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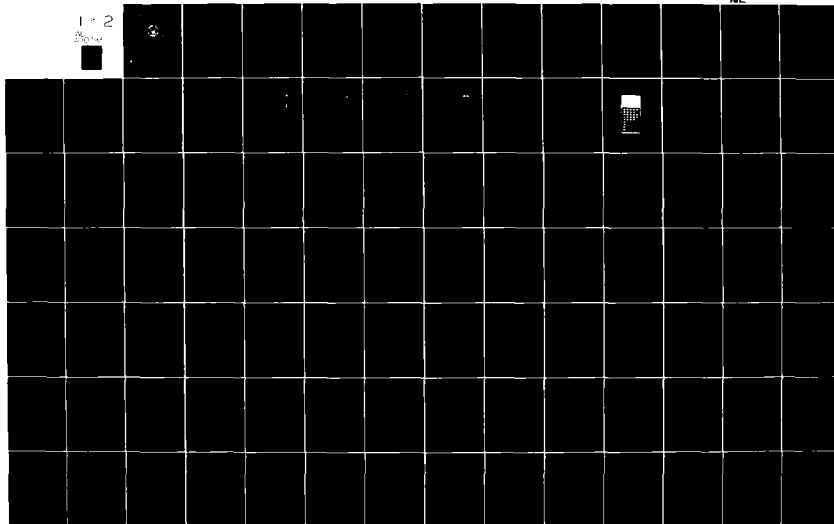
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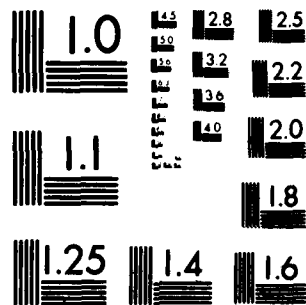
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MICROCOPY RESOLUTION TEST CHART
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THESIS

Programmable Hand-Held Calculators
in the Operating Forces of
the Marine Corps

by

James LeBaron Reeve

March 1981

Thesis Advisor: W. H. Skierkowski

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Programmable Hand-Held Calculators
in the Operating Forces of the Marine Corps

by

James LeBaron Reeve
Major, United States Marine Corps
B.S., Iowa State University, 1969

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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ABSTRACT

This thesis provides usage and cost data on programmable hand-held calculators (PHHC's) in the operating forces of the U. S. Marine Corps (USMC). In 1978 PHHC's that computerized aircraft performance charts were procured for USMC AV-8A pilots. During 1979 the U. S. Army successfully tested and began procuring a PHHC for use by artillery fire direction centers (FDC's). USMC artillery batteries will receive this PHHC in 1981. In 1980 the Army tested and approved procurement of PHHC's for mortar FDC's. In September 1980 Beech Aircraft Corporation started selling a PHHC module which enabled Super King Air pilots to enjoy 10% fuel savings. In February 1981 Naval Air Systems Command began reviewing a proposal to provide a PHHC for the CH-53E. Each of these systems is described, and available cost information is analyzed. In order to do their jobs faster and more accurately, several individuals have written or purchased software for their personal PHHC's. Four examples which have application in the USMC are presented and explained.

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I. INTRODUCTION

A. GENERAL INFORMATION

The evolution of the computer, and in particular the recent developments in programmable hand-held calculators, has not gone unnoticed by the military services. Many base facilities are taking advantage of the new minicomputers, microcomputers, and word processing equipment on the market today. The operating forces can foresee a need for rapid information processing and electronic decision support systems; however, it must be portable, light weight, low cost, and not easily affected by the elements.

In 1974 Hewlett-Packard (HP) introduced their HP-65, which was the first card programmable hand-held calculator. Until Texas Instruments (TI) began marketing their SR-52 in January of 1976, the HP-65 was without competition. The HP-67 introduced by Hewlett-Packard in June of 1976 had twice the capability of the HP-65. Texas Instruments replaced their SR-52 with a much improved TI-59 in June of 1977. [Ref. 1: pp. 9-10]

The TI-59 was a state-of-the-art improvement in that it was not only card programmable but also "chip programmable". The terms "chip programmable" and "module programmable" are sometimes used interchangeably. In reality, a chip is a tiny piece of silicon, and a module is the molded plastic

housing containing the chip and the copper connectors through which the chip "communicates" with the calculator's operating system. A Texas Instruments module measures 11/16 by 7/8 by 5/16 inch. It is inserted in a special opening in the back of a TI-59. Program instructions can be recorded on, or deleted from, magnetic cards by using the card reader/card writer. Chips can only be encoded by a complex industrial process. One advantage of chip programming is that more information can be stored on one Texas Instruments chip than on ten of their magnetic cards. Since the TI-59's random access memory can only store, at any one time, the information on two magnetic cards, TI's chip programming increased by five fold the amount of information immediately available for automated processing by the calculator. This feature was not answered competitively until May of 1980 with the advent of the HP-41C. As might be expected, the HP-41C is another step forward. It has more storage, constant memory, and improved alphanumeric capability.

The TI-58 was introduced by Texas Instruments at the same time as the TI-59. The TI-58 is chip programmable by the same module as is the TI-59; however, the TI-58 does not have a card reader and has only about half the storage of the TI-59. Both have the same face plate and are identical in size. A constant memory version of the TI-58 is now offered and is called the TI-58C. Texas Instruments has not, as yet, marketed a constant memory TI-59.

During January of 1981 the TI-58C could be purchased for \$89.95, the TI-59 for \$199.95, the HP-67 for \$299.95, and the HP-41C for \$189.95. To be card programmable the HP-41C requires an attachable card reader which costs \$169.95. In addition, the HP-41C can be programmed with an optical wand which reads bar code from standard paper. The optical wand is available for \$109.95. Hewlett-Packard also markets the HP-41CV which is an HP-41C with additional built-in memory modules. The HP-41CV costs \$239.95. For a package price of \$394.95 you can purchase an HP-41CV and the plug-in card reader. [Ref. 2]

Thermal printers are available for the TI-58/TI-59 series programmable hand-held calculators (PHHC's). Likewise, Hewlett-Packard has a thermal printer for its HP-41C/HP-41CV PHHC. The Texas Instruments printer costs \$159.95, while \$289.95 will buy Hewlett-Packard's printer. The prices for these printers and the prices for the PHHC's in the preceding paragraph were advertised nationally by a discount firm selling manufacturer-warranted equipment. [Ref. 2]

During the period 15 August to 30 September of 1977 the U. S. Army Field Artillery School (USAFAS) conducted an evaluation of the feasibility of using card programmable hand-held calculators to derive aiming solutions for artillery cannons. This concept evaluation test was the forerunner of what is now formal usage of PHHC's by U. S. Army and

U. S. Marine Corps artillery units. This is discussed in more detail in Chapter II.

The card programmable calculator was not considered to be acceptable for formal usage as an aircraft flight planning aid; however, the U. S. Marines were the first to identify and incorporate the chip programmable TI-58 as a means of computerizing aircraft performance data and mission planning tasks. Chapter II provides an in-depth analysis of this concept.

B. SCOPE

This thesis will consolidate the body of information pertaining to PHHC usage in the operating forces of the U. S. Marine Corps (USMC). Accordingly, the scope of this study does not include PHHC usage at Headquarters Marine Corps (HQMC) or in the Marine Corps Districts. Usage in the Marine Corps Reserve is applicable.

The thesis will analyze the programs currently being used and will report on the programs currently being considered or under development.

C. DEFINITIONS

The term "formal program" is defined by this thesis to be usage which is developed and funded by the government.

An "informal program" is defined to be usage which is conceived, implemented, and funded by an individual serving with the operating forces.

D. PURPOSE OF THE THESIS

In addition to consolidating the body of information pertaining to PHHC's in the USMC, this thesis will investigate the way in which the software for the formal programs was produced. The information consolidation is contained in Chapters II and III.

The U. S. Army used in-house programmers, both civilians and military, to write the software for the artillery applications. After the software was written, verified, and emulated, the Army dealt directly with Texas Instruments for production and purchase of the customized modules, or the read only memories (ROM's) as the modules are sometimes called.

By contrast, the PHHC's now used in Marine Corps AV-8A squadrons were procured via a firm fixed price contract between Naval Air Systems Command and McDonald Douglas Aircraft Corporation.

In Chapter IV the cost of obtaining software by the in-house method is compared to the cost of obtaining it via an outside contractor.

The diversity and extent of informal program usage are limited only by the ingenuity of the individuals owning or having access to PHHC's. Four different examples of informal programs are cited in Chapter V. A program listing and instructions for running each program are included in the appendixes.

E. RESEARCH METHODOLOGY

Assisted by computer-generated searches, a review of the pertinent literature was conducted. Since this is a highly contemporary subject, much of the information has not yet been published. Accordingly, the research for this thesis included numerous telephone interviews.

Telephone calls were made to the Naval Air Training and Operating Procedures Standardization (NATOPS) Officer at HQMC, the NATOPS Officer in each of the four Marine Aircraft Wings, the Naval Air Systems Command Class Desk Office for each type aircraft in the Marine Corps inventory, a McDonald Douglas engineer, a McDonald Douglas technical publications supervisor, a Beech Aircraft customer service official, a new business representative at Texas Instruments, a Hewlett-Packard customer service official, a Hewlett-Packard custom ROM (read only memory) district manager, a Warrant Officer in the firepower branch at the Marine Corps Development Center at Quantico, Virginia, a Marine First Lieutenant instructing at the U. S. Army Field Artillery School at Fort Sill, Oklahoma, several artillery officers at Camp Lejeune, North Carolina, the test officer for the Army's PHHC Mortar Data Module Firing Program Evaluation, several programmers who worked on the artillery PHHC modules, three former thesis authors whose subject pertained to PHHC's, and numerous other individuals known by this author to have special interest in programmable hand-held calculators.

Personal interviews were conducted with two officers at the Naval Aviation Safety School at the Naval Postgraduate School in Monterey, California and with an officer in the 7th Division Artillery Headquarters at Fort Ord, California.

Each of the contacts mentioned in the above two paragraphs provided information, generally in the form of letters or publications, but sometimes just verbally. In addition, the four Marine Aircraft Wing NATOPS Officers each completed and returned a questionnaire soliciting their opinions on PHHC usage by aircrews.

II. EXISTING FORMAL PROGRAMS

A. AVIATION APPLICATION

1. Background Information

In order to fly an aircraft near the edge of its safe operating envelope it is necessary to know the performance limits for the configuration and situation in which the aircraft is going to be flown. Those limitations can change drastically with temperature, altitude, wind, aircraft weight, and aircraft drag index. For example, an A-6 aircraft may require as little as 800 or as much as 8500 feet of runway to become airborne. On a day at 60 degrees Fahrenheit temperature at sea level an A-6 aircraft in a certain configuration will use 4500 feet of runway before it will fly. The same aircraft on a 90-degree day at 4000 feet above sea level will never become airborne regardless of the length of the runway. Another example involves the differing amounts of fuel required to fly a certain distance as the mission changes. The A-6 may require as little as one gallon per nautical mile, or as much as five, depending on the number of bombs carried, the speed, and the altitude at which the mission is flown.

Making the right decision regarding whether it is safe to fly in a certain configuration in a specific situation necessitates a decision support system (DSS). The

following sections will describe the current DSS, its problems, and how programmable hand-held calculators (PHHC's) can create a new DSS. The obstacles to incorporating PHHC's as flight planning DSS's for additional aircraft will be discussed in Chapter IV. Recommendations on how the obstacles might be overcome will be offered in Chapter VI.

2. The Current Decision Support System

Each aircraft type has a different Naval Air Training and Operating Procedures Standardization (NATOPS) flight manual. Section XI of this manual contains a performance data section. In the A-6 aircraft NATOPS manual, Section XI's 182 pages include 150 different figures and the instructions for using them. Figure II-1, Figure II-2, Figure II-3, and Figure II-4 are reduced-in-size copies of four of those 150 figures. Figure II-1 is used to determine the takeoff distance under all possible circumstances. Figures II-2, II-3, and II-4 are used to determine the time required, fuel required, and distance required to descend to sea level from a specific altitude. These are only four of many types of computations which must be considered in rendering effective and efficient decisions regarding flight missions.

3. Problems With the Current System

Using NATOPS flight performance charts and graphs is so time consuming and tedious that many Naval Aviators and Naval Flight Officers avoid using the NATOPS manual when

Figure II-1

NAVAIR 01-85ADA-1

PERFORMANCE DATA
Takeoff and Climb

TAKE-OFF DISTANCE (normal)

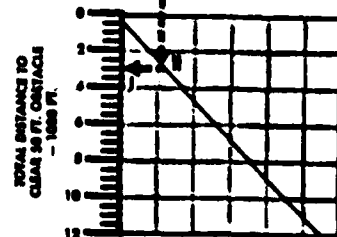
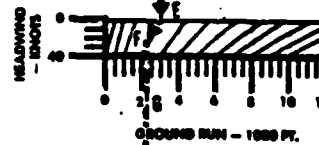
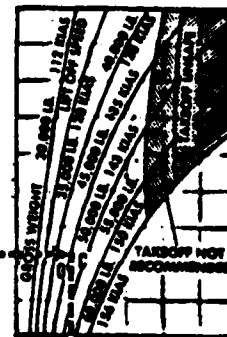
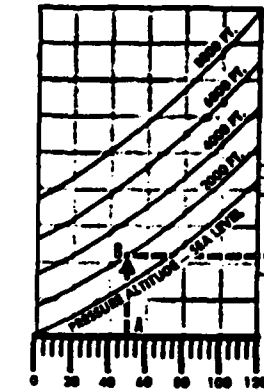


AIRCRAFT CONFIGURATION:
TAKEOFF FLAPS, GEAR DOWN
ALL EXTERNAL STORE CONFIGURATIONS

**MILITARY POWER
HARD DRY RUNWAY**

DATE 13 FEBRUARY 1971
DATA BASIS: ESTIMATED

FUEL GRADE: JP-6
FUEL DENSITY: 6.8 LB/USAL



Source: A-6 NATOPS Flight Manual, page 11-19

Figure II-2

PERFORMANCE DATA
Drag Count

NAVAIR 01-85ADA-1

MAXIMUM RANGE DESCENT

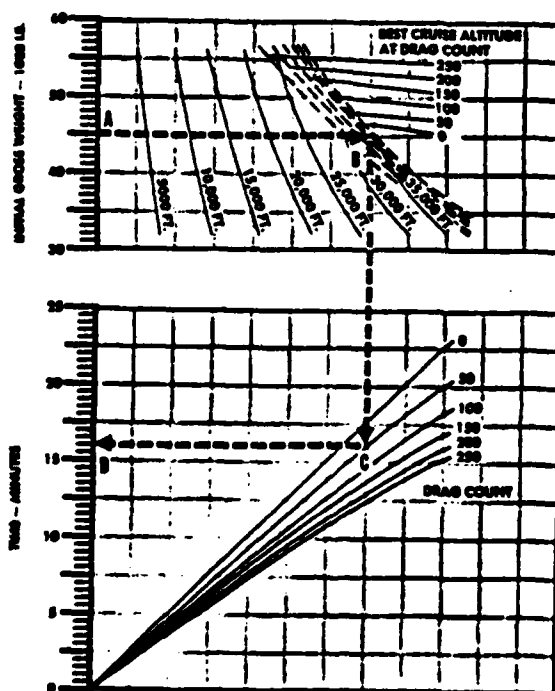
SP-8 ENGINE

**TIME REQUIRED TO DESCEND FROM SELECTED
ALTITUDE TO SEA LEVEL IDLE POWER**

DATE 18 MARCH 1991
DATA BASE: ESTIMATED

REMARKS
ICAO STANDARD DAY

FUEL GRADE: JP-5
FUEL DENSITY: 6.8 LB./GAL.



Source: A-6 NATOPS Flight Manual, page 11-162

Figure II-3

NAYAIR 01-88ADA-1

PERFORMANCE DATA
Drag Count

MAXIMUM RANGE DESCENT

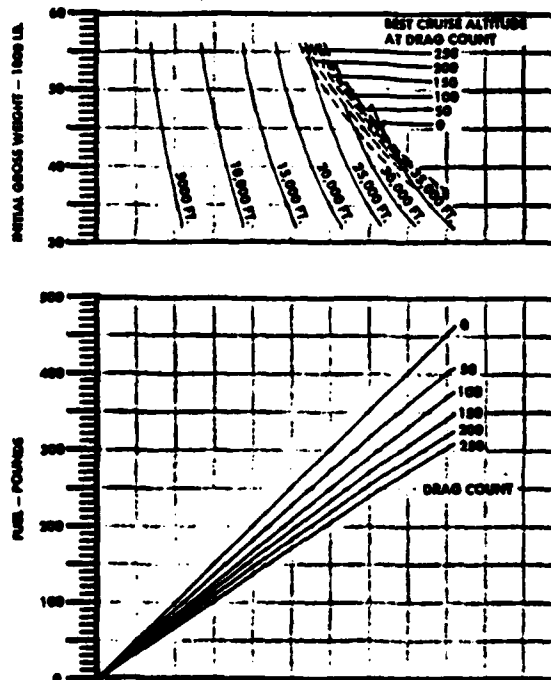


**FUEL REQUIRED TO DESCEND FROM SELECTED
ALTITUDE TO SEA LEVEL IDLE POWER**

DATE 15 MARCH 1971
DATA BASE, ESTIMATED

REMARKS
ICAO STANDARD DAY

FUEL GRADE, JP-8
FUEL DENSITY, 6.8 LB./GAL.



Source: A-6 NATOPS Flight Manual, page 11-163

Figure II-4

PERFORMANCE DATA

Drag Count

NAVAIR 01-85ADA-1

MAXIMUM RANGE DESCENT

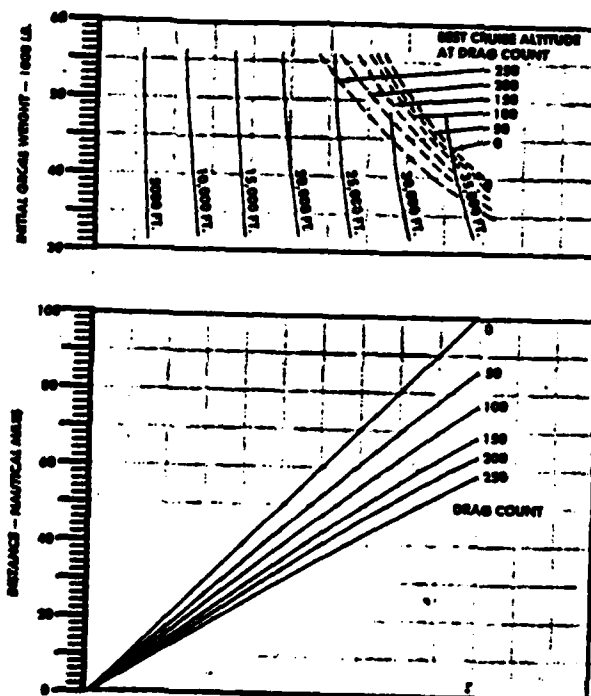
P-8 ENGINES

DISTANCE REQUIRED TO DESCEND FROM SELECTED ALTITUDE TO SEA LEVEL IDLE POWER

DATE 15 MARCH 1971
DATA BASE: ESTIMATED

REMARKS
ICAO STANDARD DAY

FUEL GRADE: JP-8
FUEL DENSITY: 6.8 LB./GAL



Source: A-6 NATOPS Flight Manual, page 11-164

doing their flight planning. Instead they substitute figures learned from experience or obtained from "rough gouge" cards they or someone else prepared for a stereotyped situation. This is not a problem if the flight mission does not involve operation at or near the edge of the envelope. It can become a problem, with disastrous consequences, if any one of several parameters is violated.

If inadequate aircrew planning occurs in the following examples, loss of lives and equipment will most probably result. Increased temperature, increased elevation, and decreased headwind component all cause a greater takeoff distance in order for an aircraft at a specified weight to become airborne. Attempting to takeoff with insufficient runway length for the specific aircraft weight, or runway temperature, or runway elevation, or headwind component will result in a crash every time. It is also true that altitude, temperature, wind speed, wind direction, aircraft speed, aircraft weight, and ordnance drag index have known effects upon the fuel required per mile flown. The result of running out of fuel while airborne can be predicted without reference to any NATOPS chart.

Lieutenant Commander W. M. Siegel, an aeronautics student at the Naval Postgraduate School in Monterey, California, quoted an interview with the former Director of the Naval Aviation Safety School in regard to a one-hour test which was administered to sixteen officers attending

the Command Safety Course. This course is for commanding officers and executive officers. The test required that these pilots and naval flight officers compute the maximum range at which a specified mission could be flown. The director stated:

"It is a startling, but typical, fact that the correct answer of 538 nautical miles was not achieved by any member of the class. The closest answer was in error by 126 miles, and the spread of answers ranged from 336 to 868 nautical miles. Additionally, the correct answer was attained by the class instructor only after a measured sixteen hours of effort with the NATOPS manual." [Ref. 3: p. 10]

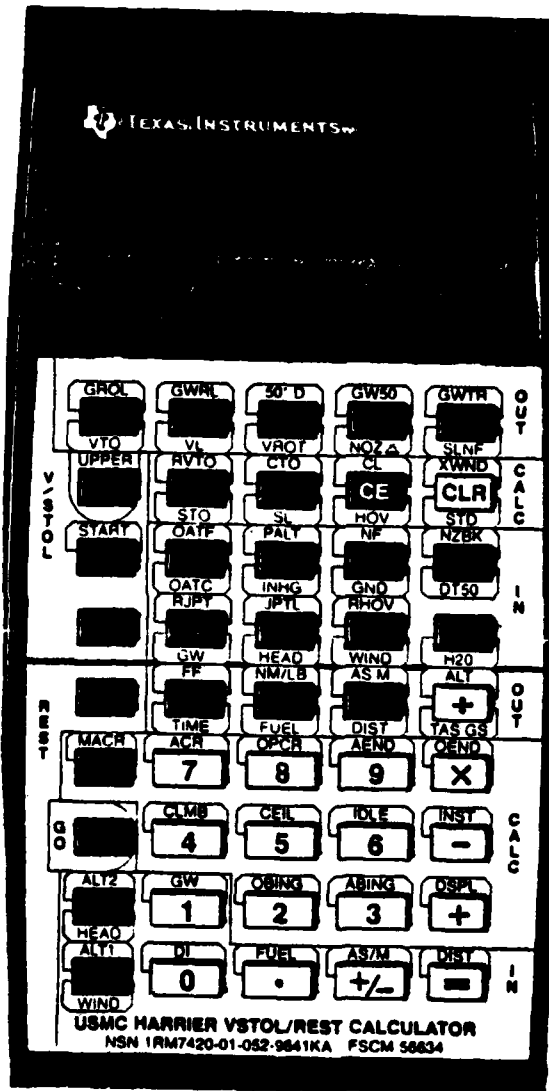
4. An Improved Decision Support System

In 1978 another Naval Postgraduate School aeronautics student, Lieutenant Commander G. L. Koger, demonstrated that a programmable hand-held calculator (PHHC), the Texas Instruments Model 59 (TI-59), could be card programmed to compute data which previously had to be derived from NATOPS manual performance charts. [Ref. 4: pp. 90-138]

Even before Major J. D. Restivo [Ref. 5], Seigel [Ref. 3], and Koger [Ref. 4] had presented their theses demonstrating that NATOPS performance charts and graphs could be computerized, U. S. Marine Corps AV-8A Harrier pilots had recognized the need for a better DSS. In August 1977 Naval Air Systems Command contracted with McDonald Douglas Aircraft Corporation "for development of an electronic hand-held calculator and delivery of 200 units." [Ref. 6] These calculators were delivered in June 1978; their usage was

Figure II-5

The AV-8A/TAV-8A V/STOL-REST Flight Performance Calculator



Note: The above picture is the same size as the actual calculator.

implemented immediately by Marine Corps AV-8A Harrier squadrons at Cherry Point, North Carolina. The Harrier calculator is a Texas Instruments Model 58 (TI-58) with a modified face plate and a customized module. Figure II-5 is a picture of the Harrier calculator. The foreword to its operating instructions is reproduced, in part, below.

"The AV-8A/TAV-8A V/STOL-REST Calculator has been designed to calculate the performance of AV-8A and TAV-8A aircraft easily. In essence, the entire Performance Data Section of the NATOPS Flight Manual has been incorporated into the calculator. The fit of the performance data for the Calculator has been done mathematically, while the fit for the NATOPS Manual was done graphically. This introduces some differences in specific performance points in certain cases, but these differences are small.

The Calculator can be used for calculating all Vertical or Short Takeoff and Landing (V/STOL) and wingborne Range, Endurance, Speed, and Time (REST) maneuvers. The characteristics of an individual aircraft can be entered to provide the aircraft's maximum capabilities to the pilot. The possibility of error is greatly reduced when using the Calculator as opposed to the "reflector" and "chase-around" charts in the NATOPS Manual." [Ref. 7: p. 2]

Although there have been no formal studies conducted regarding the time savings enjoyed by users of this calculator, interviews with Harrier pilots indicate at least a 25% savings. No pilot interviewed said it required more than ten hours to become proficient in using the calculator, and one pilot reported 95% proficiency after only 1.5 hours of instruction and practice. The accuracy of the calculator-generated data is nearly 99% perfect, which is considerably more accurate than using the NATOPS charts and graphs where the width of a pencil line drawn on a most of the graphs

will limit accuracy to 95%. Accuracy can also be degraded in the manual mode if transfers between graphs on the same figure are not exactly parallel to the axes of the graphs.

In order to facilitate in-cockpit use of the calculator, a special strap was designed and procured which enables the pilot to strap the calculator to his leg in a manner similar to that done with the conventional aviator's kneeboard. For a variety of reasons, most of which are related to either the small size of the AV-8A cockpit or the high workload rate, a majority of the pilots found it was not practical to use the calculator during flight. Accordingly, the requirement for a strap was deleted from the contract specification of the planned-for AV-8C calculator, which will be discussed in more detail in Chapter IV.

B. ARTILLERY APPLICATION

1. History of PHHC Adoption and Implementation

a. Card Programmed Phase

During the period from 15 August to 30 September of 1977 a Concept Evaluation Test was conducted at the U. S. Army Field Artillery School (USAFAS), Fort Sill, Oklahoma. This test employed the TI-59 in its card programmable mode to solve gunnery problems. Due to the encouraging results of this test, the USAFAS initiated plans to develop the PHHC as a "universal tool to be used for sound and flash, cannon/lance gunnery, and survey procedures." [Ref. 8]

Although the Army published the TI-59 program listings and program operating instructions, the information was not to be construed as official doctrine concerning the solution of artillery gunnery problems. In addition, the Army published the flow charts and equations used to write the TI-59 program. This was to "allow programming of any other calculator with the same features and capabilities as the TI-59." [Ref. 8] Another PHHC with similar card programmability was the HP-67.

Due to the fragile nature of magnetic cards, the unpredictable reliability of the card reader in cold, wet, or dusty weather, and the inherent storage limitation of magnetic cards, the card programmed hand-held calculator was never adopted for doctrinal artillery use.

A card programmed TI-59 can store up to 960 program steps if no data registers are needed. For each ten data registers added by repartitioning, eighty program steps are not available. By contrast, a chip or module (the technical term is ROM for "read only memory") programmed TI-59 has 5000 program steps and 100 data registers available. In addition, the module is much less affected by weather than are the magnetic cards and the card reader.

b. Module Programmed Phase

To overcome the disadvantages of card programming and to exploit the advantages of module programming, the USAFAS developed and tested a prototype module. This

test was conducted during the period 12 December 1978 to 11 May 1979. One objective of the test was to compare the operational capability of the PHHC with FADAC (Field Artillery Digital Automatic Computer) in regard to the solution to indirect fire gunnery. One major assessment of this test was that the PHHC "can function as a backup or alternate for FADAC." [Ref. 9: p. 1-6] That assessment was based on the finding that "there was no statistically significant difference between the two systems" [Ref. 9: p. 2-9] in regard to (1) the accuracy of computed firing data and (2) the time needed to compute the data. The success of this testing and the Material Readiness Command's inability to logistically support FADAC in the 1980's led the Army to develop and procure nine different customized modules. Five of the modules are for five different cannons. The other four modules are used in ancillary artillery support roles. The January-February 1980 issue of Field Artillery Journal [Ref. 10] contains an excellent article which explains the features and capabilities of this new doctrinal application of the TI-59 to the needs of the field artillery. Army units have already received their "Computer Sets", as the Army has chosen to call this new usage of the PHHC. Marine Corps units will receive theirs during 1981.

A "Computer Set, Field Artillery, General" contains a TI-59 (with no module), applicable technical instruction manuals, and external power source connectors so

that the TI-59 can receive electrical power from any of the following four sources in addition to its own organic rechargeable battery pack: (1) a jeep battery, (2) a standard vehicle cigar lighter outlet, (3) an AN/PRC-77 radio battery (BA 4386), or (4) a 115V 60 Hz outlet. All the above, plus the Texas Instruments printer for the TI-59, are included in the "Computer Set, Field Artillery, Missile", which is issued only to the survey information centers in the various headquarters. Any of the nine developed modules needed for the unit's mission are ordered separately.

2. Comments from a Marine Artillery Officer

In order to keep abreast of the evolving PHHC technology and its application to artillery, Marine First Lieutenant Edward A. Bream purchased a TI-59 and its associated printer during May of 1979. Using the TI-59 cannon program information in Reference 8, Bream was able, in his capacity as a battery fire direction officer, to perform a personal feasibility evaluation of that program. In a letter solicited by this thesis author, Bream wrote that one of the advantages of the TI-59 over the manual methods is the precision in which data is determined. Bream succinctly stated that:

"Manual methods of determining target location involve the relative placement of pins on a firing chart, coupled with a variety of tools designed to numerically categorize the pins' relationship to the chart and to each other. Imbued in this method, however, is the recognized error generated by the manual nature of the system itself. Although two charts are used as a countercheck for errors

against each other, comparative errors of thirty meters in range and three mils in deflection are acceptable. Error skews that develop simultaneously on both charts are almost totally undetectable. Generation of data by the TI-59 is developed along constant mathematical relationships which results in extremely accurate and refined computations."

The disadvantages Bream pointed out dealt with (1) the nature of card programming and (2) the power-source problems. These disadvantages are overcome by module programming and by adaptations for alternate sources of power as explained earlier.

III. FORMAL PROGRAMS UNDER DEVELOPMENT

A. AVIATION APPLICATION

1. The Marine Corps/Navy CH-53E Heavy Lift Helicopter

Naval regulation requires that certain categories of transport aircraft be provided with a system for calculating center of gravity under all possible load conditions. In the past this has been accomplished by procuring, at considerable cost, a specially designed slide rule. In May of 1980 Naval Air Systems Command requested that Sikorsky Aircraft submit an engineering change proposal to the CH-53E procurement contract which would substitute a PHHC for the center-of-gravity slide rule. The request stated, "Electronic calculators are available for approximately the same price as the MIL-C-6092A balance computer." [Ref. 11] A CH-53E calculator similar in function to the AV-8A calculator would be able to do certain performance calculations in addition to the center-of-gravity computations because the latter would only use a portion of the 5000 steps available in a TI-58 module.

The Sikorsky proposal probably would have been quickly submitted except for one development. That development was Hewlett-Packard's newest PHHC, the HP-41C. Its enhanced alphanumeric capability, increased storage capacity, and constant memory caused Sikorsky and Naval Air Systems

Command to agree that Sikorsky should take the additional time necessary to evaluate this new PHHC and how it could be employed in a flight planning decision support system role for the CH-53E. Accordingly, Naval Air Systems Command now expects Sikorsky will, during February of 1981, submit two proposals: one for using a TI-58 and one for using an HP-41C. Naval Air Systems Command will evaluate both proposals and will select the one with the higher benefit-to-cost ratio.

2. The Beechcraft Flight Planning Computer

Sikorsky's research and Naval Air Systems Command's analysis will both be made much easier and more accurate thanks to a Beech Aircraft Corporation innovation, an innovation which is truly a state-of-the-art breakthrough for flight planners. During September of 1980 Beech Aircraft Corporation introduced a flight planning decision support system (DSS) for the Beechcraft Super King Air, which is a twin-engine jet prop and is their top-of-the-line airplane. The military C-12B is a Super King Air with the heavy duty landing gear option. The DSS consists of an HP-41C with a custom module. The Beech module, a special keyboard overlay for the HP-41C, and the operator's manual cost \$910. The HP-41C is not included in that price, but it is obviously required. A printer is optional. The "Flight Planning Computer", as Beech has named the DSS, operates thirteen programs to aid the pilot during preflight planning and

during flight. Brief descriptions of the thirteen programs are reproduced, in part, from the operator's manual and are contained in Figure III-1. [Ref. 12] The program named SAVE is likely to be the big selling point for the system. SAVE's function is to find the most economical altitude for any flight. In making its selection, SAVE considers (1) the cruise power setting, (2) forecast winds aloft, (3) and fuel required to climb to, cruise at, and descend from each legal altitude available during a flight. SAVE calculates the following: (1) total fuel and total time required for the flight at both the least-fuel and least-time altitudes, and (2) fuel saved and additional time required if the least-fuel option is selected over the least-time option. In the September 1980 issue of AOPA Pilot, M. F. Silitch reports that:

"Using a flight-planning computer to calculate minimum-fuel altitudes could result in fuel savings of about 6,000 gallons a year for each Super King Air, based on 550 to 600 hours of use." [Ref. 13]

Silitch probably based the 6,000-gallon figure on owners' reports of 10% savings. In cruise flight a Super King Air averages 100 gallons of fuel per hour or 60,000 gallons in 600 hours. It is unclear whether the owners were claiming to have flown 10% more miles on equal amounts of fuel or were consuming 10% less fuel on equal mileage. In either case, assuming the pilot religiously selected the least-fuel option, it would be safe to forecast that Beech's

Figure III-1
Programs in the Beechcraft Flight Planning Computer

```

*****
*  Name                Program Description  *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* SAVE:                Gives least-fuel and least-time altitudes and *
*                      the differences in time and fuel between the *
*                      two.                                           *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* CLIMB:               Gives time, fuel, and distance required to *
*                      cruise climb with zero wind.                  *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* CRUISE:              Gives engine torque setting, fuel flow per *
*                      engine, and true airspeed values for recom- *
*                      mended cruise power at 1700 rpm.              *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* DESCENT:             Gives time, fuel, and distance required to *
*                      descend with zero wind.                        *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* RHUMB:               Gives rhumb line navigation distances and *
*                      constant true heading from departure point *
*                      to destination.                                 *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* GREAT:               Gives great circle navigation distance and *
*                      initial true heading from departure point to *
*                      destination.                                    *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* TAS:                 Gives Mach number, true outside air tempera- *
*                      ture, and true airspeed during flight.        *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* WEIGHT:              Advises whether a specific airplane is loaded *
*                      within center of gravity and weight limits.   *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* COMPUTE:             Works basic flight computer problems, such as *
*                      distance/time = ground speed, and time X fuel *
*                      flow = quantity required.                     *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* WIND:                Figures in-flight wind true direction and *
*                      velocity.                                       *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* TREND:               Provides values of deviation from standard *
*                      for three engine operating parameters, which *
*                      can be used as data points to plot engine- *
*                      condition trend lines.                         *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* LOAD:                Loads the empty weight, moment, and other *
*                      special items for the specific airplane in *
*                      question into the computer memory.            *
*  *  *  *  *  *  *  *  *  *  *  *  *  *
* START:               Sets up calculator prior to first run.       *
*****

```

Flight Planning Computer would pay for itself in about the first 150 hours of flight time after its purchase. A pilot does not have to be a computer expert to use the Flight Planning Computer. It is programmed with 65,000 questions/answers [Ref. 13] that lead the pilot through the programs. An example of this technique for each of the thirteen programs is contained in the operator's manual. The initial actions are the same for all programs. First, turn on the HP-41C and push the key called NAME on the Beech keyboard overlay. Second, "NAME PLEASE" will appear in the calculator display. Each of the thirteen programs has a one-word English name and also a two-letter Z-code. To run, for example, the program SAVE, simply key in the letters spelling SAVE, or the code ZA, and press the key named NEXT on the overlay. The display will show the first of the series of questions listed in Figure III-2. After the appropriate value is keyed in and NEXT is pressed, the next question appears. After these questions are all answered, the HP-41C will display "WIND DATA <>", meaning it is determining what wind information is needed for the final solution. Next, a series of wind-related questions will be asked by the calculator. Examples of those questions and their meanings are contained in Figure III-3. The calculator will repeat these three wind-related questions for pertinent altitudes based on the minimum and maximum altitudes specified earlier. Next, "DES P.A. = x,xxx?" (asking for the pressure altitude

Figure III-2
Series of Questions Asked by Program SAVE

<u>Question</u>	<u>Meaning</u>

* T.O. WT = xx,xxx?	What is the takeoff weight of the
*	airplane?

* T.O.P.A. = x.xxx?	What is the pressure altitude at
*	the takeoff airport?

* T.O. TEMP = x?	What is the temperature in degrees
*	Celsius at the takeoff airport?

* DIST = x,xxx?	What is the distance of the trip
*	in nautical miles?

* TRU CRS = xxx?	What is the true course of the
*	trip?

* MN AL = xx,xxx?	What is the minimum altitude the
*	pilot will accept?

* MX AL = xx,xxx?	What is the maximum altitude the
*	pilot will accept?

Figure III-3
Temperature and Winds Aloft Questions

<u>Question</u>	<u>Meaning</u>

* 6K - DIR = xxx?	What is the direction of the winds
*	at 6000 feet in degrees true?

* 6K - VEL = xx?	What is the velocity of the winds
*	in knots?

* 6K - TMP = -xx?	What is the temperature in degrees
*	Celsius at 6000 feet. The - sign
*	before the xx in the question
*	reminds the pilot that many of
*	these temperature entries will be
*	negative numbers.

at the destination airport) will appear in the display. After making that entry and pressing NEXT, "STANDBY" will be displayed, meaning the entered data is being processed. After about 75 seconds, data regarding the least-fuel option will be displayed. If "29K,T3:48,F2,069" were displayed, it would mean that the altitude for the least-fuel option would be 29,000 feet, the time enroute would be 3 hours and 48 minutes, and 2,069 pounds of fuel would be consumed. Pressing "NEXT" will cause additional output, such as the recommended power setting at the least-fuel altitude and the altitude, time, fuel, and power setting for the least-time option. Also, the differences in time and fuel between the two options can be displayed. If a printer is available, all the output data is printed after NEXT is pressed. Without a printer, it is necessary to press NEXT several times as there is more output than can be displayed at one time. For each of the programs, error messages are generated and displayed immediately following any input which is outside the normally expected value for that input. Examples of the error messages as they would be displayed are: "TOO HIGH", or "TOO LOW", or "TOO HOT", or "TOO COLD", or "N/A INPUT", or "xxK TOO HIGH" (meaning climb to and descent from this altitude cannot be made without exceeding the total distance specified for the trip), or "xxK R/C LOW" (meaning the rate of climb at or before reaching this altitude is less than 101 feet per minute).

The software for the Flight Planning Computer was written by a Beech employee/pilot named David Horwitz, who has a master's degree in electrical engineering. He did the programming in his own time and estimates the effort required 800 hours. In a telephone interview with this thesis author, Horwitz said he had tried to write similar programs on the HP-65 and the HP-67 but was unsuccessful due to the inherent limitation of those PHHC's. He found the TI-59 could be satisfactorily programmed to computerize aircraft performance data; however, the human interface needed to run the programs was complicated and awkward. Accordingly, it was decided the average general aviation pilot did not have the time, background, or inclination to master such a program. Horwitz acquired one of the first available HP-41C's and found it to be ideal for the task he had in mind. After writing the software, Mr. Horwitz presented the concept to Beech management, who decided to validate the program and market the product as a service to Super King Air owners and operators.

B. MORTAR APPLICATION

The successful testing and introduction of the TI-59 for service with the artillery was described in Chapter II. The operational capability of the PHHC to "perform fire direction functions for mortars" [Ref. 9: p. 1-3] was evaluated during the period 12 December 1978 to 11 May 1979. This

test was made using magnetic cards programmed with ballistic constants. The test revealed that:

"Dirt and temperature affected the cards and the cards were not universally interchangeable among calculators. At 20 degrees Fahrenheit (F), the calculator would not always read magnetic cards which had been programmed at 65 degrees F. Setting up the calculator usually required two or three attempts to read the cards." [Ref. 9: p. C-1]

In spite of these problems, one of the test assessments was that the PHHC:

"has the operational capability to perform selected FDC (fire direction center) functions for 81-millimeter and 107-millimeter mortars." [Ref. 9: p. 2-16]

In order to eliminate the problems associated with magnetic cards, the U. S. Army Training and Doctrine Command (TRADOC) Combined Arms Test Activity (TCATA) developed and procured two custom Texas Instruments modules, one for 81-millimeter mortars and one for 107-millimeter mortars. During the period from 3 to 6 March 1980 a Mortar Data Module Firing Program Evaluation was conducted at Fort Hood, Texas. The stated reason for the test was:

"to determine if the use of a discrete mortar ROM module for the PHHC produced significant changes in the performance of mortar FDC's." [Ref. 14: p. 1]

Specifically, the evaluation compared the performance of FDC's using TI-59's to the performance of FDC's using the standard manual method of computing fire commands. At the Marine Corps' request, an excursion was included in the test scenario so that setup times in the battery-powered, hand-held mode could be evaluated. A major assessment of the

evaluation was that FDC personnel can compute fire commands and other ancillary functions faster and more accurately using the calculator than using the manual method. The shorter FDC setup times for the PHHC, as compared to the manual method, were statistically significant.

As a result of this test, the Army decided to procure PHHC systems for each unit employing mortars. It is expected that the mortar TI-59's will be supplied to Army units by late 1981. A purchase by the Marine Corps is pending.

IV. THE FUTURE OF THE PHHC IN THE MILITARY

Cost and user resistance are the primary and secondary obstacles which inhibit large scale adoption of formal programs using PHHC's. Both of these problems will be analyzed in the following sections.

A. COST

Two different types of costs should be recognized when considering the procurement of any system. One is the non-recurring, developmental costs; the other is the incremental costs associated with purchasing an item after it has been developed. With PHHC's, the non-recurring, developmental cost includes the cost of writing the coded instructions which cause the calculator to perform. This is often referred to as software costs. The per-item price charged by a manufacturer, such as Texas Instruments or Hewlett-Packard, could be thought of as the incremental portion of the cost of funding additional usage of PHHC's.

There are also two different methods of obtaining the software. One way is to contract with a private corporation or consulting group. The other method is to have the software written by in-house, government programmers. Both methods have been used. Examples of the historical costs are presented in the following subsections.

1. Outside Contractor

a. The AV-8A Calculator

Two Hundred Harrier flight performance calculators, described in Chapter II, were procured via a firm fixed price contract between Naval Air Systems Command and McDonald Douglas Aircraft Corporation at a stated cost of \$175,000. [Ref. 6] Additional units beyond the initial purchase of 200 were stated to be available at \$125.00 each. [Ref. 15] Although not stated, that \$125.00 figure was probably only true for the next fifty calculators and for a batch of an additional 250 beyond that. The reason is because Texas Instruments has a minimum charge for fabricating custom modules. That minimum charge is currently \$12,500 for 250 modules. The non-recurring, developmental costs would include (1) software costs, (2) cost of designing and fabricating the modified face plate, (3) cost of writing the user's manual, and (4) the cost of designing the special leg strap. Thus, the contract price could be apportioned as follows:

Incremental costs (200 @ \$125.00)	\$ 25,000
Non-recurring developmental costs	150,000
Total	\$175,000

The contract was approved in August 1977, and the calculators were delivered in June 1978.

b. The AV-8C Calculator

The AV-8C is scheduled as a follow-on model to the revolutionary vertical/short takeoff and landing

(V/STOL) close air support jet. McDonald Douglas submitted a bid of \$300,000 to provide 200 flight performance PHHC's for the AV-8C. That bid could be apportioned as follows:

Incremental costs (200 @ \$150.00)	\$ 30,000
Non-recurring developmental costs	<u>270,000</u>
Total	\$300,000

In this case, the non-recurring costs include the same items as for the AV-8A calculator except for the leg strap which was not a specification on the AV-8C calculator request for proposal (RFP). The AV-8C calculator contract was not awarded due to uncertainties during 1980 about funding for the aircraft itself.

The following explanation is offered for the significant increase in the bid for the AV-8C calculator over the cost of the AV-8A calculator. Inflation in the 2.5 years would account for a 30% increase above \$175,000, an amount equal to \$52,500. Thus, $52.5 / (300 - 175)$ or 42% of the increase can be attributed to rising price levels. The other 58% of the increase was explained by McDonald Douglas as being due to their having lost money on the AV-8A calculator contract. It is certainly necessary for private industry to make a profit. One way to insure that the profit is not excessive is through the use of competition. Competitive bidding is required by the Defense Acquisition Regulations unless one of the seventeen exceptions to the general requirement for competition exists. If an exception is granted, the final price is determined by negotiation, a process

in which cost accounting standards play an important role in determining a fair estimation of the costs the contractor can reasonably expect to encounter.

c. The Beechcraft Flight Planning Computer

While the Beechcraft Flight Planning Computer was certainly not the result of a government contract, it is an example for which a stated price does exist. That price is:

HP-41C	\$ 190	[Ref. 2]
Beech Module	910	[Ref. 13]
Price for one	\$1100	
Price for 200	\$220,000	

It should be noted that a direct comparison between the Beechcraft Flight Planning Computer and the AV-8A Harrier calculator is not possible. The former has much more capacity and the latter is constrained by the lack of alphanumerics in the TI-58. In other words, Harrier pilots have to learn which buttons control which functions and in what order the buttons must be pressed, whereas Beechcraft pilots merely have to respond to abbreviated English questions that prompt each task.

d. The Fleet Mission Program Library

This library is maintained as a function of the Naval Tactical Support Activity whose headquarters is in Silver Springs, Maryland. The library is a collection of HP-67 programs which are used to aid a variety of the U. S. Navy's tactical missions. The only programs in that library

which have application in the U. S. Marine Corps are those pertaining to celestial navigation, which could possibly be used by Marine KC-130 squadrons. The programs which deal with weight and balance of the P-3 and S-3 aircraft could be modified for use on USMC aircraft.

The labor-related cost of this program can be traced to a contract between the Navy and the Atlantic Analysis Corporation. In return for \$45,000, the Navy receives one man year of programming assistance. This assistance involves (1) reviewing requests from the fleet for specific program applications, (2) writing the software for approved requests, (3) validating programs submitted by users for inclusion in the library, and (4) updating current programs as changes in procedures and equipment occur. On an average, this contract produces twelve new, validated, or modified programs per year. An HP-67 program can be up to 224 steps in length. [Ref. 1: p. 78]

2. In-house, Government Programmers

The artillery PHHC and the mortar PHHC are the primary examples of where the military has used its own employee programmers to write software for a formal, large-scale, PHHC project.

Cost accounting systems enable most large corporations to accurately record labor-related and material-related costs and to allocate overhead costs to each project. Without a significant amount of research (and permission/

cooperation of the the U. S. Army to perform the research), it would not be possible in these examples to recapture the exact total cost of each project. The reason this information is not more readily available is because the Army did not elect to declare either the artillery PHHC or the mortar PHHC to be a "special interest item" as is done in a large procurement such as for tanks and other weapon systems. If that had been done, each item of cost would have been charged to an account code reserved for the special interest item.

In the case of the artillery and mortar calculators, the only formal records which can be analyzed regarding the non-recurring, developmental costs are those maintained in accordance with the U. S. Army Training and Doctrine Command (TRADOC) Management Information System (TRAMIS). Under the current generation TRAMIS, man days (MD) of effort are charged to an action control number (ACN). TRAMIS is under revision; TRAMIS-Improved, scheduled to come on line in mid 1981, will capture not only the man hours but also the pay grade of the worker. Currently however, TRAMIS data is contaminated in that it includes man days from employees at several different wage rates. A labor rate standard, which takes into consideration the mix of pay grades and MD, does not exist. Thus, it is not possible to determine an exact total for the labor-related costs. No material-related costs are available. Nor is it possible to make an alloca-

tion of the overhead costs. Travel costs might be obtainable, but only by manually examining all the travel orders written during the period and being able to pick out the travel made in conjunction with the calculator project.

In the case of the artillery calculator project, two different ACN's were actually used. Fort Sill officials established ACN 51665 during 1978 only to later discover that TRADOC had assigned ACN 36808 for the same project. Accordingly, ACN 51665 was not used after Fiscal Year (FY) 1979. The following data has been extracted from TRAMIS records.

	<u>FY 1978</u>	<u>FY 1979</u>	<u>FY 1980</u>
ACN 51665	92 MD	45 MD	0
ACN 36808	0	417 MD	395 MD
FY Totals	92 MD	462 MD	395 MD

The MD accounted for above might be thought of as applying to the software developmental time required by three separate subprojects of the main project. Those three subprojects would be: (1) development of the prototype module used during the 12 December 1978 to 11 May 1979 test, (2) development of the nine modules now available to artillery units, and (3) development of additional modules for expanded application of the artillery PHHC system. Unfortunately, the aggregated MD do not allow for that distinction. In an attempt to relate MD of programming effort to a specific module, a telephone interview was conducted with Mr. Donald J. Giuliano.

Mr. Giuliano, who has a master's degree in mathematics, did the programming for the prototype module. He recalls that the time spent on that programming task was from the last week in August to the last week in September of 1978, or about twenty-two working days. Validation of the program and emulation, a step required by Texas Instruments for fabrication of the modules, required another three weeks. During this time, Giuliano was in pay grade GS 9 step 1. It should also be noted that prior to starting the programming effort, Giuliano attended classes at the Field Artillery School to become acquainted with artillery terms, concepts, and procedures. His employment at Fort Sill actually started in March of 1978. Viewed in a narrow sense, one might conclude that the direct labor cost to the Army was less than two months pay and benefits or about \$5,000. However, another school of thought would attempt to include all the cost the Army would not have incurred had they contracted out the same programming effort. That estimation could include Giuliano's wages and benefits from March 1978 to January 1979, when he became actively involved in programming six of the nine modules in current use. Even using that broad definition of the total discretionary cost, simple calculation shows the total direct labor cost to be not more than \$25,000. A rough approximation of the overhead cost associated with the prototype module might be another \$25,000. The direct material cost involved in this

software development would probably amount to less than \$5,000. Added together, we have a sum of \$55,000.

One is now attempted to compare this \$55,000 with the \$150,000 derived to be the developmental cost of the Harrier calculator. However, while on the surface that might appear to be valid comparison of the developmental cost of two custom modules, the differentiating factors should be considered. The computerization of the Harrier performance data was a new effort. Not only was it a new effort for the Harrier, it had never been done for any aircraft. By contrast, artillery aiming solutions had previously been computerized for FADAC and also for earlier evolutions of TI-59 programs on magnetic cards.

In his Naval Postgraduate School thesis, Koger wrote nine different TI-59 programs which computerized several of the A-7 aircraft performance charts. [Ref. 4: pp. 90-138] These nine programs were written in such a manner so that they would all fit within a 5000-step Texas Instruments module. In a letter solicited by this author, Koger estimated his programming effort required 400 man hours, plus or minus 25%. This figure is reinforced by Seigel, who, in a telephone interview, estimated such an effort would require two man months, which computes to 352 man hours figured on the basis of forty-four, eight-hour days. Applying the \$45,000 contract between the Atlantic Analysis Corporation and the Navy as a guide to the annual cost of a programmer's ser-

vices, and using Koger's high estimate ($400 + 25\% = 500 = 2.8$ man months @ 176 hours per month), it would appear that the cost of writing the software for an aviation-peculiar Texas Instruments module is approximately \$10,500. Extensive validation and emulation would perhaps require an additional three man months, but the total direct labor cost should still be not more than \$25,000. If the overhead cost were the same as the direct labor cost and if the direct material cost were \$5,000, the total would be \$55,000. That is the same cost as for the prototype artillery module, even though different avenues were used to arrive at the figures. Admittedly, many of the assumptions, such as the cost of overhead, are only broad estimates and cannot be verified because the industrial firms with experience in this field consider the information to be proprietary.

The Naval Weapons Center at China Lake, California certainly has the expertise to write PHHC software to computerize NATOPS performance data, but as yet, they have not been asked to perform such a task.

In addition, it should be noted that the 182 pages of performance charts, graphs, and instructions in the typical NATOPS flight manual did not come free. While that is a sunk cost in existing aircraft, it is certainly reasonable to suggest that for future aircraft the cost of generating NATOPS performance charts could be applied toward the cost of buying PHHC's with custom modules. It is not expected

that aircrews will be agreeable to giving up their paper charts until they have had more opportunity to be personally convinced of the viability of the PHHC to do the job. Thus, elimination of the traditional charts and graphs is a long term, rather than a short term, goal.

In conclusion to this section on the cost of formal PHHC systems, it should be stated that while using in-house, government programmers appears to cost less than it would cost to contract out the software development, this apparent lower cost cannot be proven. If the Army had chosen to account for the developmental cost via their job order cost accounting system, much more precise information would be available. This precise information, after being adjusted for inflation, could have been used as a benchmark for comparison with contractors' bids on the software development of future PHHC systems within the military.

B. USER RESISTANCE

While cost is the undisputed king in the list of obstacles to additional formal programs using PHHC's, a smaller, but not to be ignored, obstacle could be termed "user resistance." User resistance to potential computerization of NATOPS performance data has been expressed by reluctant naval aviators and naval flight officers in the following manner: (1) "a crutch," (2) "aircrews will never learn to use NATOPS charts," (3) "nice to have but not essential,"

and (4) "this may foster dependency while concurrently reducing a pilot's ability to use NATOPS charts properly." These objections are similar to those probably voiced by certain people years ago when asked by innovators if they would trade their horse and buggy for a car. The ready acceptance of PHHC's by Harrier pilots and Beechcraft pilots is reliable evidence that this new decision support system is a vast improvement. It is anticipated that the reluctant among us will become comfortable with PHHC's after seeing firsthand the time savings and increased accuracy which can be obtained by them.

V. INFORMAL PROGRAMS

There is great opportunity to use PHHC's for a variety of tasks. They can reduce the burden inherent in the manual manipulation of numbers. Their perfect accuracy is degraded only by the person pressing the keys. Even this problem can be diminished by creative programming which generates error codes/messages for inputs which are larger or smaller than the normal parameters for that specific input. The PHHC's potential uses are limited only by the ingenuity of those individuals having access to PHHC's. Several military officers with whom this author is acquainted have purchased PHHC's and have written programs to help them do their job better and faster. With TI-59's soon being available in USMC artillery batteries and perhaps later being available in mortar platoons also, more individuals will have a chance to harness the power of the PHHC. The Harrier calculator, with its modified face plate, is difficult to use as a conventional PHHC; however, it would be fairly easy to design an overlay which could be used to temporarily restore its original TI-58 keyboard appearance. This would enable its custodian to use it not only for flight planning but also for administrative problems. Even its flight planning capacity could be expanded via the Texas Instruments aviation module, which is discussed in more detail in Appendix B.

Calculator Clout: Methods of Programmable Calculators

by M. D. Weir, who is an Associate Professor at the Naval Postgraduate School, is recommended to those wanting to learn how to program the TI-58/TI-59. The book presents the basic elements of programming, including flow charts, looping and branching, subroutines and Master Library programs, indirect addressing, and the use of magnetic cards. There are numerous examples illustrating programming techniques to solve problems in business mathematics, algebra and trigonometry, basic calculus, and random number methods.

The following four sections will explain programs which can be used to solve arithmetic-related difficulties. Three of the program were written by military officers; the other by Texas Instruments' programmers.

A. NAVAL GUNFIRE PLAN FOR AMPHIBIOUS LANDINGS

Navy Lieutenant P. M. Loring, a Naval Gunfire Liaison Officer at Camp Lejeune, North Carolina, wrote a program for his HP-29C to reduce the time it takes him to complete the naval gunfire portion of the planning for an amphibious landing. This planning includes measuring the bearing and distance from the anticipated location of the naval gunfire ship to numerous targets in the amphibious objective area. He found that when using the program it took only ten minutes to do the planning for twenty-seven targets; whereas, it had required two hours to do it manually.

Loring also used the program after coming ashore during numerous exercises while attached to Battalion Landing Team 3/8 during its deployment with Landing Force Sixth Fleet in the Mediterranean Sea. The HP-29C is not card programmable, but it does have constant memory, which permits its user to turn it off without losing the program. By having two sets of nickel-cadmium batteries, which could be recharged by the 120 volt generator used to provide power for the Battalion Command Post, Loring expected to be able to use this program for extended periods of time.

Although the Naval Gunfire Liaison Officers are operationally controlled by the infantry commander, they are usually administratively attached to an artillery unit. Since several Marine artillery batteries will soon be receiving TI-59's, Loring's Naval Gunfire Planning Program has been translated into Texas Instruments-type programming steps so that the program will be available for wider use. Program listings and the instructions for using both the HP-29C and the TI-58/TI-59 versions of the program are contained in Appendix A.

B. AVIATION FLIGHT PLANNING

Captain J. E. Bull served during 1978 as an A-6 aircraft bombardier navigator with Marine All Weather Attack Squadron 533. One of Bull's collateral duties is known as "squadron navigation officer." Bull, then a First Lieutenant, had

purchased his own TI-58 and printer and the Texas Instruments (TI) Aviation Module. When tasked with the navigation and fuel planning for a squadron deployment from Cherry Point, North Carolina to Fallon, Nevada, Bull found the TI Aviation Module to be a great help in making the required computations. The deployment planning included in-flight refueling, which would permit a non-stop flight from Cherry Point to Fallon and also for the return flight. This use of airborne tankers intensified the need for precise time checkpoints and accurate fuel figures. Appendix B contains a copy of the printer tape generated for that return flight. The tape was generated by the Aviation (AV) Module's program number four (AV-04), which is entitled "Long Range Flight Plan." AV-04 is described in Appendix B.

Bull also found considerable use for AV-02, "Flight Plan With Wind." AV-02 determines the magnetic heading for the pilot to fly and the resultant ground speed based on (1) wind speed, (2) wind direction, (3) magnetic compass variation, (4) true airspeed, (5) and true course. Using the fuel flow rate, the leg distance, the departure time, and the ground speed, AV-02 calculates the flying time, the estimated arrival time at the next fix, and the fuel consumption for each leg. After making the above calculations, AV-02 also computes the total time enroute and the total fuel required thus far in the flight. In a letter solicited by this author, Bull wrote that it requires forty-five

seconds for his TI-58 to make the above calculations. By comparison, he reported that it takes ninety seconds using a CR-3, which is an aviation-peculiar, circular slide rule. It is not uncommon for a flight to have twenty different legs. The Aviation Module would cut fifteen minutes off the planing time required for such a flight.

Bull noted that AV-11, "Great Circle Flying", would be especially useful in preparing for a transoceanic flight. The characteristics of AV-11 and the other twenty-two programs on the Aviation Module are all explained in detail in the manual supplied with the module. The module currently retails for \$35.00.

C. CALCULATION OF PROMOTION COMPOSITE SCORES

Promotion to Corporal and Sergeant in the USMC is determined by a composite score which is calculated from such things as (1) rifle marksmanship score, (2) physical fitness test score, (3) number of essential subjects tests passed, (4) average duty proficiency score, (5) average conduct score, (6) time in grade, (7) time in service, (8) outside education courses completed, and (9) bonus points for having completed certain training. To the uninitiated, this might appear to be a simple addition exercise; it is not. The procedures to be used are detailed in Marine Corps Order P1400.29B. It is somewhat complicated, and consequently, error rates reaching as high as 4% have occasionally been

known to occur. Depending on the skill and experience of the person calculating the composite score, the time required ranges from two minutes to five minutes. In addition, each calculation should be checked by a supervisor, which means another two minutes. An infantry battalion will have about 200 Lance Corporals and Corporals on whom a composite score must be computed each promotion period, of which there are usually four each year.

First Lieutenant Edward A. Bream wrote a TI-59 program to automate the composite score calculation. He found that using the program reduced to less than a minute the time required to calculate each Marine's composite score. By having two different persons compute each score and compare the results, mistakes caused by input errors are easily detected before the scores are published. A slightly modified and partially optimized version of Bream's program and instructions for using it are presented in Appendix C. The program requires nearly all the capacity of a TI-59, which precludes the generating of error codes for spurious entries. This is not a problem as each score is calculated twice anyway, and any differences can be investigated and resolved.

D. CALCULATION OF PHYSICAL FITNESS TEST SCORES

The USMC physical fitness test (PFT) for males consists of a 3-mile run, two minutes of sit ups, and maximum possi-

ble pull ups. The raw score from each event is converted to a standard score by reference to a table in Marine Corps Order 6100.3H. To determine the overall PFT score, the training clerk extracts a number from the table, writes it on the score sheet, and adds up the three scores, a fairly simple task. In fact, the table's supporting algorithm is so uncomplicated that many Marines figure their score without looking at the table. Therefore, it was not difficult to write a TI-59 program which converts raw scores for each PFT event into standard scores and sums the three, arriving at the total. That program is explained in Appendix D and is offered as an example to encourage those who might be reluctant to try their skill at writing PHHC software.

VI. CONCLUSIONS AND RECOMMENDATIONS

The use of programmable hand-held calculators (PHHC's) in the operating forces of the U. S. Marine Corps has been initiated and survived operational testing. AV-8A Harrier pilots have been using a PHHC with a custom module since 1978. Its increased accuracy over conventional performance charts is widely acknowledged. The U. S. Army developed custom modules for use by artillery and mortar fire direction centers. Soldiers are enthusiastic about the PHHC's portability and reliability. They are quick to point out the speed with which it performs. The most obvious areas for additional usage are other aircraft communities and other artillery cannons/types of ammunition.

The major obstacle to more wide-spread adoption of PHHC systems is the software costs. An important question is whether the software development should be done by government programmers or by private contractors. It is recommended that strict cost accounting standards be used on any future projects where government programmers write the software for PHHC modules. This procedure will create a body of data regarding those costs. Alternatively, if the programming effort is contracted to private industry, competitive bidding should be employed unless an exception is granted in accordance with the Defense Acquisition Regulations.

For those who fear that computerizing aircraft performance data will require a new PHHC module with each NATOPS manual revision, it is pointed out that improved engines are only procured about once every ten years. Such a change requires flight testing to validate performance curves whether the end product is to be a revised chart in the NATOPS manual or a new module for the PHHC.

A cost-benefit analysis regarding PHHC's is fairly easy to do for transport type aircraft. Data obtained from Beechcraft Super King Air owners indicate a 10% fuel savings, which means the calculator paid for itself in less than three months of average use. For tactical military aircraft, tactics rather than economy often dictates the altitude at which an aircraft will fly its mission. However, even these aircraft conduct a certain amount of training in the cross country mode where 10% fuel savings could mean a lot of money. A-6 squadrons average about thirty hours per aircraft per month. If only three hours per aircraft per month were available for cross country training and if a Beechcraft-type PHHC were used to pick the most economical altitude, the 10% fuel savings would translate to about \$200 per aircraft per month at \$1.00 per gallon of jet fuel. Thus, it might take six months for the fuel savings to pay for PHHC's for the whole fleet of A-6's. A similar analysis could be made for other tactical communities. For aircraft which enjoy lower rates of fuel consumption, the

payback period would, of course, be longer. A fringe benefit is that tactically-oriented charts could also be computerized on the same module. Another way of looking at the costs and benefits is to predict that PHHC's, being easier, quicker, and more accurate to use, will probably prevent at least one accident during their life. One million dollars saved by one less accident would pay for all that aircraft community's calculators several times over.

APPENDIX A

A CALCULATOR PROGRAM WHICH DECREASES THE TIME NEEDED TO DO THE NAVAL GUNFIRE PLAN FOR AN AMPHIBIOUS LANDING

This appendix contains the program steps and the program operating instructions for the Naval Gunfire Planning Program introduced in Chapter V. The program has four primary subroutines. Their purposes are: (1) to compute gun-to-target range in meters and bearing in mils grid given six-digit grid coordinates of the gun and a target, (2) to compute a six-digit grid coordinate given range and bearing data from a known point, (3) to convert mils grid to degrees true, and (4) to compute the time of flight for a 5"/54 round given the range. The original HP-29C program was translated to Texas Instruments program language. Instructions on how to run the HP-29C program are presented first, followed by the HP-29C program listing and storage register uses. After that are the TI-58/TI-59 operating instructions, storage register uses, and program listing.

Operating Instructions for the HP-29C Naval Gunfire Planning Program

<u>Step</u>	<u>Instruction/Type of Data to Enter/ Subroutine Name</u>	<u>Input</u>	<u>Press Key(s)</u>	<u>Output</u>
1.	Key in program			

Operating Instructions for the
HP-29C Naval Gunfire Planning Program - Continued

<u>Step</u>	<u>Instruction/Type of Data to Enter/ Subroutine Name</u>	<u>Input</u>	<u>Press Key(s)</u>	<u>Output</u>
2.	Initialize		GSB 0	
3.a.	Gun position X coordinate	xxx	STO 2	
b.	Gun position Y coordinate	yyy	STO 4	
c.	Grid to true dec- lination (E= -)	mils	STO 8	
d.	Mils to degrees conversion	6400÷360	STO 9	
e.	5"/54 max range	23000	STO .0	
f.	5"/38 max range	15500	STO .1	
g.	Meters to feet conversion	3.280839895	STO .2	
h.	5"/54 max time of flight	167.78	STO .3	
4.	See note 1			
5.a.	Range and bearing		GSB 1	
b.	Target position X coordinate	xxx	R/S	xxx X 100
c.	Target position Y coordinate	yyy	R/S	range in meters
d.	Compute bearing		R/S	mils grid
6.a.	Grid coordinates		GSB 2	
b.	Enter bearing	mils grid	R/S	
c.	Enter range	meters	R/S	X location
d.	Determine Y		R/S	Y location

Operating Instructions for the
HP-29C Naval Gunfire Planning Program - Concluded

<u>Step</u>	<u>Instruction/Type of Data to Enter/ Subroutine Name</u>	<u>Input</u>	<u>Press Key(s)</u>	<u>Output</u>
7.a.	Mils grid to degrees true		GSB 3	
b.	Bearing	mils grid	R/S	degrees
8.a.	Time of flight		GSB 4	
b.	Range	meters	R/S	seconds

Note 1.

- a. Use step 5 to compute range and bearing information.
- b. Use step 6 to compute grid coordinates.
- c. Use step 7 to convert mils grid to degrees true.
- d. Use step 8 to compute time of flight for a 5"/54 round.
- e. For a different problem, simply enter the new data in accordance with the applicable step instructions.

Program Listing for the
HP-29C Naval Gunfire Planning Program

<u>Step</u>	<u>Instruction</u>	<u>Step</u>	<u>Instruction</u>	<u>Step</u>	<u>Instruction</u>
1.	LBL 0	20.	STO 3	39.	GSB 7
2.	GRAD	21.	RCL 1	40.	RCL 7
3.	FIX 0	22.	RCL 2	41.	+
4.	6	23.	-	42.	R/S
5.	4	24.	RCL 3	43.	P to R
6.	0	25.	RCL 4	44.	STO 3
7.	0	26.	-	45.	xy EX
8.	STO 5	27.	R to P	46.	STO 1
9.	2	28.	R/S	47.	RCL 4
10.	+	29.	xy EX	48.	RCL 3
11.	STO 6	30.	RCL 7	49.	+
12.	1	31.	X	50.	GSB 6
13.	6	32.	GSB 8	51.	RCL 2
14.	STO 7	33.	GTO 1	52.	RCL 1
15.	RTN	34.	LBL 2	53.	+
16.	LBL 1	35.	R/S	54.	GSB 6
17.	GSB 9	36.	RCL 6	55.	R/S
18.	STO 1	37.	xy EX	56.	xy EX
19.	GSB 9	38.	x > y	57.	GTO 2

Program Listing for the
HP-29C Naval Gunfire Planning Program - Concluded

<u>Step</u>	<u>Instruction</u>	<u>Step</u>	<u>Instruction</u>	<u>Step</u>	<u>Instruction</u>
58.	LBL 9	70.	RTN	82.	RCL 8
59.	R/S	71.	LBL 7	83.	+
60.	ENTER	72.	RCL 5	84.	RCL 9
61.	EEX	73.	-	85.	+
62.	2	74.	RTN	86.	GTO 3
63.	X	75.	LBL 6	87.	LBL 4
64.	RTN	76.	EEX	88.	R/S
65.	LBL 8	77.	2	89.	RCL .0
66.	x > 0	78.	+	90.	+
67.	RTN	79.	RTN	91.	RCL .3
68.	RCL 5	80.	LBL 3	92.	X
69.	+	81.	R/S	93.	GTO 4

Contents of the Storage Registers in the
HP-29C Naval Gunfire Planning Program

<u>Register Number</u>	<u>Contents</u>
0	not used
1	target's X coordinates
2	gun's X coordinates
3	target's Y coordinates
4	gun's Y coordinates
5	6400 (mils in 360°)
6	3200 (mils in 180°)
7	16 (mils per grad)
8	map grid to true declination
9	6400 ÷ 360
.0	23000 (max range of 5"/54)
.1	15500 (max range of 5"/38)
.2	meter to feet conversion
.3	167.78 (maximum time of flight in seconds for a 5"/54 round)

Operating Instructions for the
TI-58/59 Naval Gunfire Planning Program

<u>Step</u>	<u>Instruction/Type of Data to Enter/ Subroutine Name</u>	<u>Input</u>	<u>Press Key</u>	<u>Display</u>
1.	Read magnetic card or key in program			
2.	Initialize		E"	number 168
3.a.	Gun position X coordinate	xxx	A	same as input
b.	Gun position Y coordinate	yyy	R/S	same as input
c.	Grid to true dec- lination (E= -)	mils	R/S	same as input
4.	See Note 1			
5.a.	Range and bearing subroutine	target xxx	B	same as input
b.		target yyy	R/S	range in meters
c.			R/S	bearing in mils
6.a.	Grid coordinates subroutine	range in meters	C	same as input
b.		bearing in mils	R/S	xxx of the objective
c.			R/S	yyy of the objective
7.	Mils grid to degrees true	mils	D	degrees
8.	Time of flight for 5"/54 round	range in meters	E	time in seconds

Note 1.

- a. Use step 5 to compute range and bearing information.
- b. Use step 6 to compute grid coordinates.

- c. Use step 7 to convert mils grid to degrees true.
- d. Use step 8 to compute time of flight for a 5"/54 round.
- e. For a different problem, simply enter the new data in accordance with the applicable step instructions.

Note 2. If a printer is used, each input entry and all output data for steps 3, 5, 6, 7, and 8 will be printed.

Contents of the Storage Registers in the
TI-58/59 Naval Gunfire Planning Program

<u>Register Number</u>	<u>Contents</u>
0	not used
1	target's X coordinates
2	gun's X coordinates
3	target's Y coordinates
4	gun's Y coordinates
5	not used
6	not used
7	not used
8	map grid to true declination
9	6400 ÷ 360
10	23000 (max range of 5"/54)
11	15500 (max range of 5"/38)
12	meter to feet conversion
13	167.78 (maximum time of flight in seconds for a 5"/54 round)
14	used during step 5
15	used during step 6

The following pages of this appendix contain the program listing for the TI-58/59 Naval Gunfire Planning Program.

000 76 LBL
 001 12 B
 002 98 ADV
 003 99 PRT
 004 42 STD
 005 01 01
 006 91 R/S
 007 99 PRT
 008 42 STD
 009 03 03
 010 75 -
 011 43 RCL
 012 04 04
 013 95 =
 014 32 X/T
 015 43 RCL
 016 01 01
 017 75 -
 018 43 RCL
 019 02 02
 020 95 =
 021 22 INV
 022 37 P/R
 023 42 STD
 024 14 14
 025 32 X/T
 026 65 X
 027 01 1
 028 00 0
 029 00 0
 030 95 =
 031 99 PRT
 032 91 R/S
 033 00 0
 034 32 X/T
 035 43 RCL
 036 14 14
 037 67 EQ
 038 97 DSZ
 039 22 INV
 040 77 GE
 041 97 DSZ
 042 43 RCL
 043 14 14
 044 65 X
 045 43 RCL
 046 09 09
 047 95 =
 048 99 PRT

049 91 R/S
 050 76 LBL
 051 97 DSZ
 052 85 +
 053 03 3
 054 06 6
 055 00 0
 056 95 =
 057 65 X
 058 43 RCL
 059 09 09
 060 95 =
 061 99 PRT
 062 91 R/S
 063 76 LBL
 064 11 A
 065 98 ADV
 066 99 PRT
 067 42 STD
 068 02 02
 069 91 R/S
 070 99 PRT
 071 42 STD
 072 04 04
 073 91 R/S
 074 99 PRT
 075 42 STD
 076 08 08
 077 91 R/S
 078 76 LBL
 079 10 E'
 080 47 CMS
 081 58 FIX
 082 00 00
 083 06 6
 084 04 4
 085 00 0
 086 55 +
 087 03 3
 088 06 6
 089 95 =
 090 42 STD
 091 09 09
 092 02 2
 093 03 3
 094 00 0
 095 00 0
 096 00 0
 097 42 STD

098	10	10
099	01	1
100	05	5
101	05	5
102	00	0
103	00	0
104	42	STD
105	11	11
106	03	3
107	93	.
108	02	2
109	08	8
110	00	0
111	08	8
112	03	3
113	09	9
114	08	8
115	09	9
116	05	5
117	42	STD
118	12	12
119	01	1
120	06	6
121	07	7
122	93	.
123	07	7
124	08	8
125	42	STD
126	13	13
127	98	ADV
128	91	R/S
129	76	LBL
130	13	C
131	42	STD
132	15	15
133	98	ADV
134	99	PRT
135	32	X:T
136	43	RCL
137	15	15
138	91	R/S
139	99	PRT
140	55	+
141	43	RCL
142	09	09
143	95	=
144	37	P/R
145	55	+
146	01	1

147	00	0
148	00	0
149	95	=
150	85	+
151	43	RCL
152	02	02
153	95	=
154	99	PRT
155	91	R/S
156	32	X:T
157	55	+
158	01	1
159	00	0
160	00	0
161	95	=
162	85	+
163	43	RCL
164	04	04
165	95	=
166	99	PRT
167	91	R/S
168	76	LBL
169	14	D
170	98	ADV
171	99	PRT
172	85	+
173	43	RCL
174	08	08
175	95	=
176	55	+
177	43	RCL
178	09	09
179	95	=
180	32	X:T
181	00	0
182	77	GE
183	87	IFF
184	32	X:T
185	99	PRT
186	91	R/S
187	76	LBL
188	87	IFF
189	32	X:T
190	85	+
191	03	3
192	06	6
193	00	0
194	95	=
195	99	PRT

196	91	R/S
197	76	LBL
198	15	E
199	98	ADV
200	99	PRT
201	55	÷
202	43	RCL
203	10	10
204	65	x
205	43	RCL
206	13	13
207	95	=
208	99	PRT
209	91	R/S

APPENDIX B

FLIGHT PLANNING WITH AN OFF-THE-SHELF TEXAS INSTRUMENTS AVIATION MODULE

This appendix will explain the input and output data associated with the Texas Instruments Aviation Module (AV) program 04 (AV-04). As mentioned in Chapter V, AV-04 was used during the planning for a Marine All Weather Attack Squadron 533 (VMA AW 533) deployment from Cherry Point, North Carolina to Fallon, Nevada during 1978. AV-04 requires that a printer be used with the TI-58 or TI-59. The abbreviations on the printer tape and in the following text are defined as:

- WP = waypoint
- LAT = latitude
- LON = longitude
- GS = ground speed in nautical miles per hour
- FUEL = fuel in pounds at the beginning of the trip/leg
- BURN = fuel flow rate in pounds
- DIST = distance in nautical miles
- ETD = estimated time of departure
- ETE = estimated time enroute for the trip/leg
- ETA = estimated time of arrival
- EFR = estimated fuel required
- EFL = estimated fuel level at the end of the trip/leg
- LEG = the number of the leg to which the data pertains
- DLAT = degrees of latitude
- DLON = degrees of longitude
- TDST = total distance so far in the trip
- TC = true course for that leg

LON, LAT, DLAT, and DLON are expressed in DD.MMSS, where DD means degrees, MM means minutes, and SS means seconds. ETD and ETA are expressed by reference to the 24-hour military

clock and are coded HH.MMSS, where HH is the hour, MM is the minutes past the HH, and SS is the seconds past the minute. The program is divided into three parts. First, the LON and LAT of each WP are entered in order into the TI-58/TI-59 and are printed in a group along with the WP number. Second, the average GS for the whole trip, FUEL, BURN, and ETD for the trip are entered. In response, DIST, ETE, ETA, EFR, and EFL are computed and printed. In this example, EFL is a negative number because in-flight refueling will be conducted. Third, for each leg, the GS and BURN are entered if they differ from the values used on the previous leg. Also entered during this third phase are the new FUEL and the new ETD if they differ from the EFL and ETA values for the previous leg. A new value for FUEL was entered on LEG 11 due to the aerial refueling. The output data for each leg in the third phase are LEG, DLAT, DLON, DIST, TDST, TC, ETE, ETA, EFR, AND EFL. The input and the output data are printed in groups by LEG. On the following pages of this appendix is a copy of the printer tape generated during the planning for the VMA AW 533 return trip from Fallon to Cherry Point.

LONG RANGE FLT PLAN

0.0000	MP	11.0000	MP
39.2500	LAT	35.0321	LAT
118.4200	LON	94.5318	LON
1.0000	MP	12.0000	MP
39.0158	LAT	34.4100	LAT
117.1640	LON	92.1100	LON
2.0000	MP	13.0000	MP
38.1500	LAT	35.0400	LAT
114.2400	LON	89.5900	LON
3.0000	MP	14.0000	MP
37.4100	LAT	34.5800	LAT
112.1800	LON	85.0900	LON
4.0000	MP	15.0000	MP
36.4500	LAT	35.0200	LAT
108.0600	LON	81.5600	LON
5.0000	MP	16.0000	MP
35.3900	LAT	34.5500	LAT
105.0800	LON	78.0608	LON
6.0000	MP	17.0000	MP
35.1700	LAT	34.5400	LAT
101.3800	LON	76.5000	LON
7.0000	MP	400.0000	CS
35.2318	LAT	19000.0000	FUEL
99.1147	LON	4500.0000	BURN
8.0000	MP	14.0000	ETD
35.2418	LAT	1999.9031	DIST
98.4830	LON	4.5059	ETE
9.0000	MP	18.5459	ETA
35.2700	LAT	22498.9092	SFR
97.4600	LON	-3498.9092	SFL
10.0000	MP		
35.0718	LAT		
95.2213	LON		

Copy and use to RMC does not
 permit fully legible reproduction;

382.0000	GS		
13610.0000	BURN	5.0000	LEG
1.0000	LEG	35.0000	DLAT
39.0158	DLAT	105.0000	DLON
117.1640	DLON	158.0061	DIST
70.0022	DIST	684.0014	TDST
70.0022	TDST	113.0067	TC
108.7594	TC	0.0005	ETE
0.1060	ETE	15.0053	ETA
14.1060	ETA	1510.0091	EPR
3494.0577	EPR	10637.0099	EFL
16505.9423	EFL		
450.0000	GS	6.0000	LEG
4300.0000	BURN	35.0000	DLAT
2.0000	LEG	101.0060	DLON
38.1500	DLAT	172.0047	DIST
114.2400	DLON	856.0191	TDST
142.8007	DIST	96.0117	TC
212.8029	TDST	0.0060	ETE
108.2482	TC	15.0053	ETA
0.1002	ETE	1647.0091	EPR
14.3002	ETA	8989.0009	EFL
1364.5098	EPR		
15141.4025	EFL	7.0000	LEG
3.0000	LEG	35.0012	DLAT
37.4060	DLAT	99.0147	DLON
112.1800	DLON	119.0400	DIST
104.9890	DIST	976.0634	TDST
317.7919	TDST	86.0023	TC
108.2469	TC	0.0055	ETE
0.1060	ETE	16.0148	ETA
14.4402	ETA	1141.0467	EPR
1003.2283	EPR	7848.0041	EFL
14138.1742	EFL	420.0000	GS
4.0000	LEG	2000.0000	BURN
36.4500	DLAT	8.0000	LEG
108.0600	DLON	35.0015	DLAT
208.3265	DIST	98.0000	DLON
536.1184	TDST	19.0060	DIST
104.3144	TC	895.0004	TDST
0.2746	ETE	86.0006	TC
15.1148	ETA	0.0045	ETE
1990.6052	EPR	16.0031	ETA
12147.4991	EFL	90.0047	EPR
		3750.0000	EFL

340.0000	GS	450.0000	GS
6000.0000	BURN	4300.0000	BURN
9.0000	LEG	13.0000	LEG
35.2700	DLAT	34.4050	DLAT
97.4600	DLON	92.1050	DLON
50.9994	DIST	135.0100	DIST
1046.0677	TDST	1324.0807	TDST
86.6634	TC	98.7528	TC
0.0900	ETE	0.1800	ETE
16.2331	ETA	17.0807	ETA
899.9892	EFR	1290.1719	EFR
6857.5402	EFL	16278.0290	EFL

10.0000	LEG	13.0000	LEG
35.0718	DLAT	35.0400	DLAT
95.2213	DLON	89.5860	DLON
119.0061	DIST	110.7059	DIST
1165.0739	TDST	1434.7866	TDST
98.8346	TC	77.3817	TC
0.2100	ETE	0.1446	ETE
16.4431	ETA	17.3053	ETA
2100.1083	EFR	1057.8562	EFR
4757.4319	EFL	15220.1737	EFL

400.0000	GS	14.0000	LEG
18000.0000	FUEL	34.5000	DLAT
7200.0000	BURN	85.0500	DLON
11.0000	LEG	237.8562	DIST
35.0321	DLAT	1672.8448	TDST
94.5318	DLON	90.0590	TC
23.9888	DIST	0.3140	ETE
1189.0627	TDST	17.5233	ETA
99.3389	TC	2270.0007	EFR
0.0336	ETE	12950.1721	EFL
16.4807	ETA		
431.7991	EFR		
17568.2009	EFL		

15.0000	LEG
35.0150	DLAT
81.3550	DLON
158.1401	DIST
1830.4000	TDST
87.6214	TC
0.2105	ETE
18.1200	ETA
1511.0164	EFR
11439.0547	EFL

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16.0000	LEG
34.5500	DLAT
78.0608	DLOH
188.4717	DIST
2018.9566	TDST
91.0293	TC
0.2508	ETE
18.3846	ETA
1800.9517	EFR
9638.1040	EFL

420.0000	GS
2000.0000	BURN
17.0000	LEG
34.5400	DLAT
76.5260	DLOH
59.9823	DIST
2078.9389	TDST
90.6064	TC
0.0834	ETE
18.4720	ETA
285.6301	EFR
9352.4739	EFL

APPENDIX C

A CALCULATOR PROGRAM WHICH COMPUTES THE COMPOSITE SCORE USED IN THE CORPORALS' AND SERGEANTS' PROMOTION SYSTEM

This appendix contains: (1) the format specified by the Marine Corps Promotion Manual for use in recording the scores and the derived ratings applicable to each factor in the composite score, (2) instructions for using a TI-59 to calculate the composite score, (3) a description of how the TI-59's data registers are used, (4) location and purpose of each label used in the program, and (5) the program listing.

Using a TI-59 makes it possible to reduce both the required calculation time and the inherent error rate in non-automated procedures. The program works with or without a printer. The advantages of using a printer are: (1) Since all input data is echo printed, it is easier to locate errors caused by spurious entries. (2) Additional time is saved because it is not necessary to fill in the blanks on the format sheet; merely write the Marine's name on the tape and attach it to the format sheet. The only optimization technique used in the program was to place those subroutines called most frequently at the top of the program listing.

The acronyms used in this appendix are:

CON	conduct
DI	drill instructor

DSZ	decrement and skip on zero
EST	essential subjects test
GMP	general military proficiency
MSG	Marine security guard
NC	not considered
PFT	physical fitness test
PRO	proficiency
TIG	time in grade
TIS	time in service

Composite Score Format

<u>Line</u>		<u>Rating</u>
1	Rifle marksmanship score: _____	_____
2	PFT: _____ minus _____ = _____ score minimum difference	_____
3	Essential subjects: (number passed = ____)	_____
4	Subtotal	_____
5	GMP score (line 4 divided by ____)	_____
6	GMP score (from line 5) _____ X 100	_____
7	Average Duty Proficiency _____ X 100	_____
8	Average Conduct _____ X 100	_____
9	Time in Grade (months) _____ X 5	_____
10	Time in Service (months) _____ X 2	_____
11	DI/Recruiter/MSG Bonus _____ X 1	_____
12	Self-Education Bonus _____ X 10	_____
13	Composite Score (sum of lines 6 through 12)	_____

Instructions for Using the
TI-59 Composite Score Calculation Program

<u>Step</u>	<u>Instruction</u>	<u>Input</u>	<u>Press Key(s)</u>	<u>Output</u>
1.	Repartition	2	OP 17	799.19
2.	Read sides 1, 2, 3 & 4 of the mag cards			
3.	Initialize		E"	2
4.	See Note 1			
5.	Enter rifle score	xxx	A"	rifle rating
6.a	Enter Marine's age	xx	B"	min accep- table score
b.	Enter PFT score	xxx	C"	PFT rating
7.	Enter EST's passed	x	D"	EST rating
8.	PRO marks: See Note 2	x.x	A	same as input
9.	CON marks: See Note 3	x.x	B	same as input
10.	Enter TIG	months	C	TIG rating
11.	Enter TIS	months	D	TIS rating
12.a.	Enter DI/Recruiter/ MSG bonus	See Note 4	E	same as input
b.	Enter Self-Educa- tion bonus	See Note 5	R/S	Composite Score

Note 1.

If NC is applicable for line 1, 2, and/or 3 on the Composite Score Format, skip program instruction steps 5, 6, and/or 7 respectively. The criterion for NC is defined in the Promotion Manual for each case. Should step 5, 6, or 7 be skipped, the zero in the next to the last group of numbers on the printout means NC. The program will compute the correct average.

Note 2.

Enter each PRO mark applicable as directed in the Promotion Manual, and press A following the entry of each mark. The calculator program will compute the average of all marks entered.

Note 3.

Enter each CON mark applicable, and press B following the entry of each mark.

Note 4.

If no bonus is applicable, enter zero (0) and press E. If a bonus is applicable, enter the number of points authorized by the Promotion Manual and press E.

Note 5.

If the Marine is entitled to self-education bonus points, enter the number authorized and press R/S.

Note 6.

It is recommended that the program instruction steps be performed in numerical sequence so that the printout data can be easily related to the lines on the Composite Score Format. Step 3 MUST be performed before computing each Marine's score. Step 12 must be performed last.

Note 7.

A description of the printout for a typical case is provided in the following example. The vertical spacing of numbers in the example corresponds to that on an actual printout.

200.	rifle marksmanship score
4.4	composite score rating for that rifle score
18.	Marine's age
258.	Marine's score on the PFT
5.	composite score rating for that age and score
9.	number of essential subjects passed
5.	composite score rating for passing that many EST's
4.1	
4.5	PRO marks
4.9	
4.3	
4.5	CON marks
4.7	

17. months TIG
 85. composite score rating for that much TIG

 36. months TIS
 72. composite score rating for that much TIS

 0. DI/Recruiter/MSG bonus points

 1. self-education bonus points
 10. composite score rating for that much self-education

 4.5 composite score rating for the rifle score
 5. composite score rating for the Marine's PFT score
 5. composite score rating for the EST's passed

 480. $(4.5 + 5 + 5) \div 3 \times 100 = \text{GMP rating}$
 450. average PRO mark $\times 100$
 450. average CON mark $\times 100$
 85. months TIG $\times 5$
 72. months TIS $\times 2$
 0. DI/Recruiter/MSG bonus points
 10. self education bonus points
 1547. total composite score.

Data Register Usage in the Program

<u>Register</u>	<u>Usage</u>
00	used in converting the rifle score to a rating
01	composite score rating for the rifle score
02	composite score rating for the PFT score
03	composite score rating for the EST's passed
04	DSZ register - advances the tape before Step 9
05	summation register for number of GMP factors
06	summation register for PRO marks
07	summation register for CON marks
08	not used
09	composite score rating for TIG
10	composite score rating for TIS
11	minimum acceptable PFT score for Marine's age
12	PFT score less register 11
13	last PRO mark entered
14	last CON mark entered
15	number of PRO marks entered
16	number of CON marks entered
17	DI/Recruiter/MSG bonus points
18	composite score rating for self-education points
19	total composite score

Labels Used in the Program

<u>Numerical Location in the Program Listing</u>	<u>Label</u>	<u>TI-59 code for that Label</u>	<u>Purpose</u>
001	X ⁵	34	converts PFT score to composite score rating
009	1/X	35	converts rifle score to composite score rating
021	A	11	used to enter each PRO mark
034	B	12	used to enter each CON mark
050	)	54	averages all PRO marks entered
067	LNx	23	averages all CON marks entered
084	(	53	prints EST rating
091	ADV	98	advances tape before printing first CON mark
096	E"	10	initialization step
105	A"	16	used to enter rifle score
226	Y ^x	45	prints rifle rating
232	B"	17	used to enter Marine's age
259	X ²	33	provides exit from routine that determines the minimum acceptable PFT score for the Marine's age
264	C"	18	used to enter the PFT score
566	EE	52	prints the PFT rating
572	D"	19	used to enter EST's passed
659	C	13	used to enter months TIG
670	D	14	used to enter months TIS
681	E	15	enters bonus and computes total composite score

000 76 LBL
 001 34 FX
 002 43 RCL
 003 12 12
 004 22 INV
 005 77 GE
 006 52 EE
 007 92 RTN
 008 76 LBL
 009 35 1/X
 010 05 5
 011 94 +/-
 012 44 SUM
 013 00 00
 014 43 RCL
 015 00 00
 016 22 INV
 017 77 GE
 018 45 YX
 019 92 RTN
 020 76 LBL
 021 11 A
 022 99 PRT
 023 42 STD
 024 13 13
 025 44 SUM
 026 06 06
 027 01 1
 028 44 SUM
 029 15 15
 030 43 RCL
 031 13 13
 032 91 R/S
 033 76 LBL
 034 12 B
 035 97 DSZ
 036 04 04
 037 98 ADV
 038 99 PRT
 039 42 STD
 040 14 14
 041 44 SUM
 042 07 07
 043 01 1
 044 44 SUM
 045 16 16
 046 43 RCL
 047 14 14

048 91 R/S
 049 76 LBL
 050 54 >
 051 43 RCL
 052 06 06
 053 65 >
 054 01 1
 055 00 0
 056 00 0
 057 95 =
 058 55 +
 059 43 RCL
 060 15 15
 061 95 =
 062 44 SUM
 063 19 19
 064 99 PRT
 065 92 RTN
 066 76 LBL
 067 23 LN X
 068 43 RCL
 069 07 07
 070 65 X
 071 01 1
 072 00 0
 073 00 0
 074 95 =
 075 55 +
 076 43 RCL
 077 16 16
 078 95 =
 079 44 SUM
 080 19 19
 081 99 PRT
 082 92 RTN
 083 76 LBL
 084 53 (<
 085 43 RCL
 086 03 03
 087 99 PRT
 088 98 ADV
 089 91 R/S
 090 76 LBL
 091 98 ADV
 092 98 ADV
 093 61 GTD
 094 12 B
 095 76 LBL

096 10 E*
 097 47 CMS
 098 02 2
 099 42 STD
 100 04 04
 101 98 ADV
 102 98 ADV
 103 91 R/S
 104 76 LBL
 105 16 R*
 106 98 ADV
 107 99 PRT
 108 32 K/T
 109 02 2
 110 03 3
 111 04 4
 112 42 STD
 113 00 00
 114 05 5
 115 42 STD
 116 01 01
 117 01 1
 118 44 SUM
 119 05 05
 120 71 SBR
 121 35 1/X
 122 04 4
 123 93 .
 124 09 9
 125 42 STD
 126 01 01
 127 71 SBR
 128 35 1/X
 129 04 4
 130 93 .
 131 08 8
 132 42 STD
 133 01 01
 134 71 SBR
 135 35 1/X
 136 04 4
 137 93 .
 138 07 7
 139 42 STD
 140 01 01
 141 71 SBR
 142 35 1/X
 143 04 4

144 93 .
 145 06 6
 146 42 STD
 147 01 01
 148 71 SBR
 149 35 1/X
 150 04 4
 151 93 .
 152 05 5
 153 42 STD
 154 01 01
 155 71 SBR
 156 35 1/X
 157 04 4
 158 93 .
 159 04 4
 160 42 STD
 161 01 01
 162 71 SBR
 163 35 1/X
 164 04 4
 165 93 .
 166 02 2
 167 42 STD
 168 01 01
 169 71 SBR
 170 35 1/X
 171 04 4
 172 42 STD
 173 01 01
 174 71 SBR
 175 35 1/X
 176 03 3
 177 93 .
 178 08 8
 179 42 STD
 180 01 01
 181 71 SBR
 182 35 1/X
 183 03 3
 184 93 .
 185 05 5
 186 42 STD
 187 01 01
 188 71 SBR
 189 35 1/X
 190 03 3
 191 93 .

192 01 1
 193 42 STD
 194 01 01
 195 71 SBR
 196 35 1/X
 197 02 2
 198 93 .
 199 06 6
 200 42 STD
 201 01 01
 202 71 SBR
 203 35 1/X
 204 02 2
 205 42 STD
 206 01 01
 207 71 SBR
 208 35 1/X
 209 01 1
 210 93 .
 211 03 3
 212 42 STD
 213 01 01
 214 71 SBR
 215 35 1/X
 216 93 .
 217 05 5
 218 42 STD
 219 01 01
 220 71 SBR
 221 35 1/X
 222 00 0
 223 42 STD
 224 01 01
 225 76 LBL
 226 45 YX
 227 43 RCL
 228 01 01
 229 99 PRT
 230 91 R/S
 231 76 LBL
 232 17 B'
 233 98 ADV
 234 99 PRT
 235 32 X:T
 236 07 7
 237 08 8
 238 42 STD
 239 11 11

240 03 3
 241 09 9
 242 22 INV
 243 77 GE
 244 33 X²
 245 08 8
 246 04 4
 247 42 STD
 248 11 11
 249 02 2
 250 06 6
 251 22 INV
 252 77 GE
 253 33 X²
 254 09 9
 255 05 5
 256 42 STD
 257 11 11
 258 76 LBL
 259 33 X²
 260 43 RCL
 261 11 11
 262 91 R/S
 263 76 LBL
 264 18 C'
 265 99 PRT
 266 75 -
 267 43 RCL
 268 11 11
 269 95 =
 270 32 X:T
 271 01 1
 272 04 4
 273 09 9
 274 42 STD
 275 12 12
 276 05 5
 277 42 STD
 278 02 02
 279 01 1
 280 44 SUM
 281 05 05
 282 71 SBR
 283 34 FX
 284 01 1
 285 03 3
 286 09 9
 287 42 STD

288 12 12
 289 04 4
 290 93 .
 291 09 9
 292 42 STD
 293 02 02
 294 71 SBR
 295 34 FX
 296 01 1
 297 02 2
 298 09 9
 299 42 STD
 300 12 12
 301 04 4
 302 93 .
 303 08 8
 304 42 STD
 305 02 02
 306 71 SBR
 307 34 FX
 308 01 1
 309 01 1
 310 09 9
 311 42 STD
 312 12 12
 313 04 4
 314 93 .
 315 07 7
 316 42 STD
 317 02 02
 318 71 SBR
 319 34 FX
 320 01 1
 321 00 0
 322 09 9
 323 42 STD
 324 12 12
 325 04 4
 326 93 .
 327 06 6
 328 42 STD
 329 02 02
 330 71 SBR
 331 34 FX
 332 08 8
 333 09 9
 334 42 STD
 335 12 12

336 04 4
 337 93 .
 338 05 5
 339 42 STD
 340 02 02
 341 71 SBR
 342 34 FX
 343 06 6
 344 09 9
 345 42 STD
 346 12 12
 347 04 4
 348 93 .
 349 01 1
 350 42 STD
 351 02 02
 352 71 SBR
 353 34 FX
 354 03 3
 355 09 9
 356 42 STD
 357 12 12
 358 04 4
 359 42 STD
 360 02 02
 361 71 SBR
 362 34 FX
 363 02 2
 364 09 9
 365 42 STD
 366 12 12
 367 03 3
 368 93 .
 369 05 5
 370 42 STD
 371 02 02
 372 71 SBR
 373 34 FX
 374 01 1
 375 09 9
 376 42 STD
 377 12 12
 378 03 3
 379 93 .
 380 03 3
 381 42 STD
 382 02 02
 383 71 SBR

384 34 FX
 385 09 9
 386 42 STD
 387 12 12
 388 03 3
 389 93 .
 390 01 1
 391 42 STD
 392 02 02
 393 71 SBR
 394 34 FX
 395 01 1
 396 94 +/-
 397 42 STD
 398 12 12
 399 03 3
 400 42 STD
 401 02 02
 402 71 SBR
 403 34 FX
 404 04 4
 405 94 +/-
 406 42 STD
 407 12 12
 408 02 2
 409 93 .
 410 05 5
 411 42 STD
 412 02 02
 413 71 SBR
 414 34 FX
 415 06 6
 416 94 +/-
 417 42 STD
 418 12 12
 419 02 2
 420 93 .
 421 04 4
 422 42 STD
 423 02 02
 424 71 SBR
 425 34 FX
 426 07 7
 427 94 +/-
 428 42 STD
 429 12 12
 430 02 2
 431 93 .

432 03 3
 433 42 STD
 434 02 02
 435 71 SBR
 436 34 FX
 437 08 8
 438 94 +/-
 439 42 STD
 440 12 12
 441 02 2
 442 93 .
 443 01 1
 444 42 STD
 445 02 02
 446 71 SBR
 447 34 FX
 448 09 9
 449 94 +/-
 450 42 STD
 451 12 12
 452 01 1
 453 93 .
 454 09 9
 455 42 STD
 456 02 02
 457 71 SBR
 458 34 FX
 459 01 1
 460 00 0
 461 94 +/-
 462 42 STD
 463 12 12
 464 01 1
 465 93 .
 466 07 7
 467 42 STD
 468 02 02
 469 71 SBR
 470 34 FX
 471 01 1
 472 01 1
 473 94 +/-
 474 42 STD
 475 12 12
 476 01 1
 477 93 .
 478 05 5
 479 42 STD

480 02 02
 481 71 SBR
 482 34 FX
 483 01 1
 484 02 2
 485 94 +/-
 486 42 STD
 487 12 12
 488 01 1
 489 93 .
 490 03 3
 491 42 STD
 492 02 02
 493 71 SBR
 494 34 FX
 495 01 1
 496 03 3
 497 94 +/-
 498 42 STD
 499 12 12
 500 01 1
 501 93 .
 502 01 1
 503 42 STD
 504 02 02
 505 71 SBR
 506 34 FX
 507 01 1
 508 04 4
 509 94 +/-
 510 42 STD
 511 12 12
 512 93 .
 513 09 9
 514 42 STD
 515 02 02
 516 71 SBR
 517 34 FX
 518 01 1
 519 05 5
 520 94 +/-
 521 42 STD
 522 12 12
 523 93 .
 524 07 7
 525 42 STD
 526 02 02
 527 71 SBR

528 34 FX
 529 01 1
 530 06 6
 531 94 +/-
 532 42 STD
 533 12 12
 534 93 .
 535 05 5
 536 42 STD
 537 02 02
 538 71 SBR
 539 34 FX
 540 01 1
 541 07 7
 542 94 +/-
 543 42 STD
 544 12 12
 545 93 .
 546 03 3
 547 42 STD
 548 02 02
 549 71 SBR
 550 34 FX
 551 01 1
 552 08 8
 553 94 +/-
 554 42 STD
 555 12 12
 556 93 .
 557 01 1
 558 42 STD
 559 02 02
 560 71 SBR
 561 34 FX
 562 00 0
 563 42 STD
 564 02 02
 565 76 LBL
 566 52 EE
 567 43 RCL
 568 02 02
 569 99 PRT
 570 91 R/S
 571 76 LBL
 572 19 D'
 573 98 ADV
 574 99 PRT
 575 32 X/T

576	05	5
577	42	STD
578	03	03
579	01	1
580	44	SUM
581	05	05
582	08	8
583	22	INV
584	77	GE
585	53	(
586	04	4
587	93	.
588	08	8
589	42	STD
590	03	03
591	07	7
592	22	INV
593	77	GE
594	53	(
595	04	4
596	93	.
597	07	7
598	42	STD
599	03	03
600	06	6
601	22	INV
602	77	GE
603	53	(
604	04	4
605	93	.
606	04	4
607	42	STD
608	03	03
609	05	5
610	22	INV
611	77	GE
612	53	(
613	03	3
614	93	.
615	07	7
616	42	STD
617	03	03
618	04	4
619	22	INV
620	77	GE
621	53	(
622	03	3
623	42	STD

624	03	03
625	03	3
626	22	INV
627	77	GE
628	53	(
629	02	2
630	93	.
631	03	3
632	42	STD
633	03	03
634	02	2
635	22	INV
636	77	GE
637	53	(
638	01	1
639	93	.
640	06	6
641	42	STD
642	03	03
643	01	1
644	22	INV
645	77	GE
646	53	(
647	93	.
648	08	8
649	42	STD
650	03	03
651	00	0
652	22	INV
653	77	GE
654	53	(
655	00	0
656	42	STD
657	03	03
658	76	LBL
659	13	C
660	98	ADV
661	99	PRT
662	65	X
663	05	5
664	95	=
665	42	STD
666	09	09
667	99	PRT
668	91	R/S
669	76	LBL
670	14	D
671	98	ADV

672 99 PRT
 673 65 X
 674 02 2
 675 95 =
 676 42 STD
 677 10 10
 678 99 PRT
 679 91 R/S
 680 76 LBL
 681 15 E
 682 98 ADV
 683 99 PRT
 684 42 STD
 685 17 17
 686 91 R/S
 687 98 ADV
 688 99 PRT
 689 65 X
 690 01 1
 691 00 0
 692 95 =
 693 99 PRT
 694 42 STD
 695 18 18
 696 98 ADV
 697 43 RCL
 698 01 01
 699 99 PRT
 700 85 +
 701 43 RCL
 702 02 02
 703 99 PRT
 704 85 +
 705 43 RCL
 706 03 03
 707 99 PRT
 708 95 =
 709 55 +
 710 43 RCL
 711 05 05
 712 65 X
 713 01 1
 714 00 0
 715 00 0
 716 95 =
 717 98 ADV
 718 99 PRT
 719 44 SUM

720 19 19
 721 71 SBR
 722 54)
 723 71 SBR
 724 23 LNX
 725 43 RCL
 726 19 19
 727 85 +
 728 43 RCL
 729 09 09
 730 99 PRT
 731 85 +
 732 43 RCL
 733 10 10
 734 99 PRT
 735 85 +
 736 43 RCL
 737 17 17
 738 99 PRT
 739 85 +
 740 43 RCL
 741 18 18
 742 99 PRT
 743 95 =
 744 42 STD
 745 19 19
 746 99 PRT
 747 91 R/S

APPENDIX D

A CALCULATOR PROGRAM WHICH COMPUTES THE PHYSICAL FITNESS TEST SCORE

Listed below are the instructions for operating the TI-59 program which takes raw scores from the USMC male Physical Fitness Test (PFT) events and outputs the standard score for each event and a total overall score for the PFT.

<u>Step</u>	<u>Instruction</u>	<u>Input</u>	<u>Press Key</u>	<u>Output</u>
1.	Read magnetic card sides 1 and 4			See note 1
2.	Enter number of pulls ups	xx < 21	A	See note 2
3.	Enter number of sit ups	xx < 81	B	See note 3
4.	Enter run time in min. & sec.	xx.xx > 12	C	See note 4
5.	Compute total		D	See note 5

Note 1.

This program can be run with or without a printer for the TI-59. If a printer is used, labels as described in the following notes will be printed along with the scores.

Note 2.

If the Marine achieves more than twenty pull ups, enter the number 20. This is because the program generates an

error message if a number greater than 20 is entered and key A is pressed. For purposes of illustration, it could be assumed that the Marine whose score is being calculated had performed 78 sit ups and the calculator operator had correctly entered 78 but had erroneously pressed A instead of B. In that case the printer tape will look like this:

78
PULLUP ENTRY INVALID

In addition, the display will flash 9.9999999 99, which represents 9.9999999 times 10 to the 99th power, the largest number the TI-59 can generate. If a printer is not used, 9.9999999 99 will be flashed to indicate an invalid entry has occurred. In either case, simply enter the correct number and press the correct action key.

If, for example, 15 is entered, the output on the printer tape will look like this:

15
75 PULL

Regardless of whether the printer is or is not used, the TI-59 will stop with 75 in the display after 15 is entered and A is pressed.

Note 3.

If the Marine achieves more than eighty sit ups, enter the number 80. Otherwise, an error message is generated. If a number greater than 80, such as 81, is entered and B pressed, the tape will look like this:

81
SIT UP ENTRY INVALID

The TI-59 will flash 9.9999999 99 to call attention to the invalid entry regardless of whether or not a printer is being used.

If, for example, 78 is entered and B pressed, the output on the printer tape will look like this:

78
96 SIT

With or without a printer, the TI-59 will stop with 96 in the display.

Note 4.

For the three-mile run, the number to be entered into the calculator is the minutes followed by a decimal followed by the seconds. For twenty-two minutes and fifty seconds the entry will be 22.50. Since the PFT order directs that the timer only report the time in ten second intervals, 22.5 could be entered instead of 22.50. Do not enter a number such as 22.55. The printer tape for such a time will look like this:

22.5
71 RUN

The calculator displays 71 after the computation to indicate the standard score for that event.

If the calculator operator fails to press one of the number keys hard enough and doesn't notice that, for example, 2.5 instead of 22.5 is in the display prior to C being

pressed, the program will generate the following message if a printer is attached.

2.5
RUN ENTRY INVALID

As in the previous cases, 9.9999999 99 will be flashed in the display to draw attention to the error condition.

Note 5.

After pressing D to sum the three standard scores, the TI-59 display will show the total. For the three valid entries discussed in the previous notes, the total would be 242. The printer tape for the whole sequence will look like this:

```
15
75  PULL
78
96  SIT
22.5
71  RUN
242 TOTL
```

Note 6.

The steps may be performed in any order except that, of course, step 5 must be last. After step 5, the printer advances one space, and entries for the next Marine can be made.

Contents of the Storage Registers in the
TI-59 PFT Score Calculation Program

<u>Register Number</u>	<u>Contents</u>
0	not used
1	pull up entry

Contents of the Storage Registers in the
TI-59 PFT Score Calculation Program - Concluded

<u>Register Number</u>	<u>Contents</u>
2	sit up entry
3	run entry
4	pull up standard score
5	sit up standard score
6	run standard score
7	total score
8	not used
9	not used
10	not used
11	34.3
12	100
13	not used
14	34.1
15	not used
16	code to generate PULLU
17	code to generate SIT U
18	code to generate P ENT
19	code to generate RU
20	code to generate N ENT
21	code to generate RY IN
22	code to generate VALID
23	code to generate PULL
24	code to generate SIT
25	code to generate RUN
26	code to generate TOTL

The program listing for the TI-59 PFT Score Calculation Program is contained in the remaining pages of this appendix.

```

000 76 LBL
001 11 R
002 42 STD
003 01 01
004 99 PRT
005 02 2
006 01 1
007 32 X:T
008 43 RCL
009 01 01
010 77 GE
011 42 STD
012 65 *
013 05 5
014 95 =
015 42 STD
016 04 04
017 43 RCL
018 23 23
019 69 DP
020 04 04
021 43 RCL
022 04 04
023 69 DP
024 06 06
025 91 R/S
026 76 LBL
027 12 B
028 42 STD
029 02 02
030 42 STD
031 05 05
032 99 PRT
033 08 8
034 01 1
035 32 X:T
036 43 RCL
037 02 02
038 77 GE
039 43 RCL
040 06 6
041 01 1
042 32 X:T
043 43 RCL
044 02 02
045 77 GE
046 17 B'
047 61 CTO
048 99 PRT

```

```

049 76 LBL
050 17 B'
051 75 -
052 06 6
053 00 0
054 95 =
055 44 SUM
056 05 05
057 76 LBL
058 99 PRT
059 43 RCL
060 24 24
061 69 DP
062 04 04
063 43 RCL
064 05 05
065 69 DP
066 06 06
067 91 R/S
068 76 LBL
069 13 C
070 42 STD
071 03 03
072 99 PRT
073 32 X:T
074 01 1
075 02 2
076 77 GE
077 44 SUM
078 01 1
079 08 8
080 77 GE
081 18 C'
082 43 RCL
083 14 14
084 22 INV
085 77 GE
086 58 FIX
087 43 RCL
088 03 03
089 88 DMS
090 65 *
091 06 6
092 95 =
093 94 +/-
094 85 +
095 02 2
096 00 0
097 08 8

```

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MAR 81 J L REEVE

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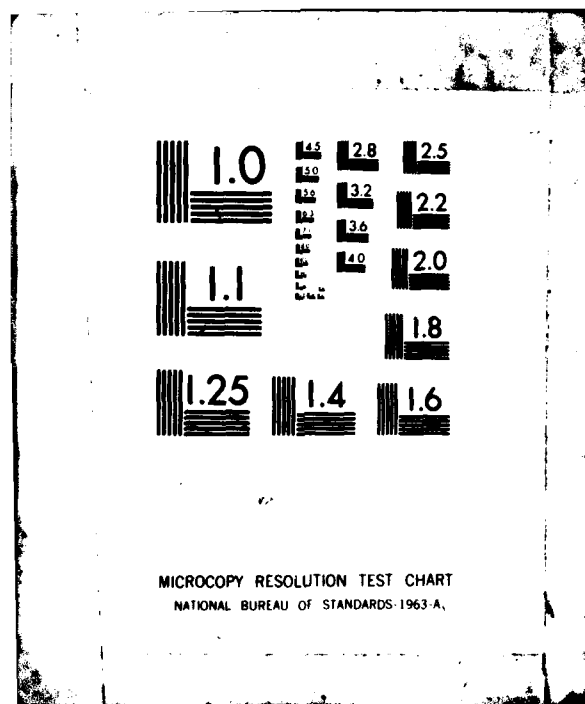
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2. 2

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11

END
DATE
4 JUL 68
3 42
DTIC



098 95 =
 099 42 STD
 100 06 06
 101 76 LBL
 102 90 LST
 103 43 RCL
 104 25 25
 105 69 DP
 106 04 04
 107 43 RCL
 108 06 06
 109 69 DP
 110 06 06
 111 91 R/S
 112 76 LBL
 113 18 C'
 114 43 RCL
 115 12 12
 116 42 STD
 117 06 06
 118 61 GTD
 119 90 LST
 120 76 LBL
 121 58 FIX
 122 03 3
 123 06 6
 124 22 INV
 125 77 GE
 126 97 DSZ
 127 03 3
 128 05 5
 129 22 INV
 130 77 GE
 131 98 ADV
 132 43 RCL
 133 11 11
 134 22 INV
 135 77 GE
 136 87 IFF
 137 03 3
 138 42 STD
 139 06 06
 140 61 GTD
 141 90 LST
 142 76 LBL
 143 97 DSZ
 144 00 0
 145 42 STD
 146 06 06

147 61 GTD
 148 90 LST
 149 76 LBL
 150 98 ADV
 151 01 1
 152 42 STD
 153 06 06
 154 61 GTD
 155 90 LST
 156 76 LBL
 157 87 IFF
 158 02 2
 159 42 STD
 160 06 06
 161 61 GTD
 162 90 LST
 163 76 LBL
 164 14 D
 165 43 RCL
 166 04 04
 167 85 +
 168 43 RCL
 169 05 05
 170 85 +
 171 43 RCL
 172 06 06
 173 95 =
 174 42 STD
 175 07 07
 176 43 RCL
 177 26 26
 178 69 DP
 179 04 04
 180 43 RCL
 181 07 07
 182 69 DP
 183 06 06
 184 98 ADV
 185 91 R/S
 186 76 LBL
 187 42 STD
 188 43 RCL
 189 16 16
 190 69 DP
 191 01 01
 192 43 RCL
 193 18 18
 194 69 DP
 195 02 02

196	61	GTD
197	76	LBL
198	76	LBL
199	43	RCL
200	43	RCL
201	17	17
202	69	DP
203	01	01
204	43	RCL
205	18	18
206	69	DP
207	02	02
208	61	GTD
209	76	LBL
210	76	LBL
211	44	SUM
212	43	RCL
213	19	19
214	69	DP
215	01	01
216	43	RCL
217	20	20
218	69	DP
219	02	02
220	76	LBL
221	76	LBL
222	43	RCL
223	21	21
224	69	DP
225	03	03
226	43	RCL
227	22	22
228	69	DP
229	04	04
230	69	DP
231	05	05
232	01	1
233	55	+
234	00	0
235	95	=
236	98	ADV
237	91	R/S

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