal parameter has exceeded a preset warning level. For example, the Category III ILS course alignment monitor is normally adjusted to cause executive transfer or shutdown action if the alignment has drifted to a value corresponding to ± 20 feet displacement at the approach runway threshold, but the Maintenance Monitor may be adjusted to indicate its warning signal when the course alignment has shifted to a somewhat less than normal alarm such as ± 10 feet or any preset value as desired. By having access to certain monitor pre-alarm conditions, preventive maintenance may be initiated by prevent any further transmitter drift, restore the monitor to service, correct shelter temperature, or do whatever

corrective action is required to prevent a potential loss of the radiated signal. The Maintenance Monitor warning level may be set at a general 75% of the alarm or, depending on experience at a level just beyond the normal parameter excursions. As presently installed, the Maintenance Monitor remotes 20, 17 and 4 indications from the localizer, the glide slope and the localizer far field monitor respectively to the tower equipment room.

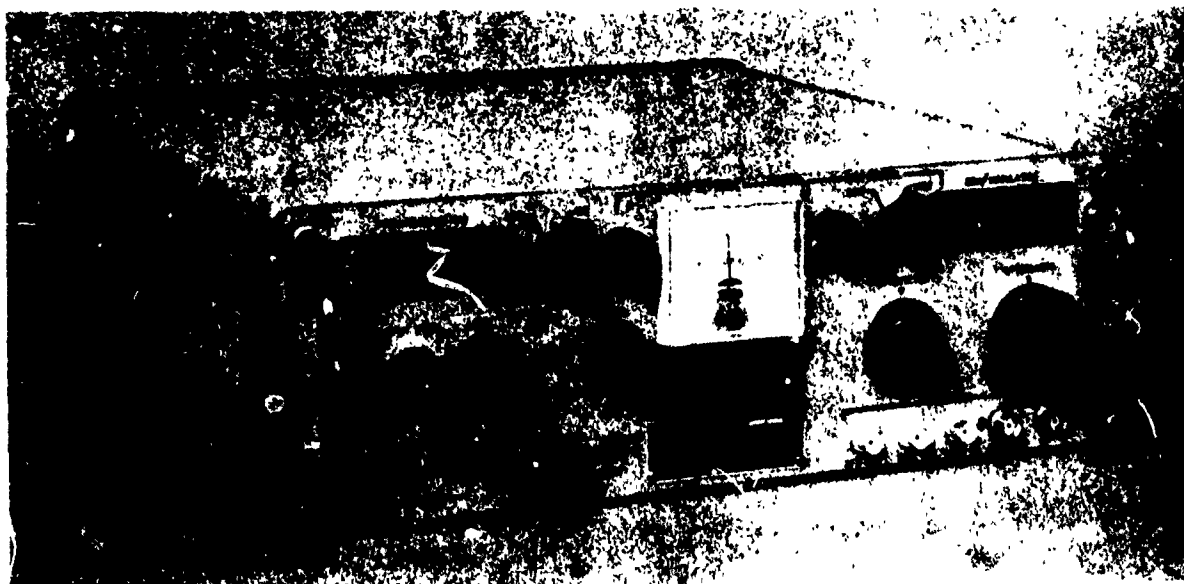
It is obvious that the Maintenance Monitor will contribute to the integrity of the ILS by indicating the need for preventive maintenance. On the other hand it also serves to give a remote indication of a system operating well within the alarm limits which may serve to reduce the frequency for preventive maintenance visits to the sites.

To date relatively limited practical experience has been obtained to demonstrate the practical usefulness of the Maintenance Monitor in order to recommend a general implementation of this equipment for all Category III ILS. The system, in principle, may have application for the Category II as well. Further evaluation to explore the capabilities and usefulness of the equipment is planned to be carried out at NAFEC.

The interface of the local equipment and the remote indication in the tower equipment room is made by means of landlines which constitute, in effect, DC loops which is completed or opened to produce a remote satisfactory or non-satisfactory status indication. The number of interface lines is 24, 21 and 5 respectively for the localizer, glide slope and far field monitor. These lines as well as the rest of the MARK III system as pointed out have been subject to lightning induced signal interference causing equipment damage. Work is being done to eliminate this problem which may also result in a number of lines reduction requirement.

3.8 ILS Monitor Precision Calibrator

The development of the ILS Monitor Precision Calibrator was undertaken for the purpose of making available a better and more adequate test equipment in the form of an ILS signal generator for the Category III ILS than was and is available from the existing commercial inventory of VOR/ILS signal generators. The Category III ILS requires maintenance to tight and absolute tolerances, and hence, dependable and accurate standards must be available for cross calibration purposes and for facilitating certain maintenance adjustments.



ILS Monitor Precision Calibrator

An example of the closer tolerance required is for the localizer navigational tone modulation percentage for Category III. Additionally, there is a need of closer correlation between absolute modulation levels seen by the flight check aircraft, on one hand and by ground maintenance on the other. In direct response to this need, another SRDS effort has resulted in the successful development of a unique self-calibrated modulation meter, and the establishment of a primary modulation standard under an Inter-Agency Agreement with the National Bureau of Standards (NBS) at Boulder, Colorado. This arrangement will serve to demonstrate any ambiguities between different calibration techniques for ILS tone modulation and has served to cross-calibrate the ILS Monitor Precision Calibrator.

The ILS Monitor Precision Calibrator operating over the localizer and glide slope bands in effect may simulate nearly any localizer or glide slope signals for monitor and receiver inputs. The output signal levels, both RF and the demodulated RF are adjustable from approximately 10 mw (into a 50 ohm load) in .1 db steps over a 100 db range. The rf carrier is amplitude modulated by variable level single 90 Hz or 150 Hz or by both within a range from 0 up to $\pm .80$ ddm depending on the set modulation levels of each tone.

The calibrator may be used to (1) align and check both audio or rf type input monitors for power, modulation, ddm, and identification alarms and adjustments (thus avoiding having to even temporarily maladjust the operating transmitter to check the monitor alarm limits), (2) align and check the Maintenance Monitor in a similar manner, (3) indirectly determine the characteristics of a normal monitor input signal by substituting this signal with the calibrator signal and adjusting the calibrator for the original monitor indication, (4) align and calibrate the localizer far field monitors and the portable ILS receivers used for ground checks, and (5) calibrate and align airborne ILS receivers.

The original development effort by Cardion Electronics was not entirely successful partly due to the fact that difficulties were encountered in determining the absolute modulation accuracy of the rf output. The modulation technique and output loading characteristics used did not yield consistent performance at higher levels of modulation and different output loading, although repeatability, stability and other aspects of the equipment were satisfactory. The now modified calibrators have been corrected for the above deficiencies and test results exhibit constant signal rf output levels over both bands within a narrow margin, modulation percentage over both bands within an absolute accuracy of $\pm .5\%$ of up to a total of 70% independent of attenuator settings, a change of an individual tone level

modulation within $\pm .3\%$ when switching from dual to single tone modulation and a very accurately known ddm signal within the $\pm .3000$ ddm range both for the localizer and glide slope functions.

For a detailed description of various development aspects and quantitative results obtained from the testing of the ILS Monitor Precision Calibrators, reference is made to the final report prepared by the Contractor. The calibrator indicated modulation levels have been calibrated against the modulation standard at NBS.

Of the six calibrators delivered by Cardion Electronics and calibrated by NBS, two each have been delivered for the Atlanta, Georgia, Hartsfield Airport Category III ILS- two each for the San Francisco, California, International Airport ILS and two for NAFEC, of which one is temporarily retained by SRDS for further evaluation and demonstration.

3.9 Current Problems and Efforts

Although the FAA MARK III ILS is now in operational use, obviously any significant remaining or potential weakness must be dealt with through corrective efforts. Advantage should also be taken of any technological development to incorporate improvements which promise to enhance Category III ILS operation and reliability.

As reflected in the results from the MARK III ILS reliability demonstration it is clear that the system, as installed, has been quite susceptible to lightning interference and damage. Various outages occurred during the demonstration itself, and have occurred both before and since. These outages have been accompanied both with and without any apparent equipment damage. Most of the operational interference from lightning has not resulted from direct strikes but rather through induced interference through the long land lines which interconnect the ILS stations. The problem is not limited to MARK III ILS alone as it affects all solid state ILS and other solid state equipment as well but is especially damaging for Category III ILS which is expected to be reliable under all weather conditions.

When it was first realized from the actual field installation experiences that the magnitude of the lightning problem had been underestimated, efforts were undertaken by the equipment contractor to resolve the problem through careful application of certain installation guidance criteria mainly for power and control lines as described in TI Technical Report No. TR 73-050(U) "Guidelines for Ancillary Electrical Systems Supporting the AN/GKN-27(V), AN/GRN-26, AN/GRN-28 Instrument Landing System Installation, November 1973." These criteria were aimed at limiting the damage potential through adequate installation, bonding and grounding techniques for equipment and lines, installation of lightning and

spark gap arresters and reducing the earth ground resistance in the vicinity of the local sites. This effort has not been adequate to resolve the problem, however.

A separate SRDS effort was undertaken through a contract with Georgia Institute of Technology to investigate various ILS equipment types with respect to remote control and status lines terminal characteristics in order to determine damage causing interference levels and exactly what lightning surge dissipator circuits would be required to prevent lightning damage. This investigation has resulted in specific recommendations (see Report No. FAA-RD-75-73, "FAA Lightning Protection Study: Lightning Protection for Mark III - Instrument Landing System (Category III)") for the installation of diode voltage suppressors and resistors at each control and status interstation cable wire termination to effectively prevent the passage of any potentially destructive interference pulses. These protection circuits have been installed at NAFEC but may not be the most effective way to deal with the problem. A remaining concern includes the likelihood of operational interference caused by low level and nondestructive interference signals.

Another approach to the lightning problem has been pursued. Lightning Elimination Associates of Downey, California, performed a design study for a system at NAFEC which was intended in effect to eliminate the probability of lightning strikes within certain protected areas (see Report No. FAA-RD-74-45, "Design Recommendations for a Lightning Elimination System for FAA Category III Instrument Landing Systems, NAFEC, Atlantic City, New Jersey"). The technique proposed involves the installation of static charge dissipation arrays which supposedly would serve to reduce the intensity of atmospheric electric fields in the presence of thunderstorms to the point that lightning discharges will not occur within a given protected area. To date no action has been taken to actually implement the technique at any FAA airport, since its effectiveness has not been satisfactorily demonstrated and remains doubtful, at this time.

Still another approach to resolve the lightning problem has been pursued through a contract with Purdue Research Foundation proposing to overcome the lightning damage susceptibility problem and other signal interference problems through, in effect system or equipment redesign. Specifically, this approach included an investigation of line transient effects on the ILS and an analysis of the current system control and status equipment interface to pinpoint weaknesses in order to develop an effective modification to improve the reliability. Partial results of the work is described in Report No. FAA-RD-75-11 "Reliable Line Signaling Techniques for the FAA GRN-27(V) and Category III ILS," followed about a year later by Report No. FAA-RD-76-24 "Application of Balanced Lines, Tone Signaling, and Microprocessor Control Techniques to a Category III Instrument Landing System." The study of the overall problem, while also taking into

account previously described preventive techniques did not result in equipment redesign or a recommendation for "circuit hardening" as one might have anticipated from such an effort.

Instead, as may be inferred from the titles of the reports, the investigation resulted in a proposal for a tone signaling interface system as a replacement of the unbalanced non-insulated DC signalling system in use. A partial ILS interstation signal configuration using telephone company type encoding and decoding of tone signalling with only minor modification to the existing ILS terminals was installed and successfully demonstrated in the early fall of 1975. Tone signalling represents a generally well-proven technique, and in addition to being practically immune to outside signal interference including lightning, has the advantage of being cost effective by reducing multi pair cable requirements to only a single pair between any two stations. A full prototype system was installed and demonstrated at NAFEC in August of 1976. Here, as part of the system, state-of-the-art microprocessor techniques have been employed to process the signals and display the status of all remote monitor and control functions to the extent of effectively more than duplicating the functions of the existing remote control and monitor with an improved display.

The final overall solution for the lightning problem is expected to contain a combination of certain installation practices, tone signaling over balanced lines and additional line protection where needed. Relative cost effectiveness and maintenance requirements will also be taken into account. The solution of the problem for the Category III ILS will, of course, find an application for any solid state ILS regardless of Category.

With regard to localizer antenna improvements as pointed out earlier in this report, a major improvement has been recently demonstrated. The present two frequency traveling wave localizer used for Category III and Category II ILS operates with two separate antenna arrays, i.e., one 14-element array for course radiation and a separate six-element array for clearance radiation. This arrangement requires a larger installation site and causes additional cost but decreased reliability in comparison with a single common array. The new combined antenna system uses directional couplers with about one third the loss of the conventional hybrid networks and allows the continued use of the present low power transmitters. The inner six elements radiate both course and clearance energy while the outer elements radiate course energy only. A new integral monitor system as part of the combined array has been extensively evaluated and tested at the original installation site at Tamiami, Florida.

Improvements on the Category III ILS (and Category II and I as well) glide slope operational availability with snow is possible based on conclusions of SRDS studies and investigations. It is known that the

glide slope near field monitor when operating with a ground snow cover level tends to reduce the availability of the facility even when the glide slope transmitter radiates a signal well within tolerance in the approach area. A better monitoring scheme could consist of an integral path monitor unaffected by weather, an antenna tower misalignment detector and/or a suitable far field monitor. In the case of the FAA MARK III ILS, an integral monitor, a near field path monitor and a tower misalignment detector are all used, suggesting that the present monitor system could be simplified. Under a development contract with Westinghouse, SRDS is pursuing the development of a glide slope far field monitor.

The existing MARK III ILS and Category II ILS far field monitors lack quick response monitor control and must be considered less than adequate to accurately monitor the overall localizer signal in the far field. In order to overcome this problem, the above mentioned Westinghouse contract also provides for the development of a good localizer approach area/monitor response correlation monitor coupled with timely executive control capability of the localizer transmitter.

REFERENCES

"Annex 10 - Aeronautical Telecommunication, Volume 1" International Civil Aviation Organization, 3rd Edition, July 1972.

"Failure Modes, Effects and Criticality Analysis (FMECA) of Category III Instrument Landing System," Report No. FAA-RD-72-8.

"Test and Evaluation of Category III ILS Ground Guidance Equipment 'STAN 37 Localizer Tests at NAFEC on R/W-4'" Report No. FAA-RD-72-50.

"Test and Evaluation of Category III ILS Ground Guidance Equipment 'STAN 38 Glide Slope Tests at NAFEC on Runway 4,'" Report No. FAA-RD-72-105.

"Failure Modes, Effects and Criticality Analysis (FMECA) of Category III Instrument Landing System with Traveling-Wave Localizer Antenna," Report No. FAA-RD-73-111.

FAA MARK III ILS Handbooks.

"FAA Lightning Protection Study: Lightning Protection Requirements for AN/GRN-27(V) Instrument Landing System" Report No. FAA-RD-74-131.

"Instrument Landing System, Category III," Final Report, Report No. FAA-RD-74-180.

"Reliable Line Signaling Techniques for the FAA GRN-27(V) and Category III ILS," Report No. FAA-RD-75-111.

"FAA Lightning Protection Study: Lightning Protection for Status and Control Lines of AN/GRN-27(V) Instrument Landing System" DOT Report No. FAA-RD-75-24.

"Design Recommendation for a Lightning Elimination System on FAA Category III Instrument Landing System, NAFEC, Atlantic City, New Jersey," Report No. FAA-RD-75-45.

"FAA Lightning Protection Study: Lightning Protection Requirements for MARK III Instrument Landing System (Category III)," Report No. FAA-RD-75-73.

"ILS Monitor Precision Calibrator, Final Report," Report No. FAA-RD-75-116.

"Application of Balanced Lines, Tone Signaling, and Microprocessor Control Techniques to a Category III Instrument Landing System," Report No. FAA-RD-76-24.

APPENDIXES

FAA Engineering Requirement
CAT III/II ILS Development

1. SCOPE

It is the purpose of the contract to develop and assemble an Instrument Landing System development model/prototype of the conventional type (Localizer 108-112 MHz, Glide Slope 329-336 MHz and Markers 75 MHz) capable of meeting the characteristics of Category III ILS operation including stringent requirements for high integrity and continuity of service. The reliability of the ground equipment must be such that its operation is extremely unlikely to impair the safety of an approaching aircraft during the critical phase of its approach and landing under Category III weather minima. The equipment must have high mean time between failure (MTBF) characteristics and be ensured by a maximum reliable monitor system not to deviate beyond operational tolerances for Category III (or Category II, as the case may be).

The objective of the development as described herein is to rely on already developed (off-the-shelf) components of ILS ground systems, if feasible, and known up-to-date techniques, and to combine these with adequate redundancy to assure continued satisfactory performance even with the loss of a transmitter or an individual monitor.

The desired ILS system includes a localizer, a glide slope, three markers (outer, middle, and inner) a remote control indicator, a DME system (not part of this procurement). In normal Category III operation, the localizer and glide slope main transmitters will operate on the air while standby transmitters operate into dummy loads and internal monitors, thus ensuring upon transfer to the standby transmitter the immediate continued radiation of a satisfactory guidance signal. Generally, each significant parameter of the transmitter on the air will be monitored by triple parallel monitors requiring two out of three alarms of an individual parameter monitored to result in transfer from Category III to Category II status, or in shutdown from Category II depending on the initial mode of operation. Upon degradation of the system out of Category III course alignment tolerance but still within Category II, the system shall operate satisfactorily as a Category II system.

2. APPLICABLE SPECIFICATIONS AND STANDARDS

The following documents, of the issue in effect on the date of invitation for bids or request for proposal form a part of this Engineering Requirement to the extent specified herein:

FAA-G-2100/1	Electronic Equipment, General Requirements
FAA-G-2100/3	Requirements for Equipment Employing Semiconductors
FAA-G-2100/4	Requirements for Printed Wiring Techniques
FAA-G-2100/5	Requirements for Equipments Employing Microelectronic Devices

FAA-C-1217	Electrical Work, National Electric Code
FAA-C-2256	Environment Controls
FAA-D-638h	Instruction Books
FAA-STD-003	Paint Systems for Structures
FAA-STD-005	Equipment Specifications
FAA AC 120-20	Criteria for approval of Cat. II Landing Weather Minima
FAA Orders 6750.4, 6750.5 and 6750.8,	Siting Criteria
FAA Order 8200.11B,	Flight Inspection Theodolite Tolerances
FED-STD-595	Colors
AC 150/5345-2 (L-810)	Obstruction Lights
ICAO Annex 10, Volume 1, dated April 1968	
USFIM, FAA Handbook OA P 8200.1	
ARP 926	SAE Aerospace Recommended Practice
MIL-STD-476	Maintainability Program Requirements
MIL-STD-471	Maintainability Demonstration
MIL-STD-721B	Definitions
MIL-STD-781B	Reliability Tests
MIL-STD-785	Reliability Program
MIL-STD-810	Environmental Test Methods for Aerospace and Ground Equipment
MIL-STD-1472A	Human Engineering Design Criteria
MIL HDBK-217A	Reliability Stress and Failure Rate Data
MIL-S-55286	Shelter, Electrical Equipment - S-280 ()/G
MIL-E-83210	Equipment Electronic, Criteria for the Utilization of Micro-Molecular Electronic Technology

(Application for copies of the above FAA and Military documents should be addressed to Federal Aviation Administration, Contracting Officer, 800 Independence Ave., S.W. Washington, D.C. 20590. To obtain copies of the ICAO publication, requests should be addressed to the Distribution Officer, International Aviation Building, 1080 University Street, Montreal 3, Quebec, Canada.)

Exceptions to parts of the above specifications may be given by the Contracting Officer if sufficient justification is provided by the Contractor.

3. REQUIREMENTS

The contractor shall furnish the equipment and services as specified herein.

3.1 General Requirements

3.1.1 Major units.- The ILS shall consist of the following units:

1 VHF Localizer Station	3.2-.3
1 UHF Glide Slope Station	3.4-.5
3 VHF Marker Beacon Stations	3.6-.7
1 Remote Control Indicator	3.8
1 Set of test equipment for Systems Maintenance	3.9

3.1.2 General specification.- The requirements of FAA-G-2100 are applicable together with this engineering requirement, except, if conflict exists, this document governs.

3.1.3 Design.- The ILS shall be designed and constructed in accordance with the highest commercial practice. Government general specifications shall apply (only) to those items specifically designed to meet the requirement of this procurement. Existing industry standards shall apply to all commercial products, which are incorporated into the system without modification. Components shall be selected which offer the greatest potential for (1) achieving high reliability; (2) shortening the development time of the end item; and (3) reducing the number of different items used in the end item.

3.1.4 Accessibility and Human Factors.- All units, components, and test points that may require servicing, repair, or replacement shall be readily accessible and shall have sufficient clearance from shelter walls for comfortable maintenance. Major units or modules shall be completely removable from their enclosures without excessive disassembly. Access shall be provided to components or circuit modules from outside the basic equipment through the use of swing-out units, pull-out drawers having drawer slides, or equivalent devices; cable retractors and circuit card extenders shall allow component or module operation in the open position. Close attention shall be paid to all aspects of the design which involve performance of a human operator. These include specific equipment and procedures utilized under normal and emergency conditions and during routine calibration and maintenance. Guidelines for satisfaction of this concern are presented in MIL-STD-1472A.

3.1.5 Controls.- Controls that are essential to the proper operation or periodic maintenance of the equipment, or other controls that are in frequent use on the various units, shall have scale markings to facilitate return of the control to a predetermined position, particularly after flight inspection adjustments. All critical tuning controls shall be resettable (without play), shall have positive stops and shall include locking devices. It shall not disturb the setting to lock or unlock the control. All controls shall be clearly marked as to function and maintenance data reference symbol.

3.1.6 Electromagnetic interference.- Each station shall be designed so that the mean power of spurious rf emission supplied to the antenna transmitter line be not less than 60 dB below the mean power of the fundamental. With

each transmitter terminated into a dummy load or a properly terminated cable, the stray radiation on any frequency from the equipment under any operating conditions shall not exceed 5.0 (Marker beacon 0.5) microwatt (ERP).

3.1.7 Interchangeability.- Due to the high degree of functional commonality between stations, a maximum of module interchangeability shall be achieved between various units of the ILS.

3.1.8 Maintainability.- Maintainability design criteria in accordance with MIL-STD-470 are applicable.

3.1.9 Corrective maintenance requirements.- The ILS shall possess a mean corrective maintenance time (M_{ct}) of no greater than 0.5 hours and a maximum corrective maintenance time (M_{MAXct}) of no greater than 1.5 hours (95th percentile). Switch-over from a failed to a redundant unit shall not be considered in computing mean corrective maintenance time. However, repair of the failed unit while the redundant unit continues to maintain operation shall be considered.

3.1.10 Major repair.- No failed component of the ILS shall require more than 8 hours for repair at the depot level. This shall include fault isolation, disassembly, repair of the failed component or assembly, reassembly and checkout after repair.

3.1.11 Preventive maintenance requirements.- The mean preventive maintenance time (MPMT) of the maximum equipment configuration for either type of station shall not exceed one hour in 336 hours of operation, including inspection and checks to assure performance. Ninety percent of all routine procedures shall be accomplished in less than 15 minutes. No single group of periodic procedures shall require more than two hours time or be required more frequently than once every 2000 hours. Parts requiring preventive maintenance, as well as system checks not revealed by the monitor, shall be specified by the supplier with recommended maintenance and replacement intervals.

3.1.12 Reliability.- Individual units of the ILS (transmitters, environment control equipment, monitors, control and transfer equipment, etc.) shall have a high MTBF and make possible the highest practical overall system MTBF. An inherent MTBF in excess of 2500 hours (10,000 hours for the Marker beacon) is desirable for a simplex (i.e., non-redundant) system loop consisting of a single transmitter, antenna and monitor at each station. Prior to the final design of the system a thorough theoretical design fault and reliability analysis shall be conducted to reveal all failure modes and the effects of all potential failures. The analysis should confirm that the system has been designed to minimize the probability of failures and that the equipment configuration and monitor switching logic is suitable. For the purpose of analyzing and demonstrating the reliability, availability/maintainability and fail safe characteristics, the general plan outlined in Section 4.0 of this Engineering Requirement shall be followed. SAE Aerospace Recommended Practice 926 shall be used as a guide in accomplishing the fault analysis.

3.1.13 Service conditions.- The localizer, glide slope and marker beacon stations shall operate under Environment III (FAA-G-2100/1 para. 1-3.2.23) at any altitude from 0 to 10,000 feet above sea level, in rain up to two inches per hour, and in up to one foot of snow in surrounding areas. Environmental controls (heaters, air conditioners, etc.) shall be supplied, if necessary, for the localizer and glide slope stations to allow operation during all the temperature extremes. If supplied, these devices shall be controlled to stabilize the shelter's internal temperature to prevent condensation, maintain test equipment in a stable mode, and provide maintenance personnel comfort. The localizer and glide slope stations shall operate continuously, without readjustment, at any temperature between the extremes specified for at least 3 hours after failure of primary power. The marker beacon shall operate continuously, without readjustment, in the specified environment for at least 72 hours after failure of primary power.

3.1.14 Primary power.- The ILS shall operate from a single-phase 120/240 V, 60 Hz (design center values) three wire single phase AC line power source.

3.1.15 Standby power.- A continuously engaged or floating battery power supply shall be provided for all units of the ILS for continued normal unit operation if the primary power fails. To maintain the batteries in operational readiness, a trickle charge shall be supplied to recharge the batteries during the periods of available primary power. Upon restoration of primary power, the batteries shall be restored to full charge within eight hours. When primary power is applied, the state of the battery charge shall in no way cause harm to or affect the operation of the ILS. The battery supply for the localizer and glide slope stations shall permit continuation of normal operation for 3 consecutive hours with battery temperature at 0°C. Ancillary functions (obstruction lights, air conditioners, and other items not directly contributing to the guidance signal) shall not be required to operate during this period. The battery supply for the marker beacon station shall maintain normal operation for at least 72 consecutive hours at any temperature between the extremes specified in 3.1.13.

3.1.16 Test points and test facilities.- The ILS design shall incorporate indicators, warning signals, test jacks, and test points as necessary to facilitate trouble shooting and malfunction isolation. Test points shall be provided to check essential waveforms and voltages and for the injection of test signals. The test points shall be strategically located for easy accessibility. Their locations shall be kept to a minimum and each shall be labeled for easy identification and reference to maintenance data, and designed for easy attachment of test probes and test equipment.

3.1.17 Meters.- Each localizer, glide slope and marker beacon station shall be provided with appropriate built-in thru-line wattmeters in the output sections. These wattmeters shall be capable of measuring forward and reverse power for calculation of the voltage standing wave ratio (VSWR). Suitable metering shall also be provided to allow monitoring power supply voltages to each equipment.

3.1.18 Abnormal condition indicator panel.- A panel shall be supplied at each of the localizer, glide slope, and marker beacon stations which provides

visual indication for a minimum of the following abnormal conditions. Any abnormal indication on this panel shall cause a simultaneous abnormal indication at the ILS Remote Control Indicator. (see 3.8)

- a. Primary Power Failure.
- b. Battery Charger Failure.
- c. Shelter temperature outside of acceptable limits (where applicable).
- d. Monitor locally bypassed.
- e. Station off the air.
- f. Monitor alarm (see 3.1.26b).

3.1.19 Not used.

3.1.20 Tools.- The variety and number of special tools and test equipment required to maintain the ILS shall be held to a minimum. When peculiar tools are required, the tool(s) shall be provided at the unit assembly where used and a convenient means for tool mounting shall be included.

3.1.21 Finish and color.- Colors of the ILS exterior surfaces shall be aviation orange, color 12197, and insignia white, color 17875, in accordance with FED-STD-595. Exterior surfaces shall be painted in accordance with FAA-STD-003.

3.1.22 System construction.- Each station of the ILS shall be designed as an operating entity that will perform as specified when installed and adjusted in accordance with data furnished by the supplier. Only required power and control wiring to the various sites in accordance with installation requirements furnished by the supplier will be provided by the procuring activity.

3.1.23 Solid state components.- The ILS shall be designed using solid state components (i.e. no thermionic tube devices shall be used).

3.1.24 Modular construction.- The ILS design shall make maximum use of sized components and easily removable plug-in module assemblies containing one or more related circuits. The design of the modules shall permit disassembly of the module for maintenance.

3.1.25 Microcircuits.- Any microcircuits used in any part of the ILS shall conform to the criteria specified in MIL-E-83210 and shall be subjected to the screening procedures of test method T5004, class B, in accordance with FAA-G-2100/5.

3.1.26 Monitor requirements

a. **General.** Each station of the ILS shall be provided with a high-integrity monitor system that provides fault detection by monitoring the specified signal parameters and initiates automatic switchover, or shutdown of the faulty equipment as appropriate. The monitor system shall operate in conjunction with a remote control-indicator that provides audible and visual indication of system status and complete, positive control of all system units. The design of all monitor components shall yield extremely high reliability and integrity, and shall be of a fail-safe nature so that failure of any individual monitor channel itself or the loss of the signal will cause a fault indication to occur. All monitors shall have adjustable sensitivity controls for each of the parameters being monitored. These controls shall be located at the local site. All monitors shall have an override switch that disables monitor action during adjustment and maintenance. Activation of the override switch shall cause a fault indication locally and at the remote control-indicator.

b. **Localizer and Glide Slope monitors.-** The localizer and glide slope stations shall have triple monitors such that each specified parameter of the transmitter on the air is examined by three identical monitor channels connected in parallel (exception, localizer course, see paragraph 3.3.4). Two out of three channels shall sense the parameter as being out of tolerance before transfer or shutdown action is initiated. However, the sensing of an out of tolerance condition by any channel shall produce indications of abnormal operation (see 3.1.18 and 3.8). Monitor antennas, pickups, cable and RF combining networks shall be exempted from the redundancy requirement. The parameters of the standby transmitter shall be monitored by single channel internal monitor channels. Upon sensing an out-of-tolerance signal from the standby transmitter, this transmitter shall be shutdown. All monitor channels shall be stabilized within 2 seconds after initial application radiated signals. Concurrently, integral monitor action shall begin within 2 seconds after initial application of radiated signals when such signals are outside of allowable tolerances. Interaction of all the monitor parameters shall be minimized allowing simple straight-forward adjustments of all monitors in turn with minimum readjustments.

The monitors shall provide a meter indication in each station of all parameters monitored. Meters shall be so calibrated that readings may be used directly to ascertain correct values of path alignment and width. Meter deflections shall be compatible in sign to aircraft crosspointer deflections. Memory lights shall be provided to indicate which monitor channel caused an alarm.

3.2 VHF localizer station performance requirements.- The localizer station shall be designed to meet the following performance requirements:

3.2.1 General.- ICAO, Annex 10, Part I, paragraphs 3.1.3.1.1-3.1.3.1.3 are applicable.

3.2.2 Radio frequency.- ICAO, Annex 10, Part I, paragraphs 3.1.3.2.1, 3.1.3.2.2, 3.1.3.2.2.2 and 3.1.3.2.3 are applicable.

3.2.3 Coverage.- With the transmitter rf power output reduced to the monitor alarm point, the localizer coverage sector shall extend from the localizer antenna to distances of 25 nautical miles within + 10 degrees from the front course line; 17 nautical miles between +10 and +35 degrees from the front course line. The localizer shall provide signals sufficient to yield a signal strength of at least 5 microvolts which results in a flag current of 240 microamperes in a standard calibrated aircraft installation and shall yield no false courses within +35° from the front course line. The localizer signal shall be receivable at the distance specified, at and above a height of 1500 feet above the elevation of the threshold or 1000 feet above the elevation of the highest point within the intermediate and final approach areas, whichever is the highest. Such signals shall be receivable, to the distances specified up to a surface extending outward from the localizer antenna and inclined at 7 degrees above the horizontal. The ratio of the course carrier signal strength to the clearance carrier signal strength along the runway centerline shall be at least 10 db. The minimum signal strength at a height of 20 feet above the threshold, and at that height along the length of the runway, shall be not less than 200 microvolts per meter.

3.2.4 Backcourse.- A backcourse shall not be provided.

3.2.5 Carrier modulation.- ICAO, Annex 10, Part I, paragraphs 3.1.3.5.1, 3.1.3.5.2 (Category III), 3.1.3.5.3c), and e), 3.1.3.5.3.2, 3.1.3.5.3.3b), 3.1.3.5.3.4b) and 3.1.3.5.3.5, are applicable.

3.2.6 Course alignment accuracy.- Based on a nominal sector width of 700 feet at threshold the equipment shall be capable of maintaining (except for radiated signal interference) a course line within the equivalent of +10 feet from the runway centerline at the ILS reference datum and adjusting the same between +35 feet from the runway centerline at the ILS reference datum.

3.2.7 Displacement sensitivity.- The nominal displacement sensitivity within the half course sector at the ILS reference datum shall be 0.00044 DDM/foot, based on a nominal sector width of 700 feet at the ILS reference datum. The increase of DDM shall be substantially linear with respect to angular displacement from the front course line up to an angle on either side of the front course line where the DDM is 0.180. From that angle to +10 degrees, the DDM shall not be less than 0.180. From +10 to +35 degrees, the DDM shall not be less than 0.155. When the course sector is widened sufficiently to cause an alarm, the DDM shall not be less than 0.165 from +4 to +10 degrees, and 0.139 from +10 degrees to the limits of coverage.

3.2.8 Course sector width.- The localizer sector width shall be tailored to a value of 700 feet at the runway threshold, except that it shall be not less than 3.0, nor more than 6.0 degrees and shall be maintained within 10 percent of that value. The sector width shall be easily adjustable between the values of 2.4 and 7.2 degrees.

3.2.9 Voice.- A voice channel capability shall not be provided.

3.2.10 Identification.- ICAO, Annex 10, Part I, paragraphs 3.1.3.7.1 through 3.1.3.7.4 are applicable.

3.2.11 Monitoring.- The automatic monitor system shall cause a degradation of Facility Performance Category III to Category II or cause radiation of Facility Performance Category II to cease for any of the following conditions.

- a. A shift of the mean course line from the runway centerline equivalent to 10 feet (25 feet for Cat. II) at the ILS reference datum.
- b. A reduction of power which causes the localizer to fall outside the limits of 3.2.3, 3.2.5 and 3.2.6 inclusive; or which exceeds a reduction in either carrier to 80 percent of normal for two-frequency configurations.
- c. A change in displacement sensitivity exceeding 10 percent of nominal.
- d. A continuous identification tone, absence of periodic identification signal, or a decrease in identification modulation level of 50 percent or more from nominal.
- e. A degradation of clearance signal causing the clearance requirements of 3.2.7 to be violated.
- f. A change of the modulation percentage outside the 19-21% limits.

The total period of radiation outside the tolerance limits specified in these performance limits shall not exceed 1 second for Facility Performance Category III operation.

3.3 Localizer Station Equipment Requirements

3.3.1 Equipment list.- The localizer station shall include the localizer transmitters, the localizer antenna, a monitor and control system, and an equipment shelter, all as described below.

3.3.2 Localizer transmitters.- The localizer transmitter system shall be a two-frequency (capture-effect) design or a single rf carrier design utilizing audio phasing techniques to achieve the capture effect. Two such systems shall be provided; one designated main transmitter system shall cause the localizer antenna to radiate while the standby system normally is transmitting internally monitored signals to dummy load(s). Upon automatic or manual shutdown of the main system, the standby transmitter system shall be immediately available for transfer to the antenna (if operating). While the standby transmitter is operating into the antenna, the main system shall remain shut down. The localizer transmitter shall include a provision to transmit an "alert shutdown" signal to the pilot whenever the localizer near field course monitor alarms and for five seconds immediately prior to expected shutdown action on the localizer by the far field monitor. Such a signal could conceivably be an audio tone in the range from 600 to 2000 Hz on the directional transmitter, triggered by the respective monitor alarms. The mutual interference between the two systems shall be reduced to a minimum with negligible mutual monitor interference. Any stray radiation from the standby system should be at least 60 db below the carrier level of the main system as measured at the transmitter antenna system. Unless it can be shown that electronic modulation is equal or advantageous, mechanical modulation shall be employed. A elapsed time indicator shall be provided.

3.3.3 Localizer antenna.- The localizer antenna shall be of sound design with the numbers and complexity of elements or reflectors held to an absolute minimum commensurate with the performance criteria specified herein. The addition of a clearance array separate from the course antenna is permitted. The clearance radiation pattern shall be designed consistent with the purpose of minimizing on course degradation due to siting effects; i.e., ideally, from the capture effect points to $\pm 35^\circ$ the signal level should remain level and decrease rapidly beyond $\pm 35^\circ$. Carrier radiation (clearance signal excepted) from the array shall have a beamwidth not exceeding ± 3 degrees at the half power points and shall be at least 20 db below the value at zero degrees for angles greater than ± 10 degrees. The peak level of course producing sideband radiation from the antenna shall occur at angles no greater than ± 3 degrees. Sideband radiation at angles greater than ± 10 degrees shall be at least 20 db below the peak value. The nominal input impedance of the antenna system shall be 50 ohms. The array shall be designed for installation on the extension of the centerline of the runway at the stop end and be made to produce course lines in a vertical plane containing the course line of the runway served. The antenna shall have minimum height to satisfy coverage requirements in 3.2.3, and should not exceed an overall height of 20 ft. The antenna shall be frangible and suitable for installation and operation in a standard approach light lane, if necessary, with minimum

mutual interference. Two each dual obstruction lights per FAA Advisory Circular AC 150/5345-2 shall be provided for mounting on both sides of the antenna array. The lamp in each fixture shall be wired in parallel and shall be rated at 100 watts.

3.3.4 Localizer monitor and control system.- To insure the integrity of the localizer signals, integral, near field, far field and standby transmitter monitors shall perform as outlined below. In addition to control of the transmitting equipments, the indicated status at the Remote Control Indicator shall be downgraded from Facility Performance Category III to Category II whenever 1) standby equipment is not available, 2) standby equipment is on the air or 3) the far field monitor indicates an out of Category III course tolerance. Upon shutdown of the localizer system a visual and audio alarm indication shall be initiated at the remote control indicator and restoration of localizer radiation shall be prevented for at least 20 seconds. It shall be possible to bypass any or all monitor channels. Fig. 1 illustrates some of the localizer monitor and control system requirements herein.

- a. Integral monitor. Each radiating element (possible exception: clearance array, see below) shall have an integral monitor pickup device; by suitable signal combining, the integral monitoring system shall provide composite signals for the monitoring of course position, course width, proper clearance signal, power level, carrier percent modulation, and identification signal. If proven advantageous and at the option of the Government, the three last-named parameters may utilize signals coupled from the antenna transmission line in lieu of antenna radiated signals. See also (b) below for an optional method of monitoring clearance signal). If a two-frequency capture effect localizer is provided, it may be necessary to monitor the directional and clearance carrier power levels separately.

The monitors utilizing integral monitor pickup devices (or transmission line signal coupling) shall, 1) if the main transmitter is on the air, immediately shut it down and, if the standby transmitter is operating into the dummy load, transfer it to the antenna, upon simultaneous any two out of the three course, width, power, modulation, clearance or identification, respectively, monitor alarms, or 2) if the standby transmitter is on the air, immediately shut it down, if at least two out of the three course, width, power, modulation, clearance or identification, respectively, monitor alarms. An alternative design as indicated in Fig. 1, applying to the course monitors alone, may be followed if proven advantageous to the Government.

- b. Near-field monitor. A near-field monitor pickup device shall be provided to verify course alignment. The signal from the near-field pickup device shall be utilized to operate two paralleled monitor channels (to be set for Category II course alignment tolerance). Whenever an out-of-tolerance condition exists for a period of 5 seconds, as sensed by both channels, shutdown action without transfer shall take place of both transmitters. The nominal 5 second delay time shall be adjustable from 2 to 10 seconds. At the option of the supplier, additional near-field monitor pickup devices may be utilized

in lieu of using integral pickups for the monitoring of proper clearance signal. In this case, an alarm delay shall be provided as specified above, and after the set delay, both transmitters shall shut down.

- c. Far-field monitor. There shall be three far-field monitor pickup antennas to be located on an appropriate support structure such as telephone poles at or near the middle marker site. The pickup signals shall be utilized to operate three receiver/monitors each provided with dual alarm limits for monitoring of localizer course alignment. The receivers shall be of the crystal controlled superheterodyne type with suitable band-pass characteristics to reject adjacent channel signals. Each monitor shall be capable of being set for Category III and Category II course alignment alarm limits simultaneously. The three Category III tolerance alarm limits shall operate in parallel with the provision that whenever at least two of the three monitors indicate an out-of-tolerance condition, a disable Category III signal shall be transmitted to the Remote Control Indicator for the duration of the fault. Two of the Category II monitor course alarm limits (any two) shall be connected in parallel and shall operate so that whenever an out-of-tolerance Category II condition exists for a period of 70 seconds, as sensed by both monitor channels, all localizer radiation shall cease unless this function is by-passed at the localizer station, without attempt to transfer to the standby transmitter. Five seconds prior to the anticipated shutdown, the monitor shall trigger the localizer transmitter alert shutdown signal (see 3.3.2). The nominal 70 second time delay shall be adjustable from 40 to 120 seconds and shall be automatically re-initialized each time the DDM as indicated by both channels lies within allowable tolerances for longer than 50 milli-seconds. The output DDM of one of the channels shall be remotely displayed on a meter at the localizer station for use as a maintenance aid. The far-field monitor shall be housed as described in 3.7.5, shall be provided with standby power as described in 3.1.15 and shall be environmentally controlled if necessary to operate during all environmental extremes.
- d. Standby transmitter monitor. An internal monitor consisting of single channels and utilizing signals coupled from the transmission line from standby transmitter(s) to the dummy load(s) shall monitor course, width, power, modulation, clearance and identification. Upon detecting a fault the standby transmitter shall shut down after an adjustable time delay from 2 to 5 seconds. While the standby transmitter(s) (are) is on the air, a disable Cat III signal shall be transmitted to the Remote Control Indicator. (See Figure 1)

3.3.5 Equipment shelter (localizer and glide slope stations).—Shelters conforming to MIL-S-55286 and the requirements specified herein or conforming to an alternate design acceptable to the Government shall be provided for both the glide slope and localizer stations and shall include a test bench. The length and width of the shelter may be increased as necessary to accommodate the ILS equipment. The localizer equipment shelter is intended to be located about 300' from the antenna array center within a sector of $+60^{\circ}$ to $+120^{\circ}$ from the centerline extended. The glide slope shelter is intended for location directly behind the glide slope mast.

- a. **Electrical system.** All power line circuitry necessary for proper operation of the ILS shall be supplied in the shelters as part of the shelters. The wiring shall be of the proper size to handle the maximum power required and shall comply with the requirements of the National Electric Code. All power and multi-conductor cables shall be shielded or constructed to minimize interference radiated by the cables.
- b. **Power input panel.** Power receptacles shall be located on the front of the shelters in suitable sloped power input panels and shall be properly labeled.
- c. **Lighting circuit.** Lighting circuits with the necessary fixtures and switches shall be provided as part of each shelter.
- d. **Convenience outlets.** A wiring raceway with at least two duplex convenience outlets on each main wall shall be provided on the inside walls around the periphery of the shelters. The wiring and fixtures of this circuit shall be adequate to carry the required current to the equipments. A minimum of five outlets shall be provided, spaced at intervals of one foot in the immediate area of the work bench.
- e. **Power junction box.** A junction box shall be provided on the front end of the shelter interior to accommodate the power input receptacles.
- f. **Distribution panel.** All electrical branch circuits shall be energized from a master distribution panel connector to the power junction box. The distribution panel shall be mounted on the inside entry wall of the shelters.
- g. **Secondary power input.** A male connector, suitably sealed, shall be provided on the outside of the shelter. This connector shall be capable of accepting power from an EMU-10 power cart to operate the localizer or glide slope facility. The connector shall be suitably switched to preclude any damage from simultaneous application of primary power and the power cart.
- h. **Fire extinguisher.** A 5-pound CO₂ fire extinguisher shall be provided in each shelter and mounted on the inside of the shelter doors.
- i. **Securing of parts.** Brackets, lugs, flanges, inserts, bolts and other mounting arrangements shall be such as to retain components and parts securely when the equipments are subjected to the specified service conditions.
- j. **Shelter layout.** Equipment layout in the shelter shall be designed for ease of maintenance. All sides of equipment racks which require access for service shall have sufficient clearance from objects and walls to permit such access.
- k. **Batteries.** Batteries for the standby power supply shall be mounted in an externally vented, easily accessible battery box in such a way that no harm can be caused by acid spillage.

1. **Environmental controls.** If environmental controls (heaters, air conditioners, etc.) are required for operation during the conditions specified in 3.1.13 these controls shall be supplied in kit form and in such a way that no specialized parts (other than those in the kit) and only minor shelter modifications are required to remove or install the kit. Air conditioners shall comply with the requirements of FAA-C-2256.

3.4 UHF Glide Slope Station Performance Requirements.- The glide slope station shall be designed to meet the following performance requirements.

3.4.1 General.- ICAO, Annex 10, Part I, paragraphs 3.1.4.1.1, 3.1.4.1.2, 3.1.4.1.2.2.b), 3.1.4.1.3, and 3.1.4.1.4 are applicable.

3.4.2 Radio frequency.- The glide slope transmitter shall be adjustable, one at a time, to all of the 20 assigned channels, spaced on 0.3-MHz increments across the band of 328.6 to 335.4 MHz. The frequency tolerance shall not exceed 0.002 percent. The frequencies of the r-f carriers shall be individually adjustable and the nominal band occupied by the carriers shall be symmetrical about the assigned frequency. With all tolerances applied, the frequency separation between the carriers shall not be less than 4, or more than 12, KHz. ICAO, Annex 10, Part I, paragraphs 3.1.4.2.2 and 3.1.4.2.3 are also applicable.

3.4.3 Coverage.- With the transmitter r-f power output reduced to the monitor alarm point, the glide slope shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in a sector of 8 degrees on each side of the runway centerline extended to a distance of at least 10 nautical miles up to 1.750 and down to 0.450 or the angle corresponding to 0.22 DDM, whichever is lower.

3.4.4 Glide path structure.- Deviations of the actual glide path from the mean glide path shall remain within the operational tolerances specified in FAA Order 8200.11B with a 95 percent probability.

3.4.5 Carrier modulation.- The nominal depth of modulation of the radio frequency carrier due to each of the 90-Hz and 150-Hz tones shall be 40 percent. The depth of modulation shall not deviate outside the limits of 37.5 to 42.5 percent but shall be continuously adjustable between those limits. ICAO Annex 10, Part I, paragraphs 3.1.4.5.2c)d)e), 3.1.4.5.2.2, 3.1.4.5.3b), 3.1.4.5.3.1b) are also applicable.

3.4.6 Displacement sensitivity.- The angular displacement sensitivity shall be as symmetrical as possible. The nominal angular displacement sensitivity shall correspond to a DDM of 0.0875 at an angular displacement of 0.30 to 0.40 degrees above and below the glide path. This value corresponds to a deflection of + 75 microamperes. The DDM below the ILS glide path shall increase smoothly for decreasing angle until a value of 0.22 DDM is reached. This corresponds to a "fly up" deviation of 190 microamperes. This value shall be achieved at an angle of not less than 0.30 above the horizontal. However, if it is achieved at an angle greater than 0.450, the DDM shall remain equal to or greater than 0.22, at least down to 0.450. The glide path width and angle shall be so adjusted that an aircraft flying in such a way

as to just clear all obstructions between the outer marker and the threshold obtains a signal of no less than 180 microamperes (0.21 DDM) "fly up". With the glide path widened or lowered to the alarm point, no less than 150 microamperes (0.175 DDM) shall be obtained. The angular displacement sensitivity shall be adjusted and maintained within ± 15 percent of the nominal value selected.

3.4.7. Monitoring.- The automatic monitor system shall cause a degradation of Facility Performance Category III to Category II or cause radiation of Performance Category II to cease for any of the following conditions:

- a. A shift of the mean glide path by more than 0.0400 from 0.
- b. A reduction of power output causing the guidance signal to fall outside the limits of 3.4.3 or those specified under 3.4.4, or which exceeds a reduction of 80 percent from nominal power output for either carrier.
- c. A change in displacement sensitivity to a value differing by more than 15 percent of the nominal value selected.
- d. A lowering of the line below the glide path at which a DDM of 0.0875 is realized to an angle less than 0.7480 from the horizontal.
- e. Deterioration of the glide slope system that would result in the reduction of below-path clearances outside the limits specified in FAA Handbook OA P 8200.1.

The total period of radiation outside the tolerance limits specified in these performance limits shall not exceed 2 seconds.

3.5 Glide Slope Station Equipment Requirements

3.5.1 Equipment list.- The glide slope station shall include the glide slope transmitters, the glide slope antennas with a suitable mast, a monitor and control system, and an equipment shelter all as described below. The equipment shall operate as a capture effect glide slope, however, it shall be possible to convert the equipment for use as a null reference glide slope, and if additional equipment is required for this conversion, it shall also be furnished.

3.5.2 Glide slope transmitters.- The glide slope transmitting system shall be a two frequency (capture effect) design. Two such systems shall be provided; one designated the main transmitter system shall cause the glide slope antenna to radiate while the standby system is normally transmitting internally monitored signals to dummy loads. If the standby transmitter output is not satisfactory, it shall be shut down. Upon automatic or manual shut down of the main system, the standby transmitter system shall be immediately available for transfer to the antenna (if operating). While the standby transmitter is operating into the antenna, the main system shall remain shut down. The mutual interference between the two systems shall be reduced to a minimum with negligible mutual monitor interference. Any stray radiation from the

standby system should be at least 60 db below the carrier level of the main system as measured at the transmitter antenna system. Unless it can be shown that electronic modulation is equal or advantageous, mechanical modulation shall be employed. An elapsed time indicator shall be provided.

3.5.3 Glide slope antenna.- The capture effect glide slope shall include three identical antenna arrays, two of which could be used for a null reference system. The antenna arrays shall be designed to provide a maximum of ± 15 degree horizontal beamwidth as measured at the half power points. The antenna and monitor mast shall be designed for a location no closer than 400 feet to the centerline of the runway being served, and shall not exceed 55 feet in height above the elevation of the runway centerline nearest it. The antenna arrays and units shall be so designed and environmentally protected that they operate properly under all climatic conditions of 3.1.13. Provisions shall be made to prevent birds from alighting on the antenna elements. A dual obstruction light per FAA Advisory Circular AC 150/5345-2 shall be provided for mounting on top of the mast. The lamp in each fixture shall be wired in parallel and shall be rated at 100 watts.

3.5.4 Glide slope monitor and control system.- To insure the integrity of the glide slope signals, integral, near field and standby transmitter monitors shall perform as outlined below. In addition to controlling the transmitting equipments, the indicated status at the Remote Control Indicator shall be downgraded from Facility Performance Category III to Category II whenever standby equipment is not available or is on the air. Upon shutdown of the glide slope system a visual and audio alarm indication shall be initiated at the Remote Control Indicator and restoration of the glide slope radiation shall be prevented for at least 20 seconds. It shall be possible to by-pass any or all the monitor channels. Fig. 2 illustrates some of the glide slope monitor and control system requirements herein.

- a. **Integral monitor.** Pickup devices shall be located at each radiating antenna array; by suitable signal combining, the integral monitoring system shall provide composite signals for the monitoring of path position, path width, power level, carrier percent modulation and, in the case of the capture-effect system, below path clearance. (If proven advantageous, and at the option of the Government, the power level and carrier percent modulation parameters may utilize signals coupled from the antenna transmission line in lieu of antenna radiated signals). The monitoring channels utilizing integral monitor pickup devices (or transmission line signal coupling) shall provide integral monitor action, i.e., shut down the transmitter on the air, and as appropriate, transfer the standby transmitter to the antenna upon sensing an out-of-tolerance parameter simultaneously in two of the three channels. The monitor channels provided for path position monitoring shall be capable of being adjusted for use with a capture-effect system, and of being disabled, if desired, when used in a null-reference configuration.
- b. **Near field monitor.** A near-field pickup device located on a suitable tower shall be provided to verify path position. The signal from the near-field pickup device shall be utilized to operate the paralleled monitor channels. Whenever an out-of-tolerance condition exists for a

period of 2 seconds as sensed by two of the three channels, the transmitter on the air shall be shut down, and if appropriate, the standby transmitter output shall be transferred to the antenna. The nominal 2 second delay time shall be adjustable from 2 to 10 seconds.

- c. GS tower deformation monitor. A device shall be provided to detect permanent misalignment or deformation of the antenna tower to a degree which would cause improper below-path clearance signals. This device shall have sufficient damping or time delay to make it impervious to tower vibration or temporary deflection caused by wind loading, etc.
- d. Standby transmitter monitor. An internal monitor consisting of single channels and utilizing signals coupled from the transmission line from the standby transmitters to the dummy loads shall monitor course, width, power modulation and clearance. Upon detecting a fault the standby transmitter shall be shut down after an adjustable time delay from 2 to 5 seconds. When the standby transmitters are on the air, a disable Category III station indication shall be transmitted to the remote control indicator. (See Fig. 2.)

3.5.5 Equipment shelter. See paragraph 3.3.5 with subparagraphs.

3.6 VHF Marker Beacon Performance Requirements.- The VHF marker beacon station shall be designed to meet the operational requirements of ICAO Annex 10, Part I, and the performance requirements specified herein.

3.6.1 General.- The VHF marker beacon station shall provide information about the distance to the runway threshold of an aircraft engaging in approaches to, and landings at, airfields.

3.6.2 Frequency.- The design center transmitter output frequency shall be 75 MHz. All specified requirements shall be met at this output frequency. The output frequency shall be within ± 0.005 percent of the design center value over the specified service conditions.

3.6.3 Radiated carrier power.- The full rated carrier power output of the transmitter shall not be less than 2 watt over the specified service conditions as measured at a 50-ohm unbalanced resistive load terminating the transmitter output.

3.6.4 Coverage.- The marker beacon field pattern shall be defined by the locus of points at which a standard calibrated aircraft installation, set for "low" sensitivity, causes its marker beacon light to come on while the aircraft is flying toward the station. The field pattern shall satisfy the following conditions:

- a. When cut by a horizontal plane, the pattern shall be an ellipse with its minor axis parallel to the course line.
- b. When cut by a vertical plane in the minor or major axis, the pattern shall be within 25 percent of the limits shown on figure 3.
- c. The above coverage shall extend to an altitude of at least 3000 feet above the station.

- d. The radiation shall be horizontally polarized.

3.6.5 Modulation percentage.-

- a. The transmitter shall be capable of being modulated from 85 to 98 percent over the full range of power output with any of the audio tone generators provided with the equipment. The modulation percentage for each tone shall be adjustable over this range.
- b. After initial adjustment to 95 percent modulation, adjustment of output power over the available range shall not change the actual percent modulation more than 3 percent.
- c. After initial adjustment to 95 percent modulation with rated power output under normal test conditions, the modulation shall be 91 to 99 percent under the specified service conditions.
- d. A switch selected position of the multimeter shall be provided to indicate percent modulation. The meter scale shall indicate 90 percent modulation at full scale left and 100 percent modulation at full scale right. The error in indicated percent modulation over the meter scale shall not exceed ± 1 percent of the actual percent modulation over the full range of power output under normal test conditions. Under the specified service conditions, the error in indicated percent modulation shall not exceed ± 5 percent of the actual percent modulation.

3.6.6 Modulation frequency

- a. The transmitter shall include the built-in tone generating and modulating facilities so that it can be modulated by each of the following audio tone frequencies, as selected:
 - (1) 400 Hz (outer marker)
 - (2) 1300 Hz (middle marker)
 - (3) 3000 Hz (inner marker)
- b. Each modulation frequency shall be within ± 1.5 percent of the design center frequency under normal test conditions. Variation of each modulation frequency shall not exceed 2.5 percent of the design center frequency under the specified service conditions.
- c. The total harmonic distortion in the demodulated output shall not exceed 8 percent with rated power output and 95 percent modulation.

3.6.7 Identification keyer.- The transmitter shall include solid state, electronic keying facilities that shall key the following audio tones without interruption of the carrier:

- a. The outer marker audio modulation frequency (400 Hz) shall be keyed to provide a continuous series of dashes.
- b. The middle marker audio modulation frequency (1300 Hz) shall be keyed to provide a continuous series of alternate dots and dashes.

- c. The inner marker audio modulation frequency (3000 Hz) shall be keyed to provide a continuous series of dots.

The keyer shall provide character timing as follows:

- d. Dot length: 0.1 second
- e. Dash length 0.3 second
- f. Length of space between dots and dashes in a continuous series and within a code character. 0.1 second

The keying rates shall remain within ± 15 percent of the design center values under the specified service conditions. Keying pulses shall start without undesirable transients, shall have no discontinuities, and shall stop without undesirable transients. Transient peaks due to keying shall not exceed 2 percent of the peak amplitude of the normal audio frequency waveform at the modulator output.

3.6.8 Siting.- The marker beacon stations shall be designed to be located to comply with the obstruction criteria of FAA AC 120-20 and the siting criteria of FAA Orders 6750.4, 6750.5 and 6750.8. The inner marker shall be so sited and adjusted that, in a typical aircraft installation on the established glide path, the marker light comes on at an aircraft altitude corresponding to the decision height.

3.7 Marker Beacon Station Equipment Requirements.

3.7.1 Equipment list.- An outer, middle, and an inner marker beacon shall be furnished. Each marker beacon shall be complete and include marker beacon transmitters, antenna, monitor and control equipment, and equipment shelters, all as described below.

3.7.2 Marker beacon transmitters.- Dual transmitters, main and standby, shall be furnished for each marker beacon station, and each transmitter shall be complete with a modulator, means for generating the three tones, an identification keyer and a front panel multimeter with a selector switch to display the d-c supply voltage, critical r-f test points, modulation percentage, and the monitor output for purposes of tuning-up and servicing the transmitter. Only one transmitter shall operate at any one time.

3.7.3 Marker beacon antenna.- The antenna shall be designed to meet the coverage requirements of 3.6.3.

3.7.4 Marker beacon monitor and control system.- The local monitor shall cause a visible and audible alarm at the remote control-indicator if the following conditions occur:

- a. The power output of the transmitter drops below 50 percent of nominal.
- b. Audio modulation or identification keying is not present.
- c. Primary power to the site fails.

- d. The antenna is damaged to the extent that the pattern is adversely affected.

A control to vary the monitor threshold sensitivity to transmitter power output shall be provided at the marker beacon site. If the power output drops below 50 percent of nominal, or if the audio modulation or identification keying is not present, the monitor shall cause the main transmitter to shut down within 5 seconds and transfer operation to the standby transmitter. In case of an alarm on the standby transmitter, it shall not shut down automatically.

3.7.5 Marker beacon station shelter.- The transmitters, monitor and control equipment, and battery charger equipment shall be housed in a double-walled aluminum or steel shelter designed for mounting on a staging platform (not furnished under this requirement).

- a. Cabinets. The outer cabinet shall be vented to provide convection cooling of the equipment while simultaneously providing protection against rain and screening against insects. The inner cabinet shall be vented as required for adequate convection cooling with (RF) screening as required to meet equipment performance requirements. A duplex convenience outlet shall be installed inside the inner cabinet and shall be wired for 120V a-c operation.
- b. Covers. The shelter shall be provided with inner and outer front covers. The inner cover shall be top hinged and secured by means of Dzus, or equivalent, fasteners along the bottom and side edges. A movable bar shall be provided to support the cover in a horizontal position as a rain shield. The hinges shall be detachable to permit complete removal of the cover when desired. When positioned as a rain shield, the cover shall not interfere with removal of the modules or use of extender cards. The outer cover shall be removable by captive thumb screws. A hasp shall be furnished for attachment of a padlock (not furnished under this requirement) to prevent unauthorized access to the equipment within the cabinet.
- c. Battery shelter.- A separate aluminum housing shall be furnished to contain the batteries needed to satisfy the power requirements of 3.1.14 and shall be designed for mounting on a platform. It shall have a hinged cover that provides adequate weather protection for the batteries and permits the necessary air flow for ventilation. A hasp shall be furnished for a padlock to preclude unauthorized access to the equipment.

3.8 Remote Control Indicator.

3.8.1 General.- The Remote Control Indicator shall consist of two panels: An ILS Remote Control Panel, and an ILS Status Display Panel. Each panel shall be designed for mounting in a standard 19-inch relay rack, and shall be an integrated unit serving all stations of the ILS. The two panels shall operate independently of each other but shall be interconnected by standard telephone cable and have parallel inputs from the individual ILS stations. The two panels shall be identical in appearance except that the ILS Status Display Panel shall not be provided with a telephone and shall not have any remote control functions. The ILS Remote Control Panel shall be the

executive control unit for the ILS (3.8.2.a). The Remote Control-Indicator and ILS stations shall be interconnected using a maximum of 8 standard telephone cable pairs, each having a maximum DC loop resistance of 2000 ohms, to each station.

3.8.2 Indicators.- Each station being served shall have the listed indicators. Where a particular function is not applicable to the station served, the indicator shall be disabled by removing the lightbulb. The indicators shall be momentary contact, illuminated push buttons, segmented, colored and marked as shown in Figure 4 and described below. Each group of two push buttons shall be mounted on a plug-in module which may be removed and replaced without affecting the operation of other stations of the system.

- a. **Status control indicator.** This push button shall indicate whether the main transmitter or the standby transmitter is radiating signal or whether the station is off. The "Main" segment shall be colored green, the "Standby" segment amber, and the "Off" segment red. Depressing this button on the Remote Control Panel shall cycle the station status as follows Station Off-Station On-Station Off, etc. The "Station Off" action shall be instantaneous; however, the localizer and glide slope main transmitters shall not be capable of being placed into operation until 20 seconds or more have expired since the last removal of radiated signal from the station (the foregoing delay to be accomplished by automatic control equipment at the VHF localizer or UHF glide slope site). A dimmer control shall provide simultaneous, continuous dimming of the "Main" segments of all status indicators on the panel.
- b. **Abnormal indicator.** This push button shall be amber colored and shall illuminate, and an audible alarm shall sound, under any of the following conditions:
 - (1) Primary Power Failure
 - (2) Battery Charger Failure
 - (3) Shelter inside temperature outside of acceptable limits
 - (4) Monitor locally bypassed (see below)
 - (5) Station off the air
 - (6) Monitor alarm (see 3.1.26b)

The button shall remain lighted until the fault is cleared. Depressing it while the audible alarm is sounding shall temporarily silence the alarm. The light shall flash at the rate of approximately 2 times per second while the monitor of the station being served is locally bypassed, regardless of any other abnormal conditions which may exist at the station. An audible alarm shall sound each time an abnormal indication occurs. It shall have the capability of being silenced by depression of an "abnormal" button. Even if so silenced, the alarm shall sound again each time a new "abnormal" indication is received. A volume control, accessible by screwdriver from the front, shall be provided. It shall not be possible to completely silence the alarm with this control.

- c. **ILS Performance Category Status.** Two indicator light panels, green and amber, and labeled CAT III and CAT II, respectively, shall be provided on each panel to allow monitoring of the ILS Performance Category Status. Only one light panel shall be lighted at any time and if the performance is below Category II status as defined below, neither light panel shall be lighted. Whenever transfer is made from one performance category status to another a momentary buzzer shall sound. A volume control accessible by screwdriver from the front shall be provided. It shall not be possible to completely silence the buzzer with this control.

The following input indications are required to light up the ILS Category III indicator light panel:

- (A) Localizer main transmitter on (See fig. 1)
 - (B) Localizer standby transmitter available (See fig. 1)
 - (C) Localizer far field Cat. III course monitor "happy" (See fig. 1)
(This alarm input (C) shall be delayable from 0-20 sec. by means of a control on each panel.)
 - (E) Glide slope monitor "happy" (See fig. 2)
 - (F) Glide slope standby transmitter available (See fig. 2)
 - (G) DME OK
 - (H) Outer marker on (and no rf level or identification alarm)
 - (I) Middle marker on (" " " " " " ")
 - (J) Inner marker on (" " " " " " ")
 - (L) Localizer Station abnormal light off, (M) GS Station abnormal light off
- Provisions for three additional optional inputs shall be provided. It shall be possible to by-pass any or all input indications.

The following inputs are all required to light up the ILS Category II indicator light panel:

- (D) Localizer Category II monitor "happy" (See fig. 1)
- (E) GS monitor "happy" (See fig. 2)
- (H) Outer marker on (and no rf level or identification alarm)
- (I) Middle marker on (" " " " " " ")
- (J) Inner marker on (" " " " " " ")
- (K) Category III indicator light panel light off.

3.8.3 Telephone handset and dial.- This unit shall provide voice communication, with ringing capability; to each site being served by the panel. A dial code shall be provided which permits monitoring of the localizer identification signal when the handset at the localizer site is in its cradle. A switch position shall be provided at the localizer site to permit local monitoring of the identification signal.

3.9 Additional Requirements

3.9.1 Test equipment.- Any ground test equipment required for the set-up and normal maintenance of the equipment, not available through regular commercial channels, shall be furnished as part of the ILS equipment system. A list of all required test equipment by type shall be furnished in the original proposal.

3.9.2 Spare parts.- Spare modules or subunits shall be furnished so that for any electronic circuit, or assembly within the system subject to failure there is at least one such module or subunit available as a replacement. Additionally, if within the entire system furnished more than 10 identical subunits exist, at least one such spare unit shall be furnished for each 10 units or a fraction of ten units. In addition, a two-year self sufficient supply of spare parts required in normal operation shall be furnished.

3.9.3 Equipment specifications.- Equipment specification (one per each subsystem) shall be prepared per FAA-STD-005 and furnished.

3.9.4 Instruction books.- Commercial type instruction books, describing the complete theory, installation, maintenance and operation of each subsystem shall be furnished. To contents shall be equal to the in-depth description as required by FAA-D-638h, but exact compliance to the format requirements of this specification is not required.

3.9.5 Test Requirements

- a. Laboratory tests. In plant inspection and testing shall be conducted to demonstrate compliance with the performance and equipment requirements herein. Each major subsystem furnished (localizer, glide slope, localizer far field monitor and markers) shall be subjected to environmental chamber tests to demonstrate satisfactory operation under temperature and humidity extremes specified in 3.1.13. The contractor shall be responsible for all the testing necessary to insure conformance and may utilize his own facility or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any inspection where such is deemed desirable to assure supplies and performance conform to the prescribed requirements.
- b. Field tests. The contractor shall be required at a location designated by the Government to assist in the installation and tune-up of the equipment and may be required to implement reasonable modifications or improvements designed to upgrade the reliability and integrity of the system, if found desirable, during the field testing of the equipment. Final acceptance is subject to successful demonstration of field performance.

4. RELIABILITY, AVAILABILITY/MAINTAINABILITY AND FAIL SAFE DEMONSTRATION TEST PLANS AND PROCEDURES

4.1 General.- The importance of safety and availability are paramount in regard to the Category III ILS equipment. This equipment must operate within the same safety standards as present Category I, II and VFR system. It is incumbent on the contractor to demonstrate his proposed equipment by an analytical and operational evaluation that the reliability, availability and fail-safe requirements specified within this work statement are met. The design evaluation shall be consistent with the latest available reliability engineering procedures and the performance evaluation shall be based on statistical techniques requiring the actual operation of the equipment. The meaning of specific terms used herein shall be in accordance with MIL-STD-721B.

The purpose of the operational demonstration tests is to assure the FAA that the proposed equipment meets the reliability, availability and fail-safe requirements described below. The contractor will create the necessary management controls to assure that the demonstration program is carried out as specified. This demonstration will be conducted by the actual operation of the equipment for a sufficient period of time to assure that the requirements specified below are met. However, prior to any operational demonstration or fabrication of the equipment, it will be necessary for the contractor to supply the FAA with the results of an analytical evaluation of the design to demonstrate that the proposed design has the inherent capability of meeting the specifications. The contractor will await approval of the final design by the Contracting Officer prior to proceeding with the final assembly of the equipment.

It is envisioned that some, or all, of the test time necessary for the demonstration will be accumulated from equipment which is installed in an airport. The contractor will be responsible for all data collection, maintenance and failure evaluation prior to the acceptance of the equipment by the FAA. Acceptance of the equipment will be contingent upon passing the demonstration test.

4.2 Test Management.

4.2.1 Organizational requirements.- A demonstration test program is a dynamic procedure, that reacts to events as they occur during the test period. The contractor shall create a central test program management organization to insure that the proper test specifications are applied and that plan requirements are met. The test-program management shall be responsible for overall coordination of the testing effort so as to prevent duplication and to insure that there are no serious omissions. If any portion of the program is subcontracted, the subcontractor shall be responsible to the contractor for their portion of the task.

The contractor's test-program management organization shall be responsible for supervising the formulation and implementation of the demonstration test plans, procedures and data reporting system. The contractor shall specify the methods of collecting data and indicate how the management team and the FAA will be kept informed as to the progress of the demonstration tests. The contractor will indicate what data collections will be used. All forms will be approved by FAA.

4.2.2 Test scheduling.- The contractor will submit a test schedule that indicates the major milestones in accomplishing the demonstration test.

4.3 Reliability Program Plan

4.3.1 Minimum requirements.- The contractor shall establish equipment reliability through a program performed in accordance with MIL-STD-785 and MIL-HDBK-217A. The reliability analysis shall contain the following as a minimum:

- a. A reliability block diagram of the equipment indicating all redundancies, series elements, voting logic, etc.
- b. Failure rates for each element of the equipment, where an element is defined as the highest level of assembly for which failure rates are available.

- c. References of all failure rate data and modification factors used to account for environmental conditions. Justification of these factors must be based on engineering analysis.
- d. All system failure modes must be identified.
- e. An estimate of the equipment reliability will be made, based on the above requirements.
- f. All assumptions concerning the reliability analysis must be documented and justified.

4.3.2 Reliability assessment.- Using the results of 4.3.1, the contractor will demonstrate that the proposed design is capable of meeting the requirements specified below.

4.4 Demonstration Test Plan Specifications

4.4.1 Reliability demonstration plan specification.- The contractor shall design and implement a reliability demonstration test plan such that the probability of the FAA accepting a system that does not meet the reliability requirements, shall not exceed 0.10. The reliability requirement is the following: That during the critical phase of a Category III landing (any 10 and 5 second period for the localizer and glide slope, respectively), the probability of a potentially hazardous signal fault including loss of signal shall not exceed $(1.0) \times 10^{-7}$. Any failure time distributional assumption made in the selection of the plan must be validated. The contractor will specify the required test time, acceptable number of failures and assumption made in the design of the plan. The contractor shall also supply operating characteristic (OC) curves to illustrate the properties of the proposed test plan. MIL-STD-781B shall be used as a guide.

For systems that have a high reliability requirement, the test time needed for demonstrating the above requirement can be very long, i.e., several thousands of hours, therefore, the contractor shall consider various methods to reduce the required calendar time to perform ILS demonstration tests. The calendar time shall not exceed 5,000 hours.

4.4.2 Availability/Maintainability demonstration plan specifications.- The contractor shall develop an availability demonstration plan and analytical model that are consistent with the reliability demonstration plan and analytical model. The contractor shall design and implement an availability demonstration test plan such that the probability of the FAA accepting a system that does not meet the availability requirements shall not exceed .10.

The availability requirement states that the system's steady state availability shall not be less than .99.

The contractor shall design plans whereby fault simulation for corrective maintenance tasks shall be performed by the introduction of faulty parts, deliberate misalignment (bugging) etc., as specified in MIL-STD-471, Maintainability Demonstration. A minimum of fifty (50) stratified (bugged) samples are required for developing time-to-repair data. Since the amount

of time in which Category III conditions exist is small with respect to VFR conditions, preventive maintenance will only be scheduled during VFR conditions and will not be charged against availability. The contractor can assume that the time-to-repair data fits a lognormal distribution. The time-to-repair data should not include logistic delay, i.e., repairmen, parts and tools are available. The contractor shall demonstrate System Maintainability (corrective maintenance) by applying Method (α = 5%) and Method 4 (90% confidence level) from MIL-STD-471 using the fault simulation time-to-repair data.

4.4.3 Fail-safe demonstration specifications.- The contractor shall demonstrate that the fail-safe properties of the Category III ILS Ground Equipment satisfy the following criteria:

- a. That all potentially hazardous failures are detected.
- b. That all potentially hazardous failures do not cause inaccurate commands.

The above criteria shall be demonstrated during the collection time-to-repair data (Section 4.4.2) by observing and recording the system's behavior to the deliberate introduction of faulty parts and/or the misalignment of the system in which a hazardous condition can occur, and if necessary to continue to introduce faulty parts and/or misalign (bug) the system so as to demonstrate a particular fail-safe characteristic that was not demonstrated during the collection of time-to-repair data.

The contractor will assure the FAA that all potential modes of hazardous failure have been studied and satisfy the fail-safe requirements.

4.4.4 Environmental condition specifications.- The contractor shall demonstrate that equipment and structures such as antennas, cables, monitors, etc., that are continuously exposed to the outdoor environment must satisfy the extreme conditions of temperature, humidity, wind, rain, snow, fog and vibrations induced by aircraft acoustical noise that can be expected at the airport site.

The contractor shall ensure that vibrations induced by aircraft acoustical noise do not have any significant effect on indoor equipment. The contractor will describe in his test plan the methods to which these requirements will be verified.

4.5 Demonstration Plan Evaluation Specifications

The Category III ILS demonstration plans formulated and implemented by the contractor with the cooperation of the FAA will be subjected to continuous evaluation by the contractor and FAA during the implementation phase.

4.5.1 Request for waiver.- Request for deviation or waiver from this specification shall be directed to FAA for approval.

4.5.2 Oral statements.- Oral statements by any person or persons shall not be permitted in any manner or degree to modify or otherwise affect the require-

ments or any portion of this specification, or any specification, standard, drawing or publication referenced herein.

4.5.3 Conflicting requirements.- Conflicting requirements arising between this specification or any specification, standard, drawing or publication listed herein, shall be referred in writing to the FAA, or appointed agent, for interpretation, clarification, resolution or correction.

4.6 Documentation Specification

The contractor shall document the formulation and implementation phases of the demonstration test plan program.

4.6.1 Documentation required for the formulation phase.- The documentation for the formulation phase shall be submitted with the contractors proposal for Category III ILS Ground Equipment as a separately bound document and shall include the following:

- a. The contractor's proposed demonstration plan management organization.
- b. A complete description of the demonstration test plans, analytic models and reliability analysis.
- c. A complete description of the data reporting system with a description and samples of data reporting forms.
- d. A milestone chart and planned work schedule indicating the time required to demonstrate the various phases of the demonstration requirements.

4.6.2 Documentation required for implementation phases.- Documentation for this phase shall consist of the following:

- a. Progress Reports are to be submitted at bi-monthly intervals with milestone charts showing the planned work schedule and work completed. The contractor's demonstration plan management must ensure that these reports are consistent with the objectives and plans described in the Formulation Phase of the demonstration test plan program.
- b. Final Report covering the completed contract effort shall contain as a minimum:
 1. Data collected.
 2. Factors which influence data.
 3. Analysis of the data (data reduction technique used, use of the data by the analytic models).
 4. Results of the demonstration.

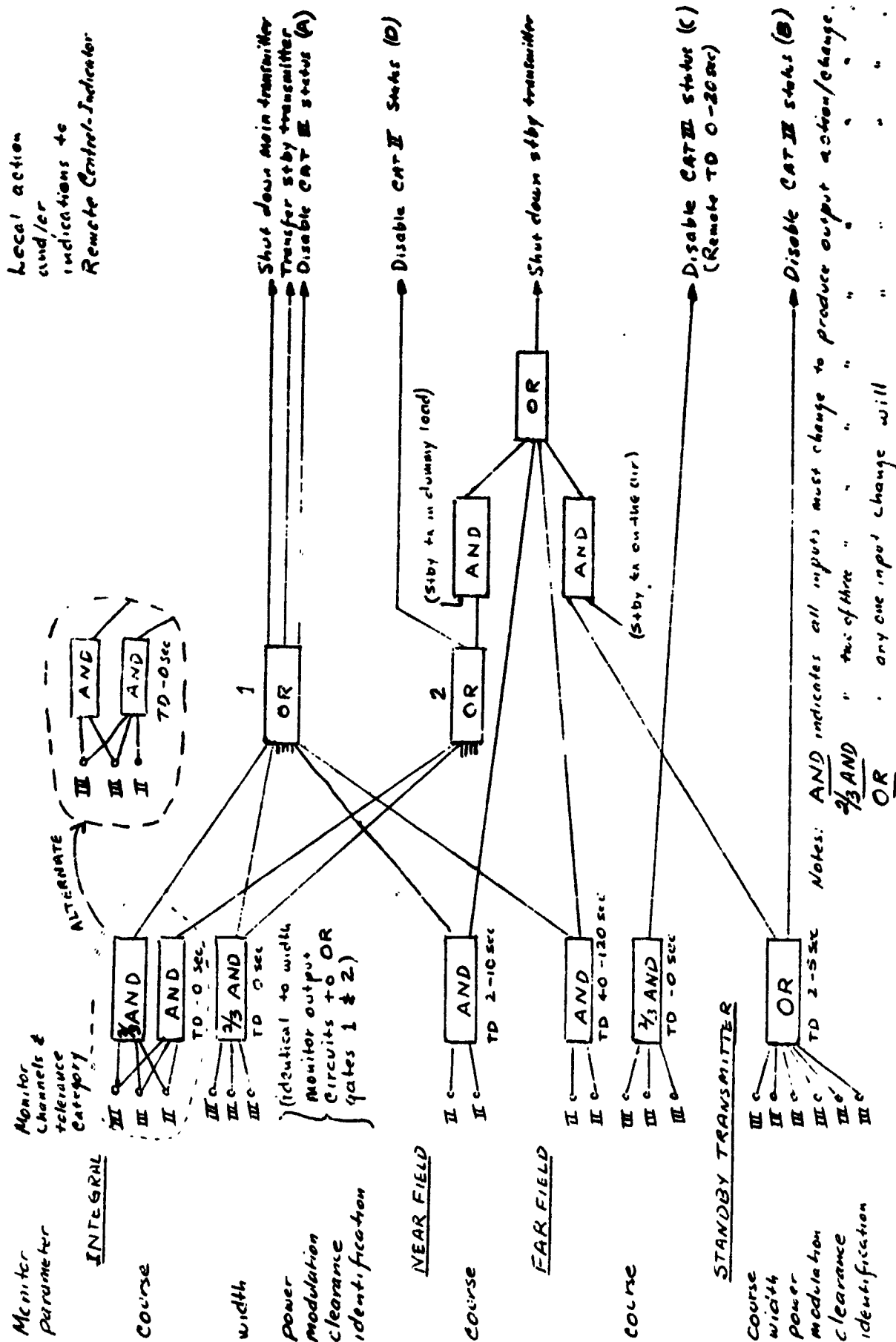


FIG. 1. Proposed Localizer Monitor Control Circuits Logic

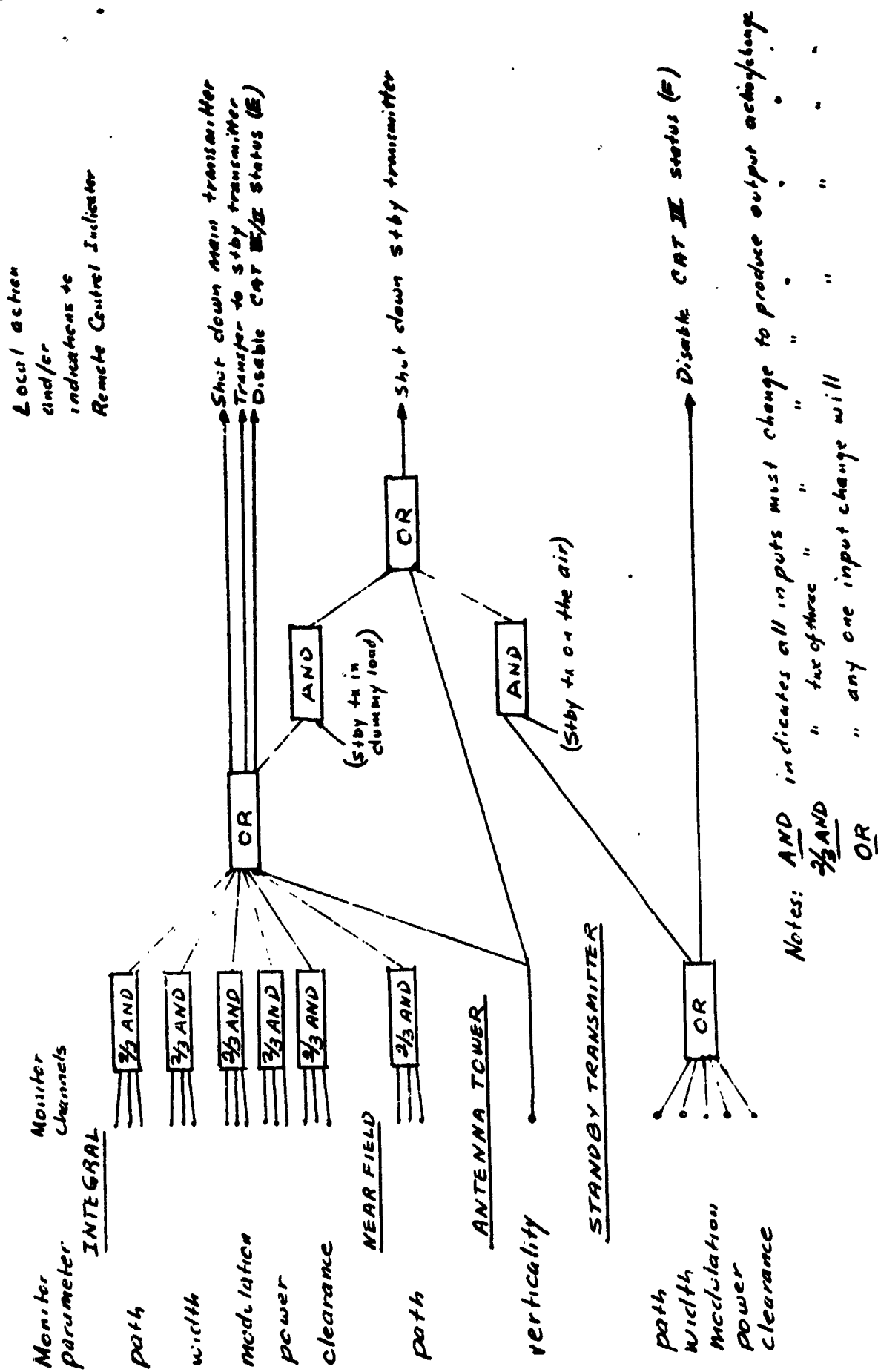


FIG. 2. Proposed Glide Slope Monitor Control Circuits Logic

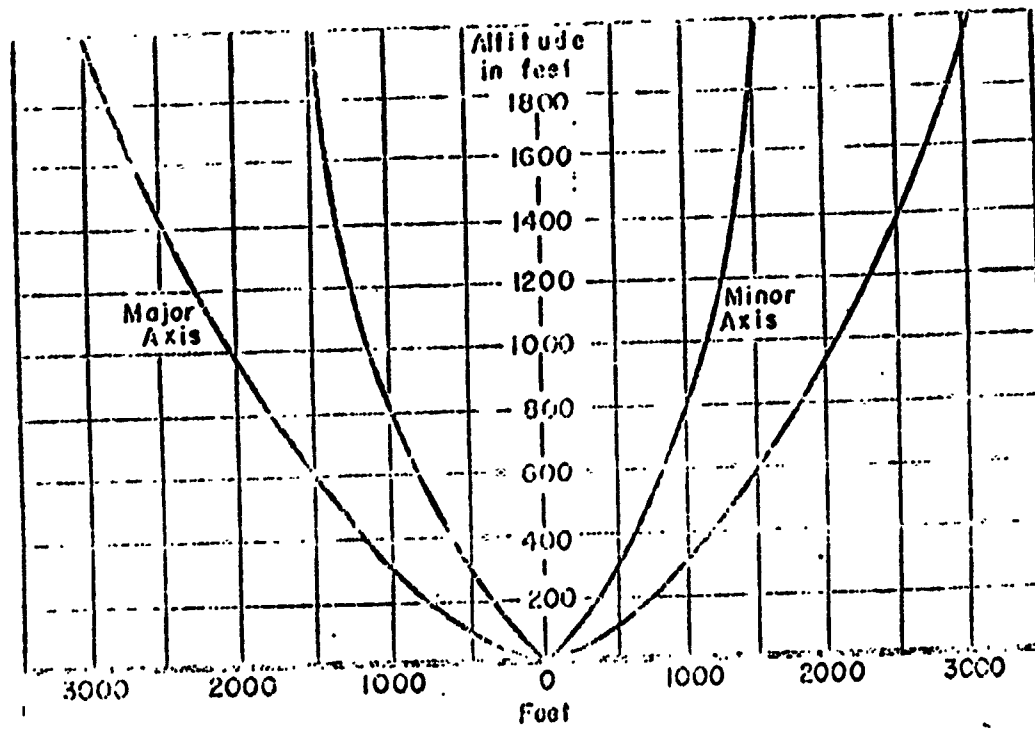


FIGURE 3. Marker Beacon Vertical Field Patterns

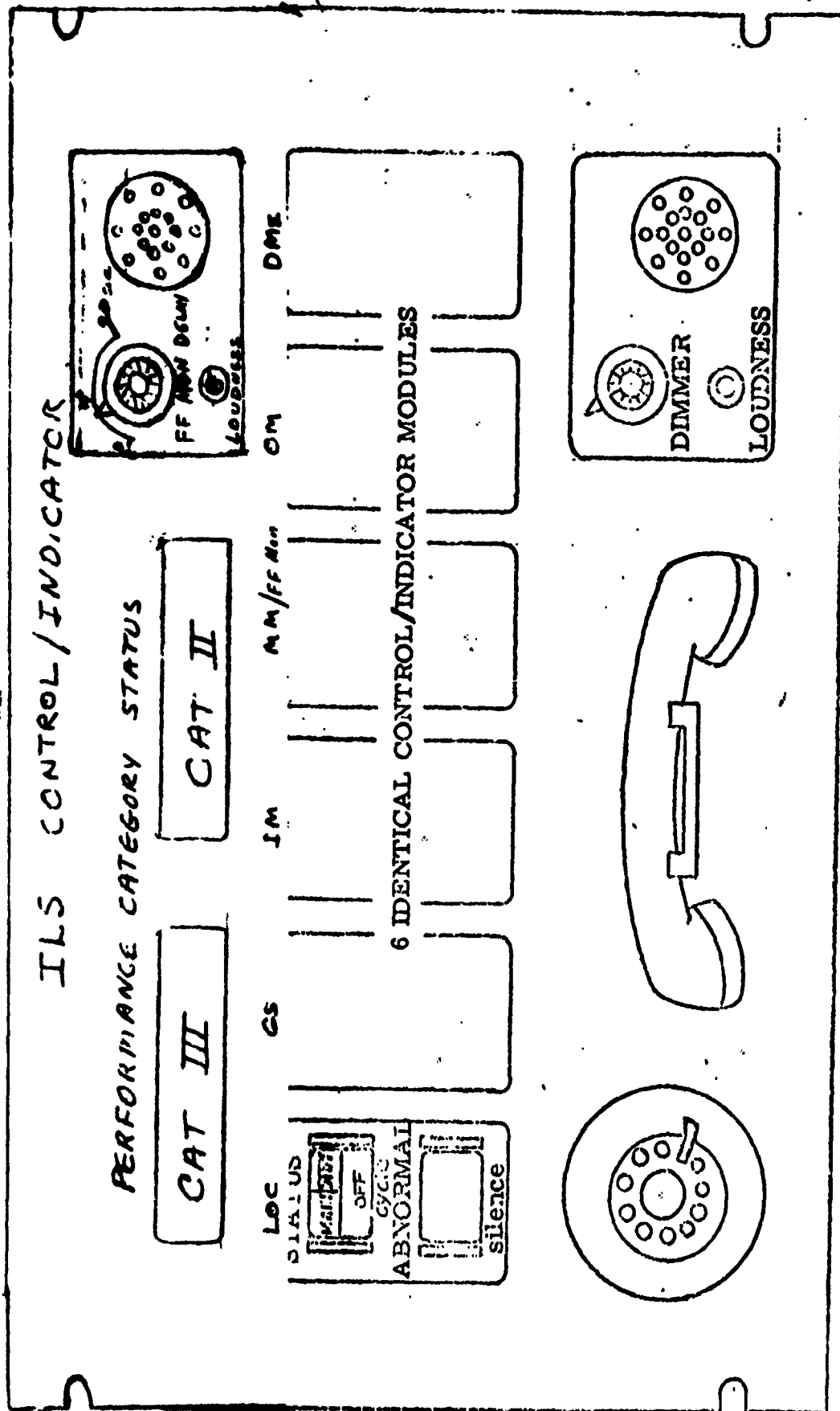


FIGURE 4. ILS REMOTE CONTROL. FUNCTIONS AND APPROXIMATE LAYOUT, NOT TO SCALE.

FAA Engineering Requirement
CAT III/II ILS Development

This amendment forms a part of FAA-ER-320-002, Rev. No. 1 February 1971.

Page 5, paragraph 3.1.15, third sentence. Change to read "...eight hours for the localizer and glide slope stations and twenty-four hours for the marker beacons."

Page 7, paragraph 3.1.26a. Modify third sentence to read: "The design of all the monitor components shall yield extremely high reliability and integrity and shall be of highest practical fail-safe nature to cause failures of any individual monitor channel itself or the loss of the monitor input signal to be detected as a fault indication."

Page 7, paragraph 3.1.26b, after the sentence ending "...abnormal operation (see 3.1.18 and 3.8)." insert "Exception: In the case of the localizer near field monitor channels, this indication shall be delayed by the nominal 5 second delay (see 3.3.4b) and in the case of the localizer far field monitors, this indication is not required for the Category III out-of-tolerance but shall be present after the nominal Category II monitor delay of 70 seconds (see 3.3.4c)".

Page 7. Add paragraph "3.1.27 Test Connector.- A conveniently located test connector with terminals for output signals from the monitors in form of dc analog levels representing rf amplitude, sdm, ddm and ident, as appropriate, shall be provided in the localizer, glide slope, and far field monitor. The terminals shall be suitable for multi-channel recorder connections to record system performance and/or a maintenance monitor without interaction with the monitor. As a minimum, the following signals shall be available at the localizer and GS: Course position 1,2,3 - RF, SDM and DDM; Course width 1, 2, 3 - DDM; IDENT 1,2,3; Clearance 1,2,3 - RF, SDM and DDM; NFM 1,2,3 - RF, SDM, DDM; STBY Course - RF, SDM, DDM; STBY Course width - DDM; STBY Clear. - RF, SDM, DDM; STBY IDENT. As a minimum the following signal shall be available at the far field monitor: DDM No. 1,2 and 3."

Page 7. Add paragraph "3.1.28 Maintenance Monitor.- The maintenance monitor shall provide local and remote pre-alarm indications of certain key parameters of the localizer and the glide slope without interaction to the executive monitor and control system. The equipment shall compare appropriate analog signal levels from each monitor channel with predetermined and adequately adjustable reference voltages and display the results locally and at a central maintenance control point. A remote indication that a given parameter has exceeded a preset value but not yet gone into alarm will signal the possible need for preventive maintenance. Table 1 presents a list of the selected parameters which shall serve as inputs to the maintenance monitor, all of which, with the exception of the localizer far field monitor and the batteries, are available at the test connectors referred to in paragraph 3.1.27. The ILS system operation shall, for practical purposes, be unaffected by the addition or the removal of the maintenance monitor.

The maintenance monitor system shall consist of four chassis with associated status indicator panels. Each chassis shall house the required electronics. The finish and markings on the panels shall be consistent with the IIS cabinet panels and the remote control indicator. The remote status panel shall operate on 115v 60 Hz single phase power supply. Power for the maintenance monitor circuitry located at the localizer, glide slope, and far field monitor shall be taken from the associated cabinet battery charger output and the battery power supply. The additional power required at each station shall be within the station standby power capability as specified in paragraph 3.1.15.

Figures 5 and 6 illustrate signal display requirements and possible layouts of the indicator panels. Alternately, the localizer and glide slope panels, in the interest of interchangeability may be made identical. Each indicator panel shall contain a power on/off switch and a lamp bulb test switch. A lamp power switch, if required, shall also be located on each local station panel to permit conserving power by removing the display light voltage for periods while station is unattended.

Figures 7 and 8 illustrate how the signals may be processed from the input and on to the remote display. A near-out-of-tolerance condition on a given input is detected and fed, if appropriate, to an OR gate whose output causes appropriate local and remote indications. The stations panels are connected to the remote maintenance monitor status panel at the central maintenance control point by multi-pair cables furnished by the Government. Three line pairs are required for the far field monitor, 9 pairs for the glide slope, and 10 pairs for the localizer.

Page 9, paragraph 3.2.11.f. Change to read: "A change of the 90/150 Hz modulation percentage sum beyond $\pm 5\%$ of nominal."

Page 10, paragraph 3.3.2. Delete the last sentence.

Page 11, paragraph 3.3.3. Modify the last sentence to read: "The lamp in each fixture shall be 116 watt, GE #116 A21/TS lamp."

Page 11, paragraph 3.3.4. In the sentence "It shall be possible to bypass any or all monitor channels" change "any or all" to read "all the".

Page 11, paragraph 3.3.4a last sentence. Delete "as indicated in Figure 1".

Page 12. Delete the first sentence of paragraph 3.3.4c. Far field monitor. Substitute therefor the following:

"Far field monitor. There shall be three far field monitor pickup antennas to be located on an appropriate support structure such as telephone poles at or near the middle or inner marker sites."

Page 15. Delete the sentence under paragraph 3.4.7b and substitute therefor the following:

"A reduction of power output causing the guidance signal to fall outside the limits of 3.4.3 or those specified under 3.4.4, or which exceeds a reduction to 80 percent from nominal power output for either carrier."

Page 16. Modify paragraph 3.5.2, sixth sentence to read: "Any stray radiation from the standby system shall be at least 50 db below the carrier of the main system..". Delete the last sentence.

Page 16, paragraph 3.5.3. Modify the last sentence to read: "The lamp in each fixture shall be 116 watts, GE #116 A21/TS lamp."

Page 17, paragraph 3.5.4b. After "two of the three channels," change to read "the main and standby transmitters shall shut down. The nominal..."

Page 18, paragraph 3.6.5, third sentence. Change to read "...shall not exceed 3 percent..." from "...shall not exceed 1 percent..."

Page 20, paragraph 3.7.5 and sub-paragraphs. Delete.

Substitute:

"3.7.5 Marker beacon station shelter. - The Marker beacon station, including batteries, shall be housed in a standard FAA Marker beacon building, per FAA drawing D-5601-1, -2 and -3, or similar (not to be furnished by the Contractor), or if specified, in a suitable shelter which shall be of adequate size to enclose one set of a dual Marker beacon station, or a localizer far field monitor, plus adequate room for one maintenance technician to perform routine maintenance. The shelter shall provide protection against wind, precipitation, insects and excessive heat by means of air louvers. The enclosed equipment shall not require the shelter to be temperature controlled. A duplex convenience outlet shall be provided. Requirements of E.R 3.3.5 a, c, f, j and k are also applicable.

Page 21, paragraph 3.8.2b. Change to read: "Abnormal indicator. This push button shall be amber colored and segmented into two sections. The two sections (A), and (B) shall illuminate respectively for the following conditions accompanied by an audible alarm:

- (1) Primary power failure (A)
- (2) Battery charger failure (A)
- (3) Shelter inside temperature outside acceptable limits (A)
- (4) Monitor locally bypassed (see below) (B)
- (5) Station off the air (B)
- (6) Monitor alarm (see 3.1.26b) (B)

The button shall..."

Page 22, paragraph 3.8.2c. Delete line beginning with "(L)" and the following line.

Substitute:

"When abnormal indicator Section (A) (localizer and/or GS) illuminates, it shall disable the Category III Status only after an adjustable delay from 0 to two (2) hours and fifty (50) minutes. When abnormal indicator Section (B) (localizer and/or GS) illuminates, it shall not disable the Category III status, except, if either or both localizer and GS monitor is bypassed neither the Category III nor the Category II status lights shall illuminate. Provisions for two additional inputs shall be provided."

Page 22, paragraph 3.8.3. Delete "and dial" in "Telephone handset and dial."

Page 23, paragraph 3.9.4. Modify to read "Commercial type instruction books shall be furnished. The contents (not necessarily format) shall be equal to the indepth description as required per FAA-D-638 with the following exceptions. Type test data per FAA-D-638 paragraph 3.39.4 are not required. As applicable special information required under FAA-D-638 paragraph 3.36.1 and 3.36.3 may be deleted; information per paragraph 3.36.2 and 3.36.4, if furnished elsewhere with the equipment need not to be included in the book, and information required per paragraph 3.36.5 and 3.36.6 may be included in the Operation Section at the Contractor's option. Requirements per FAA-D-638 paragraph 3.45.2.1 are deleted. Specific step by step fault isolation procedures below the PWB level for the control unit and the assembly level for the rest of the equipment are not required."

b) Paragraph 3.9.5a: Change second sentence as follows: "Each major subsystem furnished with the first system (localizer, glide slope, localizer far field monitor and markers) shall be subjected to environmental chamber test to demonstrate satisfactory operation under temperature and humidity extremes specified in 3.1.13.

c) Paragraph 4.0: Change title as follows: "RELIABILITY DEMONSTRATION TEST PLANS AND PROCEDURE"

d) Paragraph 4.1: Change third sentence as follows: "It is incumbent on the contractor to demonstrate his proposed equipment by an analytical and operational evaluation that the reliability requirements specified within this work statement are met."

e) Paragraph 4.1: Change sixth sentence as follows: "The purpose of the operational demonstration is to assure the FAA that the proposed equipment meets the reliability requirement described below."

f) Paragraph 4.1: Change twelfth (12) sentence as follows: "The contractor will be responsible for all failure evaluation prior to the acceptance of the equipment by the FAA."

Page 24. Paragraph 4.3.1 Substitute "RADC Notebook Vol II" for "MIL-HDBK-217A".

g) Paragraph 4.4.2: Delete entire paragraph.

h) Paragraph 4.4.3: Delete entire paragraph.

Page 27. Paragraph 4.6.1. Delete the sentence under b. and substitute the following: "A complete description of the plan for demonstration test plans, analytic models and reliability analysis."

Figure 4. Revise Control/Indicator "Abnormal" indicator to show two segments, one labeled "ABN P/E" and the other labeled "ABN MON."

Add Table 1 and figures 5,6,7 and 8.

* * * *

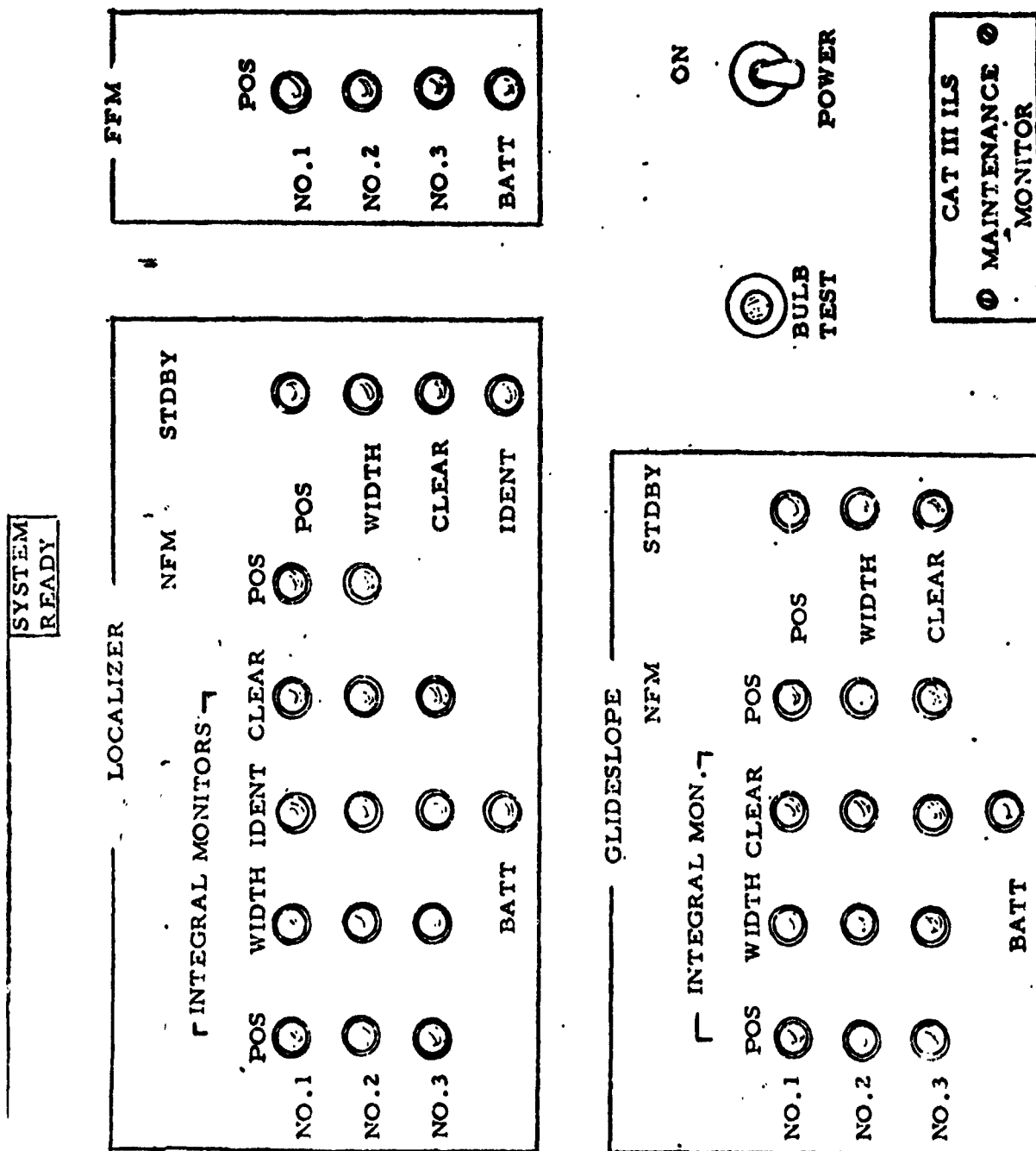


FIGURE 5. MAINTENANCE MONITOR STATUS PANEL

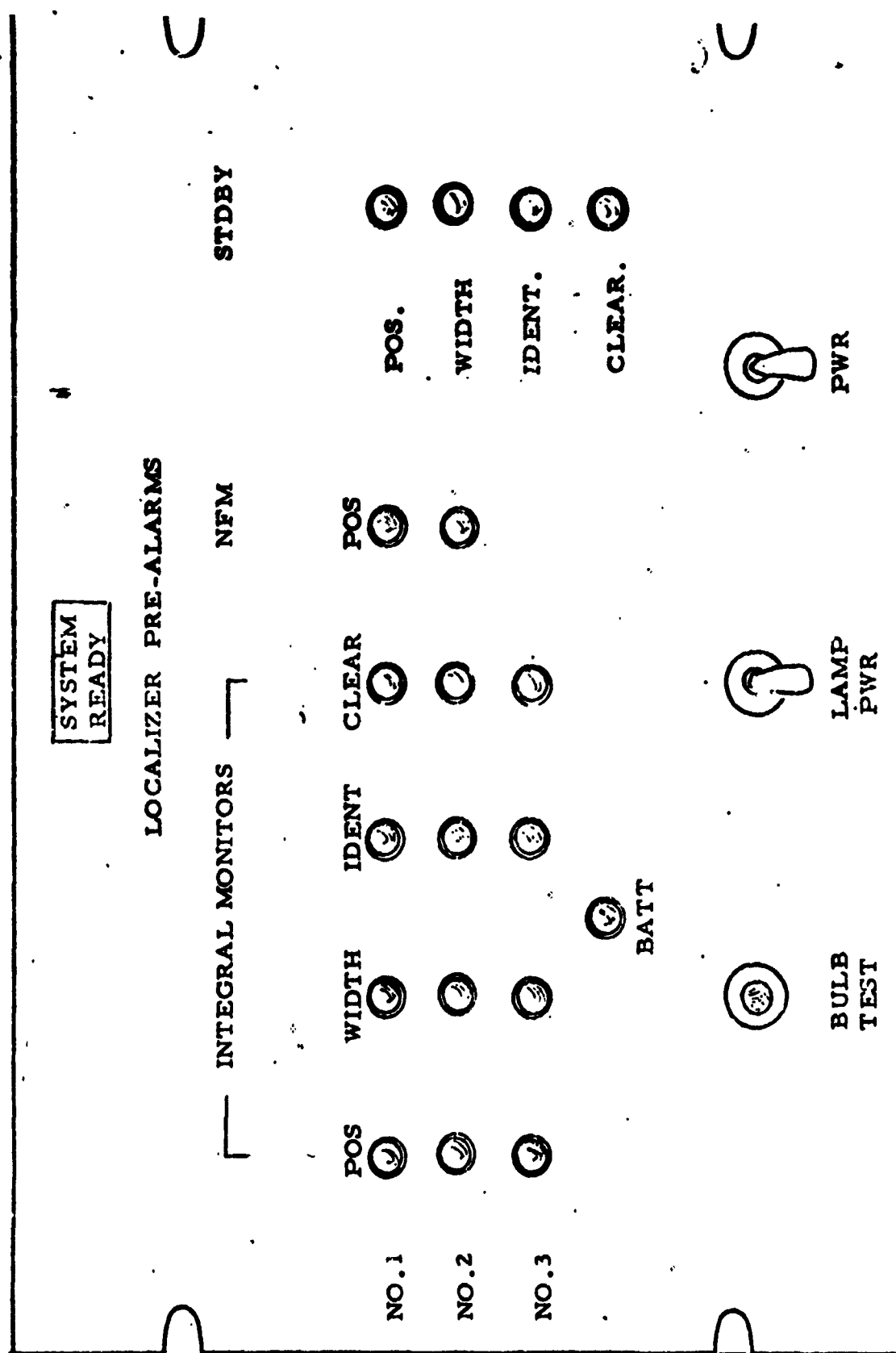


FIGURE 6. LOCALIZER STATUS PANEL

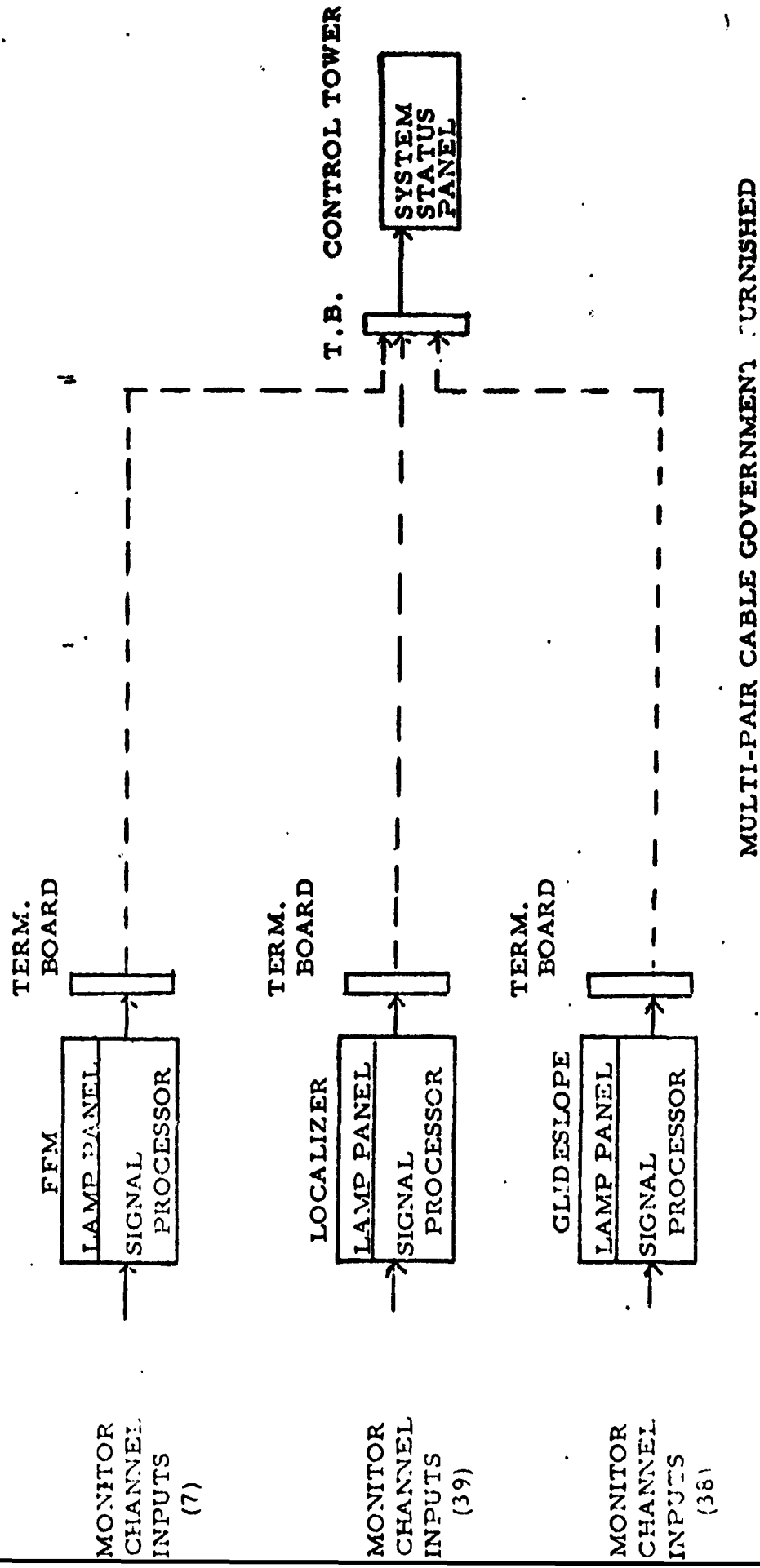
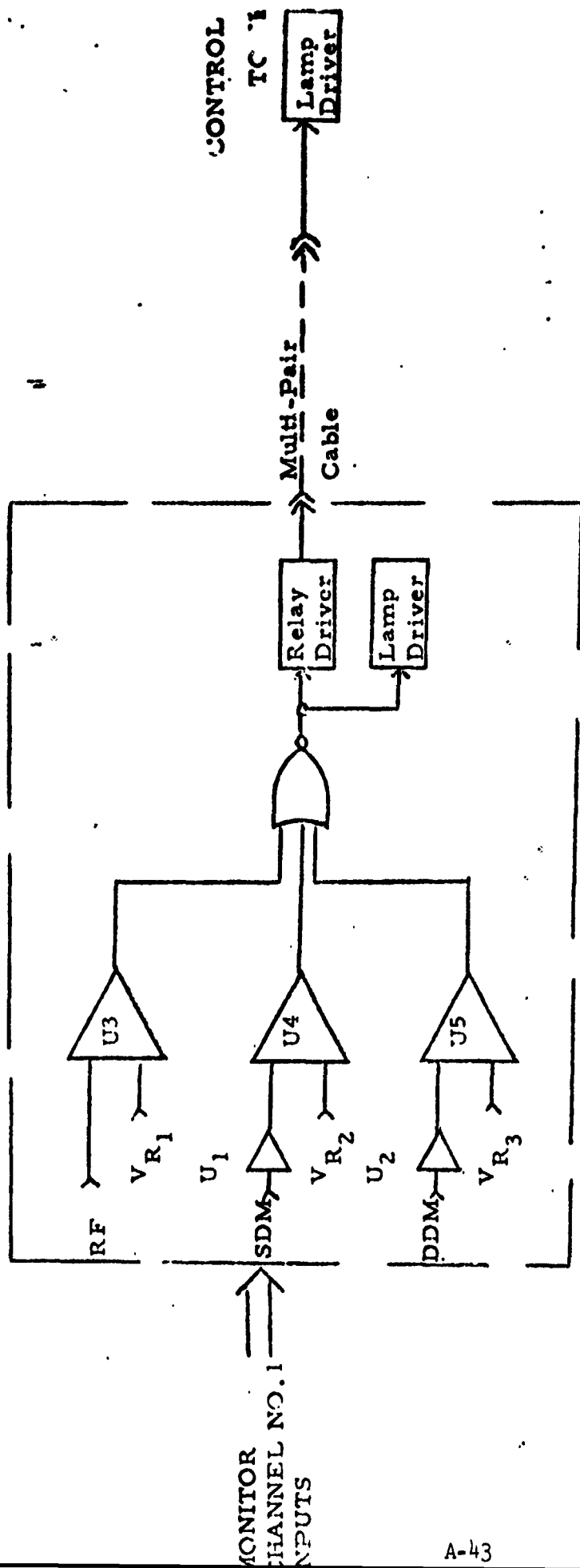


FIGURE 7. CAT III ILS MAINTENANCE MONITOR
BLOCK DIAGRAM

LOCALIZER STATION



U₁, U₂ BUFFER AMPLIFIER

U₃ SINGLE COMPARATOR

U₄, U₅ DUAL COMPARATOR

FIGURE 8. TYPICAL SIGNAL PROCESSOR CIRCUIT

Table 1. Selected Parameters for Remote Monitoring

Monitor Channel	Parameter	Localizer Quantity	Glideslope Quantity	FFM Quantity
Course Position No. 1	RF, SDM, DDM	3	3	2 (SDM, DDM)
Course Position No. 2	RF, SDM, DDM	3	3	2 (SDM, DDM)
Course Position No. 3	RF, SDM, DDM	3	3	2 (SDM, DDM)
Course Width No. 1	DDM	1	1	-
Course Width No. 2	DDM	1	1	-
Course Width No. 3	DDM	1	1	-
Identification No. 1	* Site Identification	1	-	-
Identification No. 2	* Site Identification	1	-	-
Identification No. 3	* Site Identification	1	-	-
Clearance No. 1	RF, SDM, DDM	3	3	-
Clearance No. 2	RF, SDM, DDM	3	3	-
Clearance No. 3	RF, SDM, DDM	3	3	-
RFM Course Position No. 1	RF, SDM, DDM	3	3	-
RFM Course Position No. 2	RF, SDM, DDM	3	3	-
RFM Course Position No. 3	RF, SDM, DDM	-	3	-
Standby Course Position	RF, SDM, DDM	3	3	-
Standby Course Width	DDM	1	1	-
Standby Clearance	RF, SDM, DDM	3	3	-
Standby Identification	* Standby Site	1	-	-
Battery Voltage	Battery Voltage	1	1	1
TOTAL		39	38	7

Alarm digital signal

**DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION**

**NATIONAL AVIATION FACILITIES
EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY 08406**



DATE: 23 JAN 1973

**IN REPLY
REFER TO:**

SUBJECT: NAFEC Category III ILS Tests prior to 1968

FROM: Director, ANA-1

TO: *[Signature]* ARD-1

The enclosed report covers only those significant facets of the effort expended during the 1964-1966 period. The purpose of the effort was to evaluate individually developed components and to integrate them into a Category III ILS System. A system evaluation was not performed because the components in combination did not provide the minimum required system performance.

[Signature]
C. A. COMMANDER

Enclosure

**LETTER REPORT
CATEGORY III ILS TESTS
DURING THE 1964-1966 PERIOD**

This report covers only significant facets of the work performed during the 1964-66 time period. The purpose of the effort was to evaluate developed components and eventually evolve a Category III ILS System. When the components were combined into a system, a minimum system performance did not result, and an evaluation was not performed. However, some knowledge was gained and utilized in subsequent Category III ILS evaluations.

Background:

The equipment delivered to NAFEC was procured during the time when FAA procurement policies precluded system development in the ILS area. Systems were developed by component and subcomponent specification. The problem of system interface and component marriage was left to the installer or, in this case, to the NAFEC evaluators. Although each subcomponent was checked out individually; as a system they failed to perform.

Basic Component Procurement:

1. The main and standby glide slope transmitters were manufactured by Hazeltine Corporation.
2. The main and standby localizer transmitters were manufactured by Airborne Instruments Laboratory.
3. The monitoring equipment was manufactured by the Wilcox Company.
4. The localizer antennas were manufactured by Scanwell Corporation.
5. No glide slope antennas were provided so the system was improvised by using the antennas and tower from the low cost ILS development by International Telephone and Telegraph Corporation.
6. The marker beacons used were also part of the low cost ILS development by International Telephone and Telegraph Corporation.

System Conditioning:

As mentioned previously, inadequate consideration of a system concept left

the interfacing and marriage of components into a system to a large extent to the discretion of NAFEC project personnel. Approximately a year's time was consumed in debugging individual components, evaluation and alignment of individual components and finally the assembly of the components into a quasi system.

The following are examples of debugging and testing:

1. Transmitter Changeover: A design objective was to provide the capability of completing the transfer from the main to standby transmitter, either localizer or glide slope, within a maximum of two seconds. That objective was never accomplished because of the inherent recovery time constant of the meter alarm relays located in the primary monitors. In addition, with a compliment of twelve individual and independent monitors, it was virtually impossible to keep these monitors satisfied for an acceptable period of operating time.
 2. Remoting Far-Field Indications: A positive gain of the test was acquiring the knowledge that the localizer performance could be effectively assessed on a continuing basis by remoting the far-field monitor indicators to the localizer shelter.
 3. Localizer Antenna: The localizer antenna configuration consisted of two (150' and 105' aperture) v-ring arrays. Specifications called for radiation from both antennas simultaneously. Testing indicated a mutual interference between radiation patterns thereby negating the usefulness of such an arrangement. Subsequent tests were conducted utilizing only the 150' array.
- The localizer was never tested as a complete subsystem because of the inability of the antenna contractor (Scanwell) to develop a near-field monitoring configuration.
4. Glide Slope Antenna and Monitor: Because of space limitations, the Category III glide slope antenna was located adjacent to and separated by 25' from the commissioned glide slope antenna on Runway 13. The lack of selectivity in both the commissioned and Category III glide slope monitor detectors required the placing of resonant cavity traps between the monitor antenna and detector in both systems.

The Wilcox glide slope monitor, as delivered, was not adequate for clearance measurement. The monitor's maximum range was 30 percent difference in depth of modulation (DDM) whereas the clearance monitoring point was at 35 percent DDM. The NAFEC project manager modified the unit to extend the DDM range to 50 percent thus meeting operational requirements.

Instability was evident in some receiver type monitor detectors supplied by Wilcox which rendered them for all practical purposes useless.

5. Solid State Reliability: The use of solid state circuitry proved to be a weakness in terms of reliability because following severe electrical storms, numerous instances of transistor outages were noted especially in the monitor circuits. These outages could not be attributed to direct strikes.

6. System MTBF: The performance of the Category III system showed no evidence that would verify a design goal of 4,000 hours MTBF. The results of the tests conducted indicated that performance tolerances could not be achieved in concert with maintaining stability.

Results Summarized:

1. System transfer within a two second maximum could never be accomplished due to recovery time constants of meter alarm relays and monitors.
2. As a subsystem the localizer was never completed because of the lack of near-field monitoring.
3. Instability was evident in some of the receiver-type glide slope detectors.
4. Solid state circuitry proved to be a system weak point due to its susceptibility to electrical storms.
5. Minimum system performance and system stability could not be achieved simultaneously.

6. Although individual components performed satisfactorily when combined into a system, the system failed to provide minimum satisfactory performance.

The information in this report was transmitted to SRDS orally and in a series of letters prior to the decision to evaluate STAN 37/38.

**DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION**

DATE: AUG 28 1974

**NATIONAL AVIATION FACILITIES
EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY 08406**



**IN REPLY
REFER TO:**

**SUBJECT: Letter Report on the Installation of the Category II to III ILS
Upgrade Kit PAA 07-319, Subprogram 072-321-000**

FROM: Director, ANA-1

TO: ARD-1

The purpose of this activity was to conduct an evaluation of (1) the installation of a Category II to Category III ILS Upgrade Kit by Contractor personnel from Texas Instruments, Inc., and (2) to determine the adequacy of the Contractor-written installation Handbook. The equipment upgraded was the AN/GRN-27 (V) Instrument Landing System serving RWY-31 at NAFEC. The equipment upgrade kits were provided under Contract No. DOT-FA73WA-3289 and the technical manpower at NAFEC was provided by Contract No. DOT-FA74NA-1072 (6/28/74). The work was performed in three phases - namely, mechanical installation, electrical and electronic checkout, and flight tests.

GENERAL

Four ILS technical personnel from Texas Instruments (T.I.) arrived at NAFEC on May 1. A briefing was held on May 2 and the work started on May 3. A fifth member from T.I. joined the first four on May 20 after most of the mechanical work and most of the electrical/electronic checkout had been completed.

MECHANICAL WORK

Primarily, two team members worked on glideslope facility modifications and the other two team members worked on localizer facility modifications. The instructions used were in the Texas Instruments Handbook, No. HB104-EG73, dated April 15, 1974, titled "Category II to Category III ILS Upgrade Kit Installation Instructions for AN/GRN-27 (V) Instrument Landing System." Major work areas were as follows:

I. Glide Slope

- A. Shelter modifications
- B. Transmitter group modifications
- C. Monitor, misalignment detector, and near-field monitor antenna modifications

II. Localizer

- A. Shelter modifications**
- B. Transmitter group modifications**
- C. Antenna interface equipment installation**
- D. Far-field monitor modifications**

III. Marker Beacon

Change complete cabinet

IV. General

- A. Remote control indicator status display system modifications**
- B. System interconnect, cabling, and telephone wiring modifications**

All of the above items were completed between May 2 and May 25, 1974, except the Marker Beacon modification which was completed in June. The total mandays expended to complete the mechanical work for the localizer and the Far-Field Monitor (FFM) was 23.5 mandays; the glideslope work required 18.5 mandays. In addition, the Remote Control Indicator and Monitor Panel Assembly and System Interconnect, etc., required 5 mandays to complete. The Contractor personnel meticulously followed the Handbook instructions, and corrected the errors and sequences of the instructional procedures as work progressed. A corrected copy (longhand notation) of this handbook is available at NAFEC for review. No major problems were encountered during the mechanical work phase or the subsequent electrical/electronic checkout phase. It is noted that the monitor units from the localizer were utilized in the glide-slope equipment as a cost-saving measure. The monitor logic used in the upgraded glideslope is the same as the "OR" logic used in current Category II systems, except that two out of three instead of two out of two monitors must alarm for a system changeover. Glideslope operation over a two-month period has shown that the different logic did not have an adverse effect on the system operational availability. Items requiring changes in future kits include: (1) better fitting doors on the localizer heated detector boxes, (2) protective covers over battery-box vent fans, and (3) larger cable ducts inside the shelters.

ELECTRICAL/ELECTRONIC CHECKOUT

This phase of the upgrade work included the turn-on procedures, equipment alignment, and system checkout for the stations, and performing necessary troubleshooting/repair to make the Upgraded ILS ready for the Flight Test phase. The glideslope facility checkout was completed on May 17, 1974, and the Localizer/FFM facility checkout was completed on May 22, 1974. Again, as in the mechanical work phase, the technical personnel followed and corrected the Handbook procedures. The installation personnel displayed excellent working skill and familiarity with the equipment, and can be considered as having the most expertise of anyone at Texas Instruments. The electrical/electronic checkout for the localizer facility required 11.5 mandays, the glideslope facility required 9 mandays, and the Remote Control Indicator and Monitor Panel Assembly Change-out required 1.5 mandays - the flight-test phase required 7.5 mandays of contractor personnel assistance. An additional 5.5 mandays of checkout and repair were required after flight testing ended on May 24, 1974, to correct discrepancies/failures, which did not affect the flight test results. Two weeks after the NAFEC flight tests, a serious wiring deficiency was discovered on the glideslope "mother-board." The etch carrying DC voltage for the monitor detectors burned through requiring the addition of larger wire, with appropriate fusing, to restore operation. Any future kits should have a different supply arrangement (with fusing) for the DC voltage buss supplying the monitor detectors.

FLIGHTS TESTS

NAFEC flight tests were performed during the week of May 20, 1974, with a DC-6 (N-114) aircraft for preliminary system alignment and performance checks. The Eastern Region performed standard flight inspection certification tests from May 28 to June 7, 1974. Glideslope and localizer alignment required a total of 16 flight hours with the NAFEC aircraft. Due to time limitations complete performance data were not collected with the NAFEC aircraft - only minimal data were obtained to insure satisfactory performance to Category III tolerances. Final system alignment using Category III alarm limit tolerances was performed during the Eastern Region flight inspection test without serious problems or major discrepancies.

The ILS was restored to operational commissioned status on June 9, 1974. All of the NAFEC-obtained data are available at NAFEC for review. No further testing is planned since it is in a commissioned status.

CONCLUSIONS

Based on our observations during the Upgrade work, it is concluded that:

1. A satisfactory and efficient way to implement the installation of an upgrade kit is by means of an installation contract employing knowledgeable and experienced personnel.
2. The implementation of the upgrade kit as furnished and installed is considered an acceptable technique for upgrading an existing GRN 27 (V) type Category II ILS to Category III.
3. The upgraded glideslope monitor logic differs from the MARK III ILS glideslope monitor logic but is not expected to have a relatively appreciable adverse effect on the system operational availability.
4. A minimum of one week of trouble-free operation after completion of flight checks would be desirable to demonstrate the acceptability of an installation.
5. The Installation Handbook, as furnished with the upgrade kit and corrected, provides adequate installation instructions and is satisfactory.


C. A. COMMANDER