Range Commanders Council

ELECTRONIC TRAJECTORY MEASUREMENTS GROUP

TECHNICAL REPORT

LOW-ALTITUDE TRACKING DEVELOPMENT PLAN

JUNE 1976

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LOW-ALTITUDE TRACKING DEVELOPMENT PLAN

Prepared by

Electronic Trajectory Measurements Group
Range Commanders Council

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INTRODUCTION

This report contains the Low-Altitude Tracking Development Plan prepared by the Low-Altitude Tracking Committee of the Electronic Trajectory Measurements Group (ETMG) of the Range Commanders Council (RCC). The development plan is the end product of RCC Task ET-6 (refer to Appendix A for details) which directed that the ETMG provide the impetus needed for an interrange development effort to be supervised and performed by one agency to meet the needs of all ranges requiring a low-altitude tracking capability.

Since the Naval Research Laboratory (NRL) has for several years pioneered in the development of system techniques for use in low-altitude tracking and because the committee identified the need for additional studies and recommendations, NRL was suggested as the lead agency. Other ranges and agencies have also provided support when necessary.

The committee has included in the report a Specification for Dual-Band Instrumentation Radar based on the use of surplus Nike-Hercules components (most notably the pedestals). In addition, the plan contains a list of prioritized electives necessary in various combinations to meet the individual requirements of each range.

This report is the result of a coordinated effort geared to assure that the plan: 1) fulfills the needs of most ranges (refer to Appendix B for the list of range activity requirements and to Appendix C for correspondence received from the various facilities polled) and 2) insures that duplication of effort will not occur. Further inquiries may be forwarded to Mr. Dean Howard, Chairman, Low-Altitude Tracking Committee of the Electronics Trajectory Measurements Group, Code 5333, Naval Research Laboratory, Washington, DC 20375.

CHAPTER 1

LOW-ALTITUDE TRACKING DEVELOPMENT PLAN

1 SUMMARY OF RECOMMENDATIONS

1.1 SCOPE

Most ranges have common urgent requirements for precision low-altitude tracking and precision tracking in an Electronic Counter Measures (ECM) environment. Based on a recently concluded assessment conducted by the Low-Altitude Tracking Committee of the ETMG of the various technologies for precision target location, a precision tracking radar in the 35 GHz atmospheric window frequency region was selected as the most cost effective approach to meeting requirements. In addition, the radars will utilize surplus precision Nike-Hercules pedestals, eliminating a major cost item. General specifications of the proposed tracking system are included in this plan.

1.1.2 The desired system for low-altitude target tracking includes a basic 35 GHz precision monopulse tracking radar combined with a 9 GHz monopulse tracking radar as a dual-band system and a set of electives which can match the system to each range. The basic 35 GHz radar is within the state-of-the-art for production for operational use. However, several of the necessary electives for most effective range utilization require further research and development (R&D).

1.1.3 It is recommended that a prototype dual-band (9 and 35 GHz) precision monopulse tracking radar be procured from each of two competing contractors based upon solicited proposals reviewed for adequacy by representatives of the ETMG. These systems would be used in a competitive, side-by-side evaluation to demonstrate the capabilities which are appropriate to the various range applications. This would establish the basis for selection of a contractor as well as assessment of the performance capability of the dual-band trackers under operational conditions. The contractor must establish the adaptability of their approach to the electives described herein. The basic 35 GHz tracker is significantly limited, in part, by an acquisition problem due to its narrow beamwidth. The dual-band monopulse system will provide for acquisition and long-range tracking and is necessary to provide the full capability required by the ranges. The dual-band tracker can be designed to accommodate other priority electives.

1.1.4 It is further recommended that parallel research and development be funded to develop the necessary priority electives to enhance the system's precision and increase its ability to operate independently as a field transportable radar.

1.1.5 The estimated total cost of the two tracking radars is $2.5M. The cost for development of the necessary electives is approximately $500K. It is estimated that the most cost effective combination of basic radar and electives will have a production cost between $600K and $800K.

1.1.6 The low cost of this versatile high-precision tracker is based on utilization of surplus Nike-Hercules precision tracking pedestals. It is recommended that the procurement be initiated this fiscal year and that the priority R&D items be supported in parallel.

1.2 DEVELOPMENT PLAN DETAILS

1.2.1 Introduction. The 35 GHz frequency region was selected by the committee as the desired band for the low-altitude target tracking system. Although there is no single operating band that meets all requirements, the 35 GHz region provides an optimum. Other aids for acquisition and special low-altitude target problems are recommended as available options. These include both optical and microwave devices.

1.2.2 A simple 35 GHz tracking system has been operated, demonstrating the feasibility of building a tracking radar from state-of-the-art components. However, an optimum system which will meet essentially all requirements is dependent upon a modicum of additional development. The development plan, in general, is to specify a dual-band precision monopulse tracking radar that is within the state-of-the-art with features that are essentially common to all ranges with low-altitude target tracking requirements.

1.2.3 The next step is to complete development of the priority electives that can be added to the basic radar to tailor the system to the specific requirements of each range. Several of the desired electives such as circular polarization, 35 GHz-band beacons, and short-pulse operation are not state-of-the-art and require further development. The development plan includes funding for the development of priority electives which require R&D.

1.3 BACKGROUND

The choice of 35 GHz was dictated in part by the requirements of an electromagnetic environment and the need to provide high-precision tracking of low-altitude targets. Atmospheric attenuation must be minimized to obtain the desired range on small cross-section skin-tracked targets. The atmospheric attenuation at frequencies above 18 GHz reaches the lowest value at about 35 GHz. Rain is a major source of clutter and attenuation at 35 GHz. Also, initial experiments indicate that skin tracking is enhanced by large target cross-sections at 35 GHz.

1.3.1 Components in the millimeter-wave region are most readily available in the 35 GHz region. A reliable off-the-shelf coaxial magnetron, VA-319 (was SFD-301), can provide reliable 135 kW peak power. Adequately narrow beamwidth for low-altitude tracking can be provided at 35 GHz with a reasonable-size antenna.

1.4 GENERAL SPECIFICATIONS

The specifications originally proposed were expanded and revised by the Low-Altitude Tracking Committee of the ETMG to clarify some areas and to cover a dual-band tracking radar that is within the state-of-the-art and will meet most of the range requirements. The specifications will also include goals which can be met in the near future with system electives to increase capability.

1.4.1 The resulting system will be a dual-band tracking radar restricted to an essentially state-of-the-art technology. In addition to the basic radar, there will be electives to allow the ranges to tailor the system to meet their own requirements. At present, some of the electives require additional development. Therefore, the development plan includes recommended R&D to meet the desired dual-band tracker capabilities. A Moving Target Indicator (MTI) specification does not appear to be feasible because there are blind speeds about every 8 knots for a 1000 Pulse Repetition Frequency (PRF) and there is heavy clutter between the blind speeds. The narrow beam will provide considerable clutter rejection. High-range resolution is recommended for any necessary additional clutter rejection.

1.4.2 Predictive tracking is required by most ranges. This is necessary to: 1) improve precision, 2) provide effective operation on tasks such as bomb scoring (particularly where the radar must rapidly acquire and track a second target), and 3) to avoid the possibility of loss of target (less lag is tolerable for the narrow beam than for conventional beamwidths).

1.5 ELECTIVES

The following is a list of electives necessary in various combinations to meet the requirements of each range. Some are listed as high-priority electives which greatly affect the full capability desired of the radar, but, in some cases require additional R&D.

1.5.1 Circular polarization dual-band operation. Circular polarization is required by several ranges, particularly for beacon operation to avoid cross polarization. Feasibility has not been demonstrated, but techniques are available which imply feasibility. The NRL antenna, using a linearly-polarized dichroic subreflector, will allow minimum effort modification for future circular polarization once the desired circularly polarized dichroic subreflector is developed.

1.5.2 35 GHz beacon. The beacon is essentially within the state-of-the-art with the exception of the transmitter. However, desired power of the order of 10 watts peak is expected to be accomplished with a minimum of effort. This development should include conventional and coded beacons. A separate beacon specification should be prepared.

1.5.3 Low-noise receiver. This area will require some study for determining the best approach. Because of the typically short range operation at 35 GHz and the minimal improvement offered by available low-noise RF amplifiers, it is presently a lower priority elective.

1.5.4 Automatic Frequency Control (AFC). Because of the low percentage bandwidth, small local oscillator (LO) drift is a problem and AFC is necessary. An AFC package is being obtained by NRL (funded by Naval Air Systems Command) for evaluation in the NRL 35 GHz tracker.

1.5.5 High average power short-pulse. Because of MTI problems at 35 GHz, short-pulse operation is desirable for clutter rejection. Pulse compression is necessary to maintain average power for the desired operating range. It is recommended that high power Traveling Wave Tube (TWT) development for 35 GHz be pursued to provide a pulse compression ratio of 40:1 for a typical 4-microsecond transmit pulse to 0.1-microsecond receive video. By scaling available TWT designs, average power performance could be increased in the order of 3 to 6 dB, while performing effective clutter rejection with short-pulse reception. The Nike-Hercules tuned slip rings would be adequate to handle this bandwidth.

1.5.6 Conversion to higher band. The presently specified dual-band system is expected to operate at a frequency clear of ECM sources (35 GHz), there are both radar and ECM developments expected in this region. A requirement for an elective conversion to the 70 GHz or 94 GHz regions is expected in the future. Although new hardware at these bands is costly, the conversion process should be straightforward.

1.6 OTHER HIGH-PRIORITY ELECTIVES (NOT REQUIRING R&D)

1.6.1 Optical acquisition and tracking aids. Relatively low-cost TV trackers or other optical aids are required by most ranges.

1.6.2 Predictive tracking. Predictive tracking with angular rates up to 60^{o} per second is required by most ranges.

1.6.3 Continuous level calibration monitoring. A precision level meter, such as the tiltmeter by Rockwell International Autonetics Division, greatly enhances calibration capability at low cost.

1.6.4 Power programmer. Power programming is generally required for close range targets.

1.6.5 Star calibration. Rapid high order calibration is required by some ranges. Star calibration provides a proven approach. This may be combined with predictive tracking as in the "on-axis" technique.

1.6.6 Improved pedestal elevation. Several applications of the dual-band radar require that the radar depress to at least -12° in elevation.

1.7 OTHER ELECTIVES DESIRED.

1.7.1 Remote control operation. Some ranges will require the capability to operate the radar from a remote location.

1.7.2 Fast recovery receiver for reducing minimum range

1.7.3 Short-pulse operation for clutter rejection (R&D required). The Naval Weapons Center (NWC), China Lake, has demonstrated feasibility for short pulsing magnetrons. This technique could be applied to the 35 GHz tracker to reduce clutter at the cost of reduced average power.

1.7.4 High-power high-range resolution monopulse (R&D required). High-power very short-pulse operation (3 nanoseconds) is desired for tasks such as bomb scoring. The very high-range resolution would allow aspect determination of non-cooperative targets and rapid resolution of a bomb released from an aircraft. This would be an extension of item 1.5.5 above to a wider bandwidth.

1.8 ADDITIONAL STUDY REQUIRED.

1.8.1 35 GHz receiver in ECM environment. It is recommended that relatively simple tests be performed with a 35 GHz superheterodyne receiver at a location where ECM resources are available.

1.8.2 Further low-altitude target experiments. The initial NRL experiments have been performed over the Chesapeake Bay with a radar height of 100 feet. For more typical radar heights of 10 to 20 feet, the multipath error could be significant at the extreme conditions; however, clutter for a level surface will be over the horizon.

CHAPTER 2

SPECIFICATION FOR DUAL-BAND INSTRUMENTATION RADAR

2 GENERAL

This chapter contains the specifications for a precision instrumentation radar based on the use of surplus Nike-Hercules components (particularly the pedestals), dual-frequency operation (nominal 9 and 35 GHz), and computer performance of many radar functions. The radar is expected to provide precision tracking capabilities equivalent to best present state-of-the-art as well as hitherto unavailable capability for low-angle tracking and for operation in the current ECM environment.

2.1 FUTURE EXPANSION

In order to minimize software and some hardware costs, the present specifications do not include operation on programming for the ultra-precision system known as "on-axis." It is expected that at least some future systems will utilize this mode of operation and radar and software design should not preclude or impede the eventual inclusion of this modification. The possibility of optical tracking (laser or TV) being added to the system should also be considered.

2.2 PERFORMANCE REQUIREMENTS

Specifications are exclusive of atmospheric and multipath effects, propagation errors, and target-generated errors, except where otherwise indicated. In all cases "tracking" shall mean centroid tracking.

2.2.1 TARGETS

Skin targets, unless otherwise specified, will have an effective cross section at the operating frequencies of 1 m^2.

2.2.1.1 Skin target tracking. The radar must track the target specified in paragraph 2.1 above continuously and unambiguously, with a minimum signal-to-noise ratio of 12 dB, at either frequency (9 or 35 GHz), from 366 m (400 yards) to 93 Km (102 K yards) slant range. Tracking shall be continuous when a change between the two frequencies is made on any or all tracking coordinates. The standard deviation (1 sigma) of the random error shall not exceed 0.1 mil in angle and 2m (2.2 yards) in range. The radar must have the same tracking performance out to 468 Km (512 K yards) with a target having an effective cross section at the operating frequencies of 625 m^2.

2.2.2 BEACONS

Beacons will be similar to those specified in RCC Document 115-69, "C-Band Transponder Standard," as revised, but will operate at frequencies displaced not less than 75 MHz from the transmitting frequencies of this radar.

2.2.2.1 Beacon tracking. The radar must track the beacons specified in paragraph 2.2.2 above continuously and unambiguously, with a minimum signal-to-noise ratio of 12 dB at either frequency (9 or 35 GHz), from 366 m (400 yards) to 468 Km (512 K yards) slant range. The standard deviation (1 sigma) of the random error shall not exceed 0.1 mil in angle and 2 m (2.2 yards) in range. Provided that the target can be tracked in the alternate modes, the operator shall be able to switch beacon frequency band, switch to skin tracking in any of the tracking coordinates at either of the radar frequencies, or switch from skin to beacon tracking in either of the frequency bands in any of the tracking coordinates without breaking track.

2.3 EQUIPMENT REQUIREMENTS

2.3.1 Transmitter

2.3.1.1 Frequency. The system shall contain two transmitters, one operating in the 8.5 to 9.6 GHz region, the other operating in the 34.5 to 35.5 GHz region. The 8.5 to 9.6 GHz transmitter will be tunable to any frequency in its operating range after installation of the transmitting tube in the system; the 34.5 to 35.5 GHz will be operated at a fixed frequency in its band of operation.

2.3.1.2 Power output. The 9 GHz transmitter shall furnish a peak power of at least 250 kW at the output flange of the transmitting tube under normal operating conditions. The K-band tube shall furnish a peak power of at least 135 kW and an average power of 50 W at the output flange of the transmitting tube under normal operating conditions.

2.3.1.3 Pulse width. Both transmitters shall furnish pulses of 0.25 microsecond duration.

2.3.1.4 Pulse jitter. Jitter of either transmitted pulse, measured with respect to the transmit trigger pulse, shall not be greater than 0.01 microsecond. Relative jitter between transmitters shall be held to a minimum and, where necessary, resultant range error will be corrected through the servo loop controls or data handling circuits.

2.3.1.5 Pulse Repetition Frequencies (PRF). The system shall be operated at PRFs from 320 to 1600, with provision for operator selection or external synchronization. Internally selected PRFs shall in all cases be multiples of 160. Externally provided PRFs may be at any frequency within the range.

2.3.1.6 Joint transmitter operation. Both 9 and 35 GHz transmitters shall operate simultaneously. A mode of operation shall also be available in which no 9 GHz power is radiated.

2.3.2 RECEIVER

2.3.2.1 Noise figure. The system noise figure of the receiver shall be no greater than 7 dB in the 9 GHz band and no greater than 10 dB in the 35 GHz band. Provision shall be made for automatic measurement of noise figure in both bands.

2.3.2.2 Bandwidth. Bandwidths for the 60 MHz IF channels shall be 6 MHz for both 9 and 35 GHz bands.

2.3.2.3. Tuning. The 9 GHz receiver shall be independently tunable from 8.5 to 9.6 GHz. The 35 GHz receiver shall be independently tunable from 34.5 to 35.5 GHz. A control shall be provided for manual tuning by the operator of both local oscillators over their respective ranges. A console control shall be provided for selection of Manual Frequency Control (MFC) or Automatic Frequency Control (AFC) for each of the receiver local oscillators.

2.3.2.4 Pull-In. Local oscillator sweep and AFC sweep and pull-in range shall be at least ±60 MHz about the center frequencies for both frequency bands and both beacon frequency bands.

2.3.2.5 Combined operation. The operator shall be able to select operation at either frequency or either of the beacon frequencies in any of the tracking coordinates (see also paragraph 2.2.2.1).

2.3.2.6 Tracking operation. Tracking shall be by means of a 3-channel monopulse.

2.3.2.7 Gain control. Both receivers shall be equipped with Automatic Gain Control (AGC) and Manual Gain Control (MGC). The minimum range for both AGC and MGC shall be at least 60dB. Instantaneous dynamic range while on AGC shall be at least 70 dB. Either AGC or MGC modes shall be separately selectable for each frequency band at the operator's console.

2.3.3 ANTENNA

The antenna shall be a parabolic dish capable of three-channel monopulse output operation at both antenna frequencies. Unless otherwise specified the word "antenna" as used herein shall include dish, feed assemblies and waveguide runs to the rear of the dish. The design shall be such as to allow the antenna to be produced at a reduced cost for single-band operation.

2.3.3.1 Frequency. The antenna shall be capable of operating over the full frequency range specified for the transmitters specified in subparagraph 2.3.1.1 above.

2.3.3.2 Power levels. The antenna shall be capable of operating over the frequency ranges included in subparagraph 2.3.1.1 at power levels of 250 kW peak and 100 W average for the 9 GHz band and 135 kW peak and 60 W average for the 35 GHz band.

2.3.3.3 Gain. The antenna shall provide at least 42 dB gain at the main lobe for the 9 GHz band and at least 52 dB gain at the main lobe for the 35 GHz band. With respect to the peak of the same frequency main lobe, the maximum level of any sidelobe shall be at least 20 dB down.

2.3.3.4 Monopulse null depth. The error pattern null depth shall be at least 35 dB down from the peak of the same frequency reference pattern.

2.3.3.5 Polarization. The antenna shall provide linear polarization at both frequencies. The polarization at 9 GHz shall be vertical and that at 35 GHz shall be horizontal. The antenna should be designed for future modification, with minimum effort, to provide circular polarization at both bands.

2.3.4 ANTENNA PEDESTAL AND ANGLE SERVOS

The system shall use a surplus Nike-Hercules pedestal.

2.3.4.1 Tracking and slewing rates. The antenna shall provide smooth tracking at the following minimum rates:

a. Track - 700 mils/sec.

b. Acceleration - 500 mils/sec^2.

c. Slew - 500 mils/sec.

2.3.4.2 Bandwidths. The closed loop servo bandwidths shall be variable from not more than 0.5 Hz to at least 3.0 Hz. Servo loops shall be closed through the computer. Control of the bandwidth may be either manual or automatic, the option to be selected by the operator. Where manual bandwidth is selected, control shall be from the operator's console (see subparagraph 2.3.4.6, below, also).

2.3.4.3 Rotation. The antenna shall be capable of unlimited rotation in the azimuth plane and shall rotate from -5 to +88 degrees in the elevation plane while tracking. The antenna shall rotate from -5 to +185 degrees in elevation under manual control during calibration procedures, and for any additional purposes other than tracking, coasting, or designation modes of operation.

2.3.4.4 Leveling and boresighting. Provision shall be made for using a Rockwell Tiltmeter or equivalent with digital readout to the computer for level calibration. Real-time correction of data for amplitude and phase of mislevel is desired. Provision shall be made for mounting a TV camera and either a 40-inch zoom lens, an 80-inch fixed lens, or a 120-inch fixed lens on the antenna mount, together with appropriate equipment for adjusting the alignment of the optical axis relative to the RF axis. Mount should be of such design as to permit user choice from among the three lenses.

2.3.4.5 Encoders. Absolute encoders shall be mounted to provide 18-bit precision, or better, data from both azimuth and elevation axes. These encoders shall be mounted and driven in such a fashion as to preserve the 18-bit precision. All interface packages attached to the encoders shall not degrade the 18-bit precision.

2.3.4.6 Pedestal servo loops. Both angle servo loops shall be Type II servos closed through the computer. They shall also possess the capability of operating as aided Type II loops (see subparagraph 2.3.4.2 also).

2.3.5 RANGE TRACKING SYSTEM

2.3.5.1 General. The range tracking system shall be all electronic and closed through the computer. Dual ranging channels for skin or beacon shall be provided for each frequency, selectable at the console or under computer control. Tracking shall be centroid tracking in all cases.

2.3.5.2 Tracking range. Refer to subparagraphs 2.2.1.1 and 2.2.2.1. above.

2.3.5.3 Beacon compensation. The operator shall be able to compensate for beacon delay from zero to 1464 m (1600 yards in 2 m increments).

2.3.5.4 Tracking rates. The range tracking system shall be capable of tracking smoothly and unambiguously a target with radial velocity of 183 Km/sec (200 K yards/second) minimum and radial acceleration of 1.8 Km/sec^2 (2 K yards/second^2) minimum. The maximum range slew rate shall be at least 183 Km/sec (200 K yards/second).

2.3.5.5 Tracking precision. The range tracking system shall provide data of 20-bit precision. Mechanical or electrical attachments or interfaces to the range tracking system shall not degrade the 20-bit precision of the system.

2.3.6 TRACKING SERVO LOOP

2.3.6.1 Type. The range tracking servo loop is to be a Type II loop closed through the computer and capable of operating as an aided Type II loop.

2.3.6.2 Bandwidth. The tracking servo loop is to be at least 10 Hz with three narrower bandwidths selectable by the operator or by the computer program.

2.3.6.3 Range reference. The timing oscillator on which range measurements are based shall have an inaccuracy no greater than one part in 10^8 over a 24-hour period.

2.3.6.4 Errors. Tracking errors shall not be affected by amplitude of the return, except when the amplitude reaches a Signal-to-Noise (S/N) level of 12 dB or lower.

2.3.7 DATA OUTPUT

2.3.7.1 Data content. Data output shall consist of a data word of a precision up to 0.23 m (0.25 yard) in range and .024 mil in both azimuth and elevation and a system status word giving time references and the operational state of the radar.

2.3.7.2 Data rate. Rate of output of both data and status words shall be from not less than 10/second to at least 100/second. Rates of data and status word output will be independently selected and/or synchronized by the user.

2.3.7.3 Compatibility. Data output shall be transistor-transistor-logic (TTL) compatible.

2.3.7.4 Form. Data output shall be digital in form and a choice of either serial or parallel output shall be available at shift rates of up to at least 100K.

2.3.8 DISPLAYS AND CONTROLS

The displays and controls specified below are intended to be a minimum. It is required that all display and controls be provided that are needed for operation of the system.

2.3.8.1 Indicators

2.3.8.1.1 Television display. A TV monitor shall be provided to display the picture visible through the TV camera specified in subparagraph 2.3.3.4 above. This camera shall also display a suitable electronically projected reticle for judging location of targets with respect to boresight and to permit visual estimates of angular error. Day-to-day boresight shift on the TV camera and lens shall be minimal and the maximum shift of the electronic reticle with respect to the boresight shall be held to less than 5 arc seconds. A portion of the TV display shall be used to display azimuth, elevation, range, 9 and 35 GHz AGC voltage in graphic form (not alphanumeric). This display shall be located centrally to the operator's panel and below some nominal operator eye-level.

2.3.8.1.2 Range display. A display shall be provided showing two parts of range acquisition (A-scope) displays, one pair for each of the operating frequencies. The upper display of each pair shall show either the full radar range appropriate to the PRF, with the range gate shown as a notch, or a 50 K yard section of the acquisition range centered on the range gate, with the range gate shown as a notch, at the option of the operator. The lower trace of each pair will show a 1 to 4 Km segment of the acquisition range, centered on the range gate, with the range gate shown as a notch, and the length of the display controllable by the operator. The return from targets at a height proportional to the amplitude of the target return will be shown on all four traces where a target is present, within the range covered by the trace, and of sufficient amplitude.

2.3.8.1.3 System parameter display. A display shall be provided which shows, under computer control, at least the following parameters in alphanumeric form:

a. Radar mode.

b. Track parameters (R, Az, El) and frequency and skin/beacon choice for each parameter.

c. Track rates (R, Az, El).

d. Gain control settings and Automatic/Manual choice.

e. LO frequency.

f. Acquisition scan.

g. Data recording on/off.

h. Time of day in hours, minutes, seconds.

i. Servo bandwidth and auto/manual choice.

2.3.8.1.4 Transmitter monitors. Meters shall be provided on the operator's console to display magnetron current, high voltage and power supply currents, as appropriate.

2.3.8.1.5 Magnetron life monitors. A running time meter shall be provided for each of the magnetrons to measure hours of operation of the magnetron. These meters shall be located near or on the respective transmitters.

2.3.8.1.6 Crystal current monitor. A meter showing crystal current in each of the mixers used shall be provided adjacent to the mixer locations. A single meter with a switch selection for crystal monitoring may be used.

2.3.8.2 Controls

2.3.8.2.1 General. The control furnished shall provide the operator with two types of feedback:

a. Distinctiveness: control shape, texture, or embossing shall be of such a nature as to allow the operator to distinguish among important controls by touch; 9 and 35 GHz band controls for the same function shall be especially distinguishable.

b. Operation: controls shall furnish both tactile and visual feedback when operated or engaged. (As an example, a button changing range tracking from 9 to 35 GHz band should both click and show back-lighting when activated and the back light on the alternate button should go out at the same time).

2.3.8.2.2 Mode selection. The following list of pushbutton switches shall be provided (at a minimum) to allow operator mode selection:

a. Start. This switch will initialize the computer, load the operating program, turn on appropriate power supplies and prepare the radar to operate. In general, it should be possible to use this mode only at the beginning of system use.

b. Standby. This switch will bring the radar to a nonradiating condition with filament supplies and other appropriate supplies activated and some computer-supervised voltage checks run. The antenna shall be held in place by mechanical brakes while in this mode.

c. On. This control should bring the radar to a standard radiating mode.

d. Calibrate. This will initiate a set of computer-supervised calibration procedures, which may also involve the operator.

e. Radar operating matrix. This will be a cluster of controls allowing the operator to choose for each axis (R, Az, and El) among the following set of operating conditions: frequency, beacon, manual, coast, autotrack, acquire, and aided.

f. Designate. This will position the radar to look at either preset or externally provided designation coordinates.

2.3.8.2.3 Manual coordinate controls. Controls shall be provided for manual positioning of the radar line-of-sight in azimuth and elevation and for manual positioning of the range gate. Controls presently furnished as part of the Nike-Hercules system may be used, or some other form of position/rate handwheels located on the operator's console may be substituted.

2.3.8.2.4 System control. Additional controls shall be provided to permit system operation and adjustment as specified.

2.3.9 COMPUTER AND SOFTWARE

2.3.9.1 General. Initial radar design will be done in such a manner as to minimize system lifetime software costs. Computer capability of the system will be sufficient to allow eventual full "on-axis" type operation of the system, including the calibration. Computer functions will include, at a minimum, data handling and processing, system control, system calibration, display control and processing, AGC and AFC, error detection and correction, loop operation and filtering, as well as intersystem communication and designation functions. Star calibration, predictive tracking, and "on-axis" type operation may be added in later modes.

2.3.9.2 Software

2.3.9.2.1 Language. Software shall be constructed, to the maximum extent possible, in a "higher" level language (e.g., FORTRAN, PL/1, ALGOL...).

2.3.9.2.2 Design methods. Software shall be designed by the "top-down" method, with frequent progress reviews.

2.3.9.2.3 Modularity. Software shall be fully modular to the lowest level possible.

2.3.9.2.4 Flexibility. Software design, implementation, and documentation shall facilitate the process of engineering changes made at a later date by the operating ranges.

2.4 PHYSICAL REQUIREMENTS

2.4.1 Configuration. The radar system shall be contained in a single shelter. Power sources, antenna, and antenna-mounted equipment need not be contained in this shelter.

2.4.2 Mobility. All equipment, including shelter, shall be configured to maintain the mobility and transportability of the original Nike-Hercules system, including mobility over the normal road network.

2.4.3 Power. Power shall be provided sufficient to run the radar system and its auxiliaries as well as heating and air conditioning.

2.4.4 Set Up. The radar shall be capable of operation at the specified performance levels within a time of four hours maximum after delivery at a prepared site.

2.5 ENVIRONMENTAL CONDITIONS

2.5.1 Operation. The system shall be capable of continuous, undegraded performances (not including propagation effects) under the following conditions:

a. Wind. Degraded performance to at least 55 knots, undegraded performance to at least 40 knots.

b. Rain. 12 cm/hr (5 in/hr) in 25 knot winds.

c. External air temperature. 49°C to -23° C (+120° F to 10°F.)

d. Altitude. 3 Km (10 K ft) to 150 M (500 ft).

e. External humidity. 100 percent.

2.5.2 Survivability. The system shall be capable of withstanding the following conditions, in a nonoperating mode, for extended periods:

a. Wind. Up to at least 100 knots; antenna shall have the capability of driving to stow in winds of at least 75 knots.

b. External air temperature. 68° C to -55° C (155° F to 50° F).

c. Snow load. 244 kg/m^2 (50 lb/ft^2).

d. Icing. 5 cm (2 inches).

e. Precipitation. 13 cm/hr (5 in/hr).

f. External humidity. 100 percent.

g. Altitude. 15 Km (40 Kft) to 150 m (500 ft.)

2.5.3 Shock and vibration. The equipment shall be capable of withstanding an average maximum shock of 10 g's and average vibration of 3 g's up to 200 Hz during shipment or when transported in its mobile configuration.

APPENDIX A

ASSIGNED TASK

ASSIGNED TASK
ELECTRONIC TRAJECTORY MEASUREMENTS GROUP

TITLE OF TASK:

Low Altitude Tracking Development Plan

SCOPE AND OBJECTIVES OF THE TASK:

A detailed plan will be prepared for the development of a low altitude tracking system to be performed or supervised by one agency and to meet the needs of all ranges requiring a low altitude tracking capability.

END PRODUCT UTILITY:

The plan will attempt to provide the direction needed for inter-range development effort, with the development schedules, development costs and cost savings as a result of joint efforts.

APPROACH:

The ETMG will form an Ad Hoc Committee of representatives of the concerned ranges. The committee will study/investigate the following areas:

a. Requirements: Detailed requirements will be determined from each range concerned. These can be expected to cover a large variety of requirements. The initial investigation indicates that a large portion of these requirements could be satisfied if the following basic specifications can be met:

(1) Altitude 60 meters and above.

(2) Range up to 32 kilometers for required accuracies and degraded position data beyond 32 kilometers.

(3) Range accuracy: 1-2 meters.

(4) Angle accuracy: 0.1 miliradian.

(5) Frequency must be capable of operation in an Electromagnetic Warfare (EMW) jamming environment, preferably above 18 GHz.

(6) Velocity - Target velocities will be from near zero to several thousand feet per second.

(7) Transportability. The system should be capable of being moved from one prepared site location to another prepared site location within a few hours plus transit time.

(8) Alignment and calibration procedures must be simplified wherever possible and be computer controlled to assure accuracy of data and to reduce set up, pre and post mission calibration and wherever possible real time data corrections.

(9) Acquisition and tracking aids must be provided to assure proper target identification and to aid tracking angular accuracies whenever possible. These would consist of electro-optical devices to be used whenever weather conditions will permit.

(10) MTI. MTI signal processing will be required in order to track low altitude targets in a high clutter background.

b. Commonalty of system requirements: Initial investigations indicate that there are many common low altitude tracking requirements among the ranges, however, it must be recognized that there are some range requirements which will be difficult or impossible to fulfill with one common system.

c. Development of system parameters: Studies will be made of radar, optics, DME, TOA and other types of systems to determine system parameters. Initial indications are that systems which will require an airborne platform should not be considered because of (1) lack of aircraft, (2) high cost of operation and (3) poorer reliability of airborne platform/instrumentation systems. From the range requirements listed above, it is believed that a system employing some combination of radar, optics and lasers will probably meet these common range requirements.

d. Development agency selection: For several years the Naval Research Laboratory has led in the development of system techniques for use in low altitude tracking. Additional studies and investigations will be required. It is recommended that NRL be the lead agency with other ranges/agencies supporting as necessary. For instance, a comparison of amplitude versus phase monopulse techniques should be made. This could be done at a range that has these two types of systems in close proximity.

e. Development Plan: Current indications are that 18 - 24 months will be required to implement a development effort with FY 76 being the earliest that funds could be requested for system development. The current uncertainty in inflation makes cost estimation risky at best but systems probably will cost between $2 and $5 million.

f. Submission of plan for approval: The plan should be ready for submission to the Executive Committee by January 1975.

TASK ASSIGNMENTS:

A five-man task committee will review existing data and reports in order to establish an operating baseline. After review of the existing data, plans will be prepared for a development plan for any additional studies required, for the development of new techniques, for the further testing of any current techniques which show promise as a result of minor changes. The development plan will be a coordinated effort to assure that (l) the plan will fulfill the needs for most of the ranges and (2) that duplication of efforts will not occur.

Estimated manhours required for the task effort are:

Effort by task committee	1200 hours
Assistance, review and comment by other RCC groups	500 hours
Typing and clerical	300 hours
TOTAL	2000 hours

OTHER RESOURCES:

Estimated funds for task committee meetings - $1000

MILESTONES:

a.	Complete review of available data	April 1975
b.	Preparation of development plan	September 1975
c.	ETMG formal review	October 1975
d.	Submittal of revised development plan to RCC	January 1976

PARTICIPANTS:

NRL	Chairman
NWC	Member
TFWC	Member
WSMR	Member
ADTC	Member

COORDINATION WITH OTHER GROUPS:

To be coordinated with OSG

COMPLETION DATE:

January 1976

APPENDIX B

NIKE SYSTEM REQUIREMENTS

APPENDIX B

NIKE SYSTEM REQUIREMENTS
(November 1974)

ACTIVITY	BAND UNKNOWN	BAND X	BAND KA
DUGWAY PROVING GROUNDS	4		
FAA, MLS PROGRAM OFFICE		3	1
BARKSDALE AIR FORCE BASE, SAC	3		
NASA, WALLOPS FLIGHT CENTER		2	1
PATRICK AIR FORCE BASE, AFETR	2		
PATRICK AIR FORCE BASE	3		
PACIFIC MISSILE RANGE			2
WHITE SANDS MISSILE RANGE			1
NELLIS AIR FORCE BASE		2	2
ABERDEEN PROVING GROUNDS			5
FMSAEG	10		
EGLIN AIR FORCE BASE		1	2
NAVAL AIR TEST CENTER		2	1
SANDIA LABORATORIES		1	1
NAVAL WEAPONS CENTER			
TOTALS	22	15	18
GRAND TOTAL	55 PEDESTALS		

APPENDIX C

NIKE-HERCULES RADAR CONVERSION PROGRAM

NAVAL TORPEDO STATION
KEYPORT, WASHINGTON 98345

7034:RAM:sb
10331

AIRMAIL

18 January 1975

From: Commanding Officer, NAVTORPSTA Keyport, WA
To: Commander (Code 3721)
Naval Weapons Center
China Lake, CA 93555

Subj: Nike-Hercules Radar Conversion Program

Ref: (a) NWC ltr 3721/SF:bf, serial 7021 of 12 Dec 1974

1. Reference (a) requested support for a radar users committee to review requirements and provide background information for the Ka Band conversion of surplus Nike-Hercules radars.

2. NAVTORPSTA has no immediate requirement for a radar of this type. We, however, may have identifiable requirements by FY 1978 and therefore support the request to the Army to hold twenty of these radars in anticipation of future needs. Please keep this Command informed of progress by the users committee so our requirements may be input as they become known.

R. L. Marimon

R. L. MARIMON
By direction

28 January 1975

Nike-Hercules Radar Conversion Program

Commander, Naval Weapons Center
ATTN: Mr. S. G. Fields, Code 3721
China Lake, CA 93555

1. References:

a. COMNAVWPNCEN letter, Ser 7021, 12 December 1974.

b. CORG message 150006Z NOV 74 (NOTAL).

2. The Tactical Fighter Weapons Center (TFWC) has been an active participant in the studies and evaluation of a program to convert Nike-Hercules target track radars into digital instrumentation radars. The potential capability of these systems to provide precise low-altitude tracking at reasonable cost by utilizing surplus Nike-Hercules precision tracking pedestals is obvious. Accordingly, the TFWC fully supports efforts of the radar users committee in finalizing specifications for the Ka band (35 GHz) radars.

3. The TFWC has an immediate need for two directed track instrumentation radar systems utilizing the Nike-Hercules pedestals and operating at both 9 GHz and 35 GHz. Future TFWC range planning indicates later procurement of another two such systems will be required. These four radars will be used for precision real-time, single-station, low-altitude target position/velocity solutions, no-drop bomb scoring, and baseline range radar/TSPI calibration applications.

4. Reference b responded to inquiry by Chief of Staff, Air Force (CSAF/RDP) and Tactical Air Command (TAC/DRP) as to desirability of acquiring surplus Nike-Hercules radars by requesting that four sets be held for subsequent use at TFWC ranges. Therefore, the TFWC fully supports a NWC hold request to the U.S. Army for a total of 20 Nike-Hercules radar systems.

David A. Kautner B/G USAF

GORDON F. BLOOD, Maj Gen, USAF
Commander

Cy to: TAC/DR
TAC/DO
TAC/LGM

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

NATIONAL AVIATION FACILITIES
EXPERIMENTAL CENTER
ATLANTIC CITY, NEW JERSEY 08405

DATE:

IN REPLY REFER TO:

SUBJECT: Nike-Hercules Radar Conversion Program
3721/SF:bf - Serial 7021 - 12 Dec 1974

FROM: Chief, Communications and Guidance Division, ANA-300

TO: Department of the Navy
Naval Weapons Center
China Lake, California 93555
Attention: G. D. Hollar

The FAA's Range at NAFEC, Atlantic City, New Jersey has a definite need for an instrumentation radar system capable of accurately tracking test aircraft at low altitudes. Our "C" Band instrumentation radar is subject to multipath, when tracking at low elevation angles, causing noisy altitude and range data. By operating at a much higher frequency this multipath would be minimized; therefore, your proposed KaBand Nike-Hercules Conversion Program is of interest since most of our tracking is done from 0° to 5° elevation angles.

NAFEC has two Nike-Hercules systems stored at Letterkenny Arsenal for use as two "X" Band tracking systems. Our long range plan would also include a radar in the KaBand, so we would be willing to work with you in reviewing specifications for KaBand radars, even though we have not budgeted for such a procurement.

GEORGE P. BATES, JR.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE EASTERN TEST RANGE (AFSC)
PATRICK AIR FORCE BASE, FLORIDA 32925

9 JAN 1975

REPLY TO ATTN OF: ENLT(B. H. Lubar/494-7096)

SUBJECT: NIKE-HERCULES Radar Conversion Program

— 37 AD

10551

1095

TO: Department of the Navy
Naval Weapons Center
China Lake CA 93555

1. Reference NWC letter dated 12 December, same subject as above (copy attached).

2. In response to paragraph 2 of the reference letter we recommend the following consideration of how the Nike-Hercules systems can help solve some of the AFETR's urgent problems germaine to this subject and applications of appropriately modified Nike-Hercules systems including utilization of major components (such as the pedestals).

3. The major problem, whose solution can be facilitated by appropriate utilization of these systems, is the support of highly-dynamic and low-level missile launches. Specific AFETR programs of this type include SAM-D and SHORADS. Current fixed-site C-band AFETR radars are not appropriate to the initial lift-off metric requirements. A set of transportable, properly modified, Nike-Hercules systems would provide the higher frequency, higher PRF and direct line-of-sight coverage required.

4. The prime modification considered for this capability would involve incorporating powered-flight ON-AXIS into the Nike-Hercules radar systems, including appropriate boresight TV systems. In addition, IR or TV tracking would be a further modification to gain additional tracking capability under adverse RF conditions. At least one such modified system positioned in proximity to the launch site would provide the heretofore unavailable metric support from T-0 to T+30 seconds.

5. An additional utilization of the existing Nike-Hercules components involves incorporating the pedestals into mobile optical (ON-AXIS) tracking systems. Such systems could not only be positioned to provide optical (engineering sequential) support for the early launch stages of not only the high-dynamic missiles but also support conventional launches and sea-launches. In addition, such mobile optics can be used to co-reference and calibrate individual AFETR sensors into one primary reference system.

6. This Directorate has previously presented the above suggestions in consideration of specific AFETR requirements (such as SHORADS). The brief description presented above is in response to the reference letter; however considerably more detail is available, if required. For additional information, the EKL contact would be John M. Kennedy (305) 494-5034 or autovon 854-5034.

Paul M Feilner

Atch: NWC ltr

PAUL W. FEILNER, Colonel, USAF
Director of Range Engineering

DEPARTMENT OF THE ARMY Mr Milvay/sic/870-5279
HEADQUARTERS, U.S. ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MARYLAND 21005

AMSTE-RU

7 January 1975

SUBJECT: Nike-Hercules Radar Conversion Program

Commander
Naval Weapons Center
ATTN: Code 3721 (Mr. Fields)
China Lake, California 9355_.

1. Reference is made to Letter, Naval Weapons Center, 12 Dec 74, subject as above.

2. This command fully supports the proposal to form a committee of radar users to consider and recommend modification to, and uses of, surplus radars such as the Nike-Hercules. This effort should provide a cost-effective solution to a number of difficult test range tracking problems through multi-agency cooperation.

3. Requirements for additional instrumentation radars, which could be fulfilled by Nike-Hercules modifications, are expected in the next ten years. These radars will be required for expended mission requirements and as replacements for more complex and expensive radars at various locations. Although no definitive estimate of total requirements can be made at this time, present trends indicate a maximum requirement of approximately six systems during that period.

4. Although this is intended as a command-wide response to the basic letter, no details are included on specific testing problems which could be solved by Ka Band Nike-Hercules Based Radar Systems. Individual TECOM test agencies will be encouraged to submit examples of particularly urgent problems of this nature directly to NWC.

FOR THE COMMANDER:

JOHN D. PHELPS
Director
Instrumentation Directorate

CF:
Cdr, USAAPG, ATTN: STEAP-MT-G
Cdr, USAYPG, ATTN: STEYP-MDP
Cdr, USAJPG, ATTN: STEJP-TD-A
Cdr, USADPG, ATTN: STEDP-PC
Cdr, USAEPG, ATTN: STEEP-MT-F
Cdr, USAWSMR, ATTN: STEWS-ID-E

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS ARMAMENT DEVELOPMENT AND TEST CENTER (AFSC)
EGLIN AIR FORCE BASE, FLORIDA 32542

8 January 1975

REPLY TO
ATTN OF: TS

SUBJECT: Nike-Hercules Radar Conversion Program

TO: Commander
Naval Weapons Center
China Lake, CA 93555

1. The Armament Development and Test Center currently is responsible for the development and testing of nonnuclear munitions for the Air Force and for the testing of Electromagnetic Warfare equipment.

2. In order to support these two mission areas, tracking of airborne vehicles and tracking of various munitions are required over a wide range of altitudes. In both of these mission areas the capability for radar tracking at low elevation angles is less than required or desired. Low altitude tracking can be obtained using optical systems; however, this is more expensive and is limited by weather.

3. An electronic tracking system which will be able to extend low elevation tracking considerably below the two-degree elevation angle of current ADTC range instrumentation is required. The solving of this problem is currently being pursued through a task assigned by the RCC to the ETMG. The ETMG task committee is currently proposing development of dual band radar-to help solve some of the low altitude tracking problems. The radar would operate at the 9 GHz band for long range tracking from about 20 to beyond 100 NM and at about 35 GHz for short range tracking from near zero to about 20 NM. The 9 GHz band radar would also provide acquisition for the narrow beam width 35 GHz band radar. Both frequency band radars should be able to track in skin or beacon modes, and the 9 GHz band radar should also have a track-on-jam capability for operation in an ECM environment.

4. Both the RCA and Vitro-Zerox proposals appear to be solutions to low altitude tracking problems to tracking in an ECM environment.

5. We do not at this time have any funding programs for acquisition of additional radars for solving of the low altitude problem. We would expect to program for two low altitude tracking radars as part of a tri-service procurement when they become available.

6. We are currently supporting through the RCC - ETMG the low altitude tracking development task. As a result of this task we would also request that at least two Nike-Hercules pedestals be requested to be held for potential use in low altitude tracking radars for ADTC.

7. The two radar systems stated above, although required for general range tracking support are envisioned to be installed along the coast line of the Gulf of Mexico with primary emphasis on Electromagnetic Warfare test support. It is also envisioned that in later years probably two additional radar systems will be required for inland sites near existing munition test ranges. They would also be available for moving to other ranges or remote sites on an as required basis to support short term special test programs.

8. This Center is currently using 12 Nike-Ajax pedestals as slaveable antenna pedestals. These pedestals are used for the Ground Monitor Facility spectrum analysis system and for EMW signal source mounts. As these are old pedestals, it is highly desirable to replace them with Nike-Hercules pedestals to reduce maintenance time and for better future logistics support. Therefore, request that the hold request to the Army be for at least a total of 14 pedestals for ADTC.

9. We hope that this letter will provide the information requested. Once again, it must be stated that all of these requirements are tentative and are provided for general support of the program to DOD. Detailed hard requirements will be provided through normal Air Force channels as required in the annual fiscal budget submissions.

Lloyd R. Norris

LLOYD R. NORRIS, Colonel, USAF
Director of Range Engineering