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AN EVALUATION OF DIGITAL LIQUID CRYSTAL DISPLAY QUARTZ MOVEMENT WATCHES FOR MILITARY/GOVERNMENT USE

PRODUCTIVITY, RELIABILITY, AVAILABILITY, AND MAINTAINABILITY PROGRAM OFFICE

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May 1979

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Final Report For Period June 1978 – March 1979

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AERONAUTICAL SYSTEM DIVISION
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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L.E. ULMAN, MAJOR, USAF
PROGRAM MANAGER

DAVE GUNNING
ENGINEERING PSYCHOLOGIST

FOR THE COMMANDER

ELBERT C. PARKER, COL, USAF
DIRECTOR, PRAM PROGRAM OFFICE

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The PRAM Program Office conducted an evaluation to determine the feasibility of replacing mechanical analog watches with a commercially marketed quartz crystal digital display watch for those military and civilian personnel who normally use a government issued watch. It was believed that this type of watch would be less costly and inherently, more reliable, rugged and accurate than the currently used analog watches. An initial quantity of 500 digital display watches were procured for test and evaluation: 50 were used in laboratory hardware performance testing and the remaining 450 were distributed -

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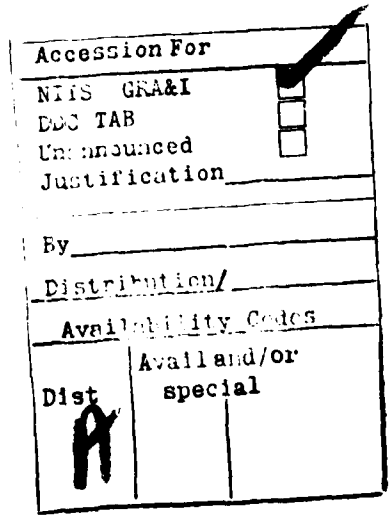
to personnel of the Air Force, Army, Navy and non-DoD government agencies. The majority of these were tested by USAF pilots, navigators and other aircrew personnel.

At the end of the evaluation period, each subject completed a detailed questionnaire. These were then analyzed with the following results: (1) a digital display would be readily accepted by US Government personnel as a substitute for currently issued analog watches, (2) the test watch was judged to be more reliable, rugged and more accurate than currently issued analog watches, (3) navigators and divers require additional features not available on the test watch (e.g. continuous seconds display, 24 hour clock, longer stop-watch function, etc.) while some additional features would be desirable for other users. Military specifications are recommended for navigator's and diver's watches while a commercial item description will suffice for other government watch procurement. Army and Marine combat operations may preclude the use of tritium backlighting in watches procured for those agencies.

PREFACE

This report (ASD-TR-79-5008) summarizes the findings of PRAM Project 20376-02 (Part 1), entitled "Use of Quartz Crystal Digital Display Movements in USAF Aircraft and Aircrew Watches," conducted by the Productivity, Reliability, Availability, and Maintainability (PRAM) Program Office of the Aeronautical Systems Division, Wright-Patterson AFB OH 45433. This report covers only that portion of PRAM Project 30276-02 which pertains to aircrew watches. Data on the aircraft clocks will be published at a later date under a separate report.

Engineering support for this project was provided by USAF, San Antonio Air Logistics Center, US Army Research and Development Command, US Navy Ships Engineering Center Mechanicsburg Division, General Services Administration (GSA) and the Defense Logistics Agency (DLA). Human factors support was provided by the Crew Equipment Engineering, Aeronautical Systems Division, AFSC. Data analysis and the final drafting of this report were supported by US Air Force Reserves Officers assigned to the Reserve Component of the AFSC Aeronautical Systems Division.



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SECTION I

INTRODUCTION

Digital wristwatches are one of the many products that resulted from the semiconductor revolution of the 1960s. However, it was not until early 1970 that technology reached the point where industry was capable of coupling together light emitting diode and liquid crystal displays with an electronic circuitry into a small package which did not exceed ten cubic centimeters in volume. As a result of the sudden saturation of the commercial market in 1976 and 1977 with digital wristwatches, this study was undertaken to update Air Force technology to include personal electronic timekeeping devices and to investigate the possible application of small electronic timepieces to the various requirements within the military for wristwatches and stopwatches.

1. Background

In June 1977, the PRAM Program Office recognized the need to adopt a standard commercial quartz crystal watch movement to replace the present mechanical analog navigator's watch. The program to accomplish this task was designated a PRAM project number 30276-02.

This need for a replacement of the mechancial movements surfaced principally because of spiraling buy programs and the requirement for increased performance at reduced costs. The use of standard commercially available quartz movements in lieu of mechanical movements specially built and qualified for the military was believed to be beneficial because of the inherent reliability, ruggedness, and accuracy of the quartz movement.

Presently, the Air Force is using at least four different types of watches. A navigation/submersible watch, managed and bought by the Air Force, is primarily used by the Air Force and Navy, navigators and underwater divers. A pilot hack watch is bought for the Air Force, Navy and other government departments by General Services Administration (GSA). The term "hack" is military jargon for the watch temporarily stopping and refers to the capability of being able to synchronize the watch with other timepieces. Another watch, the low priced, non-repairable, general purpose watch, procured by the Defense Logistics Agency (DLA), is used mainly by the Army, but also by the Air Force and Navy. The fourth type, a pocket stopwatch, is procured by GSA, DLA and USAF for the Air Force, Army, Navy and other departments. These numerous varieties, plus the fact that the only manufacturer of the Air Force navigator's watch is phasing out of the watch business, were other considerations that prompted the need for this study.

2. Objectives

The principle objectives of this project were as follows:

a. To determine the acceptance of digital display by military and civilian personnel who normally use government-issued mechanical analog dial timepieces.

b. To determine what features are essential and desired on a digital display electronic timepiece in relation to the individual's job requirements.

c. To determine what types and style of digital display wristwatches could be used in place of the present mechanical analog styles.

d. To develop a specification for navigation/submersible wristwatches.

e. To develop a commercial item description for a simplified version of a digital watch which will meet the general timepiece requirements of GSA and DLA customers.

3. Overall Approach

In order to best meet the objectives, the approach taken was to procure a quantity of 500 watches. These watches were tested and evaluated to help develop a military specification to coincide with the top industry standards of electronic timepieces and to integrate selected electronic timepieces in the government logistics system as a preferred replacement for current mechanical devices. Of the 500 watches procured, 50 were used in various laboratory hardware performance tests. The other 450 were distributed throughout the Air Force, Army, Navy and other government agencies that have personnel who are authorized a government issued watch.

SECTION II

DESCRIPTION OF THE TEST WATCH

The prototype test watches were battery powered, quartz crystal, 3 1/2 digit, six function liquid crystal display (LCD) commercial timepieces with solid state circuitry.

A standard Timex Marathon Model watchcase and module (reference Figure 1) was modified to include an aluminum black anodized coating, plastic unisex strap (reference Figure 2), tritium backlighting, 15 minute stopwatch, larger digit size, larger LCD viewing window, and enhanced water resistance to meet military specification, qualification and acceptance tests.

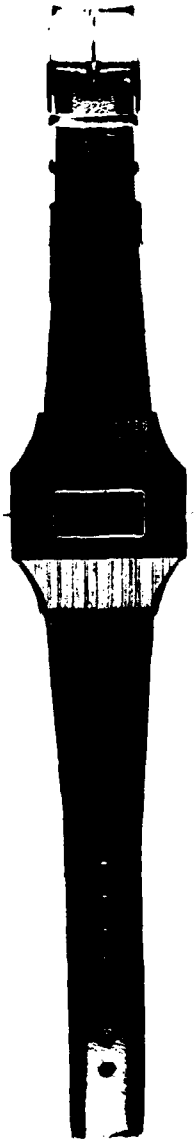


Figure 1 - Prototype Test Wristwatch

(A Modified Timex Marathon Model)

The watch circuit was contained on a single integrated circuit chip to provide all logic necessary to display either hours and minutes, month and date, or seconds, which were controlled by a single pole, single throw push button switch on the right-hand side. The logic also included a 15 minute, one second resolution stopwatch feature which was activated by means of a single pole, single throw push button switch on the left side of the watch (reference Figure 3). The left button also served as the setting function when rotated 180 degress with the flat side up (reference Figure 4, Operating Instructions).

Unlike most commercial watches, these prototypes had a shutdown feature which allowed the watch to be turned off for long term storage, thereby eliminating any drain on the battery.

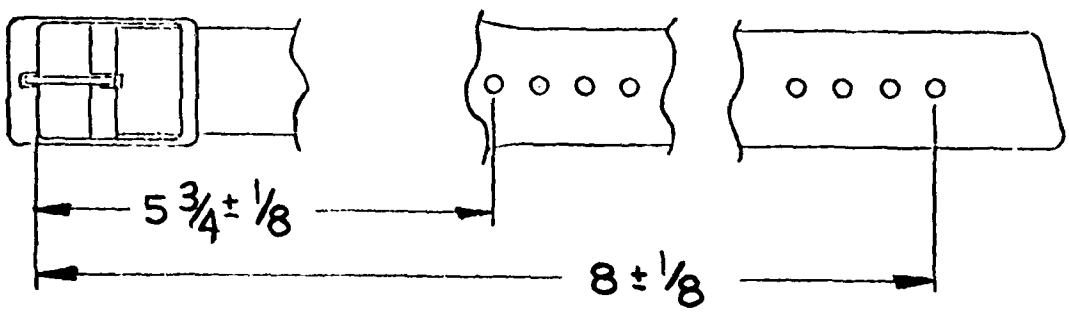


Figure 2 - Dimensions of Commercial Strap

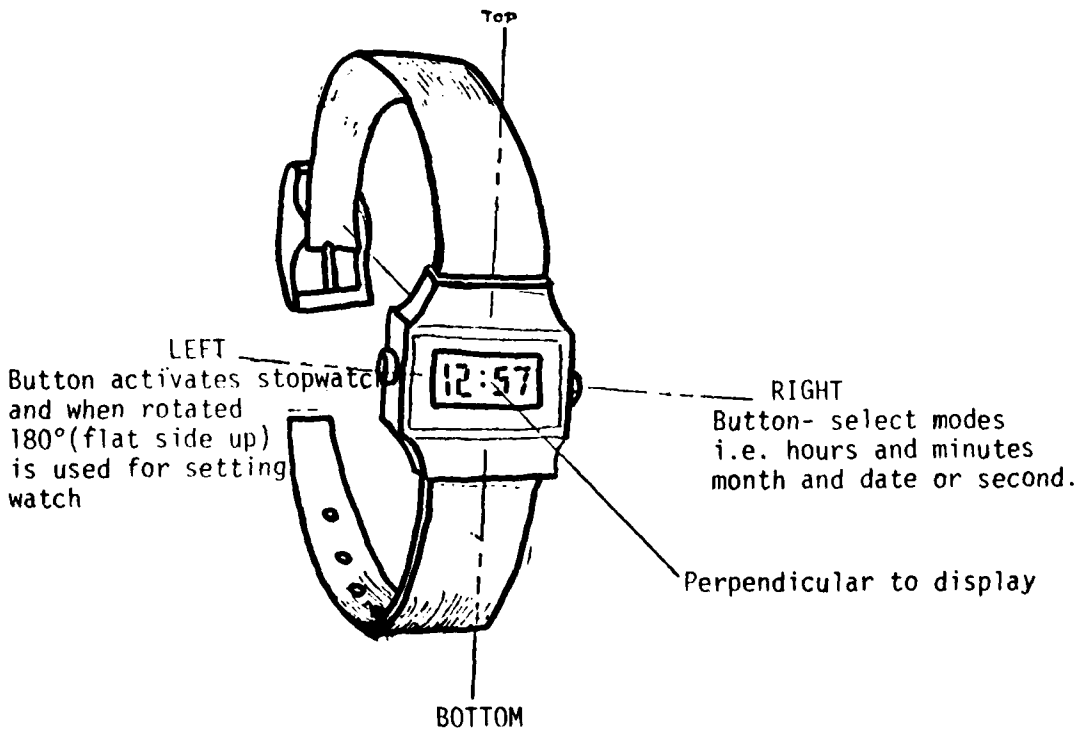


Figure 3 - Function(s) of push button switches

OPERATING INSTRUCTIONS

Your Timex Digital watch has a self-constructed tritium backlight that is completely independent of the battery on which the watch operates.

Starting of Your Timex SSQ Watch

To start your watch rotate the left button so the flat side is up, and rotate the right button so the flat side is down. Press both buttons once and the display will appear. Press the right button once and the colon will start to flash.

Setting Your Timex SSQ Watch

Rotate left button so flat side is up.

To Set Month

Press the left button repeatedly until month (no colon shows) appears on the left of the display. Press the right button and hold in until the number representing the proper month appears.

To Set Date

Press the left button once until the date (no colon shows) appears on the right of the display. Press the right button and hold until the proper date appears.

To Set Hours

Press the left button once until the hour (colon shows) appears on the left of the display, and "A" (AM) or "P" (PM) appears on the right on the display. Press the right button and hold until the proper AM or PM hour appears.

To Set Minutes

Press the left button once until the minute (colon shows) appears on the right of the display. Press the right button and hold in to set one or two minutes ahead of correct time. Press left button once to display time (colon not flashing). At the exact instant when the correct time (i.e. a time signal) is the same as the displayed time press the right button once (colon will start flashing). Rotate the left button so that the flat side is down. Seconds are automatically set to zero when minutes are set. The watch is now set and buttons are in the normal operating position.

Stop Watch Operation

The flat side of the left button must be facing down for the stop watch to operate.

1. Press the left button once and all zeros will appear on display.

2. Press the left button once and the stop watch will start to count at a one hertz rate.

3. Press the left button once and the stop watch will stop counting and display elapsed time.

4. Press the left button once and the watch will reset to all zeros. To return the watch to regular timekeeping, press the right button once. Your Timex Digital watch will continue to keep correct time while being used as a stop watch.

Operation of Your Timex SSQ

1. To display month and date, press the right button once. The date will be displayed momentarily, and then the time will reappear.

2. To display seconds, press the right button twice. Second will stay displayed until the right button is pressed again, and then the time will reappear.

How to Change the Energy Cell

1. Remove case back and old energy cell. A strong knife blade may be used to pry off the case back at the case back opening slot.

2. Insert a new Timex energy cell with the positive (+) side up. We recommend you use a geniune Timex energy cell type H (1504).

3. Align the case back and press case back firmly into place.

4. Reset all features on your watch referring to setting instructions.

5. Do not dispose of old energy cell in fire.

Figure 4 - Watch Operating/Setting Instructions

The watches were distributed to test subjects in a shutdown mode with a blank display. This required each test subject to thoroughly read the instructions in order to get the watch operating (turned on) and subsequently set each mode to the accurate time, day and month. The instructions did not include an explanation of the basic feature of the watch.

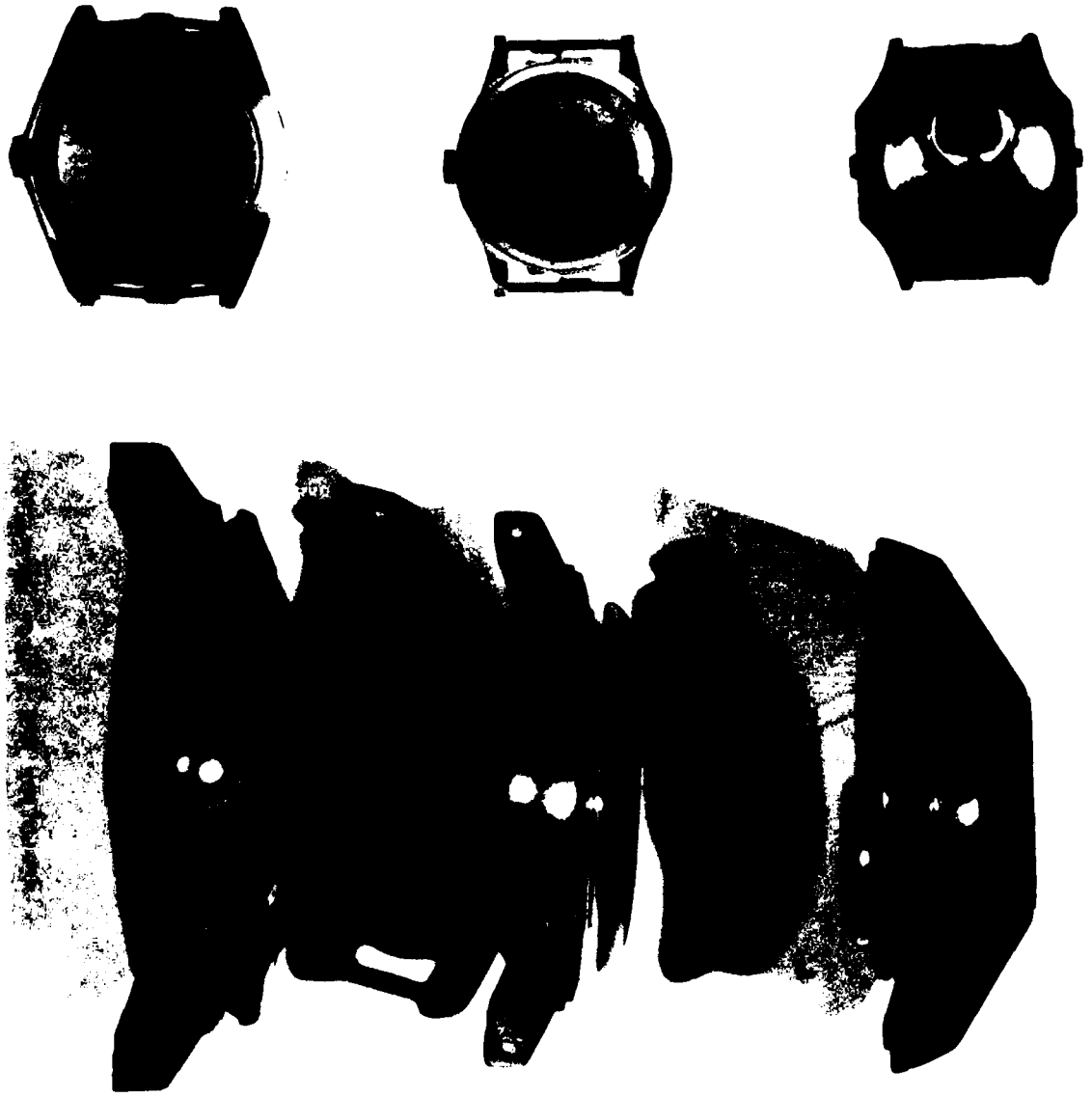
The Timex watch was selected because of its shock and water resistance features and possible low cost when produced in large quantities. It was also selected as one of the commercial styles which correlated closely to the size of mechanical watches most commonly used in government agencies (reference Figure 5). The case dimensions on the Timex watch are presented in Figure 6.

The watch was designed to meet the requirements of Federal Specification GG-W-113A wristwatch, hack; military specifications MIL-W-46374B General Purpose Watch; and MIL-W-50717A Navigation and Submersible Watch. It is capable of operation at a depth of 165 feet below sea level and an altitude of 35,000 feet. The watch was designed to have daily mean rate at 23°C ± 1.0°C within ± 2.5 seconds, and withstand storage temperatures of -20°C +60°C without evidence of damage. The watch was also designed to withstand shock equivalent to an uncontrolled drop of 30 inches onto a hardwood block, and 30 minutes of vibration between 10 and 55 Hz without showing evidence of damage. While running the daily mean rate, the watch was not affected when subjected to a magnetic field of 125 gauss.

The liquid crystal was designed with a minimum life of 50,000 hours.

Digit dimensions are listed in Figure 7.

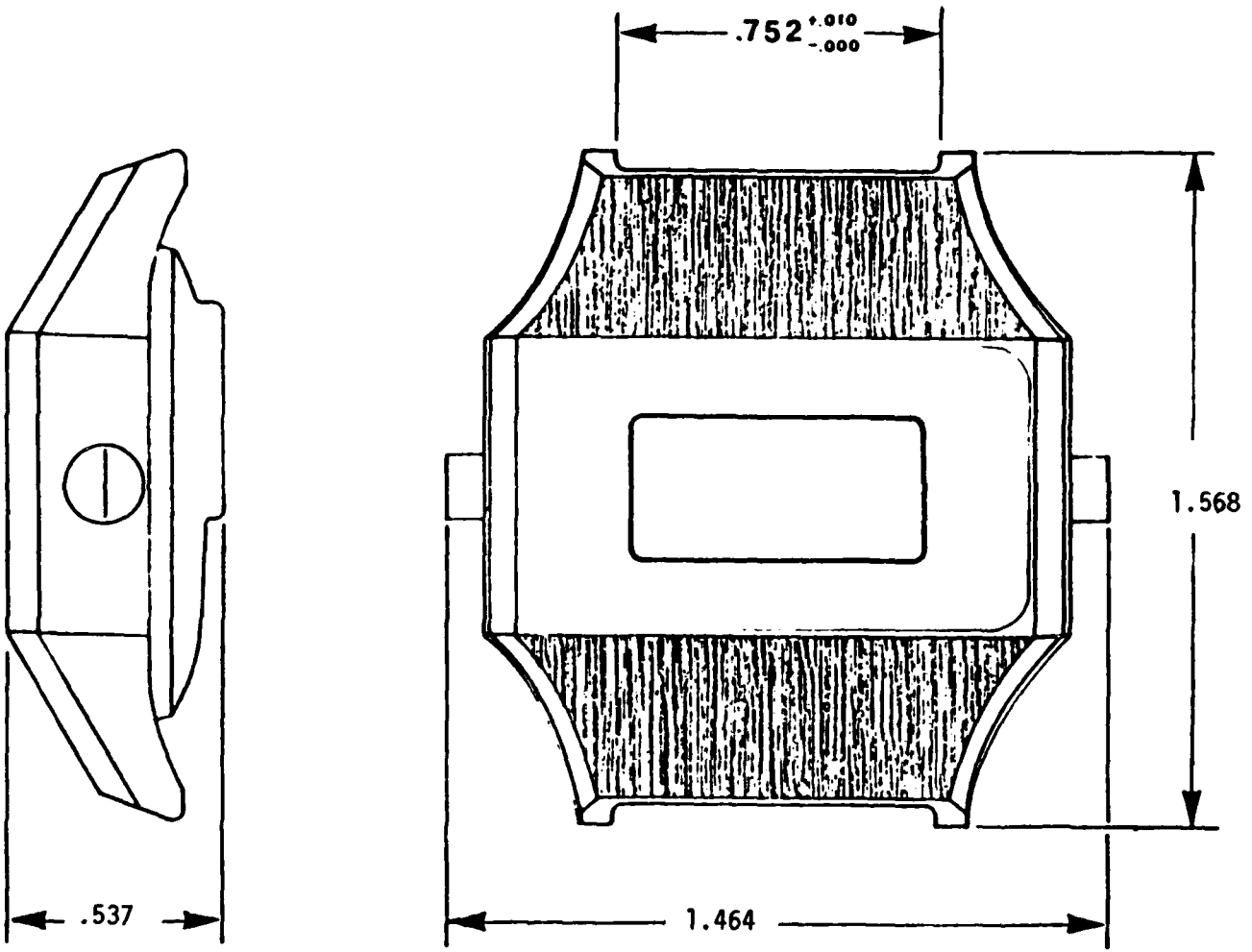
The digital watch was evaluated as a possible substitute for any one or all of the watches commonly utilized in the government (reference Figures 8 and 9).



1 2 3

FIGURE 5 - Comprison of Watch Case Sizes

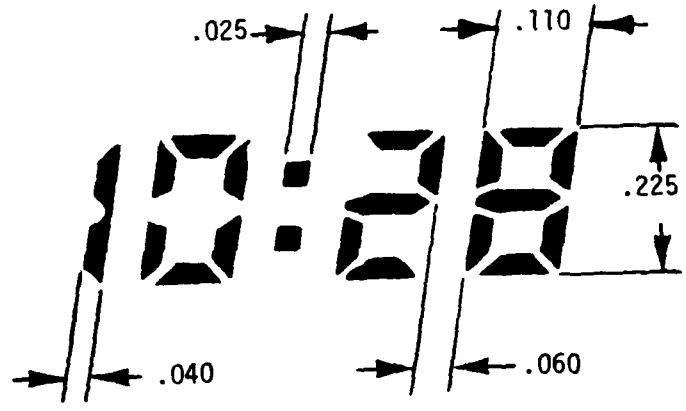
Comparison of Mil Spec MIL-W-50717 Navigation Watch (#1) NSN 6645-00-225-1741 to federal specification GG-W-113A wrist watch (#2) NSN 6645-00-066-4279; and digital prototype watch (#3).



NOTE:
DIMENSIONS IN INCHES
UNLESS OTHERWISE
SPECIFIED

TOLERANCES
DECIMALS ±.010

Figure 6 - Prototype Watch Case Dimensions



NOTE DIMENSIONS IN INCHES
UNLESS OTHERWISE
SPECIFIED

TOLERANCES
DECIMALS ± .010

Figure 7 - Digital Display Dimensions

Wrist Watches

1. Wristwatch
   GSA Managed
   GG-W-113A NSN 6645-00-066-4279

2. General Purpose Watch
   DLA Managed
   MIL-W-46374B NSN 6645-00-952-3767

3. Navigation and Submersible Watch
   USAF Managed
   a. MIL-W-50717A NSN 6645-00-225-1741
      Type 2 Class A Style N

   b. MIL-W-50717A NSN 6645-00-477-4210
      Type 1 Class A Style N Luminous dial

   c. MIL-W-50717A NSN 6645-00-595-5431
      Type 1 Class A Style N Luminous dial

4. Submersible Watch (Non-magnetic)
   Navy Managed
   MIL-W-22176A NSN 6645-752-8638

Pocket Watches

5. GSA/DLA Managed
   a. MIL-S-14823 NSN 6645-00-126-0286
      Pocket stopwatch

   b. GG 5764 NSN 6645-00-250-4680
      Pocket stopwatch

   c. WS 605 NSN 6685-00-241-3280
      Pocket watch (replaced by watch 6645-00-225-1741)

   d. MIL-W-5492A NSN 6645-00-526-7374
      Navigators pocket stopwatch

   e. NSN 645-00-052-7288 Pocket watch
      coded local purchase by GSA

Figure 8 - Timepieces Commonly Used By the US Government
(Specifications and National Stock Numbers)

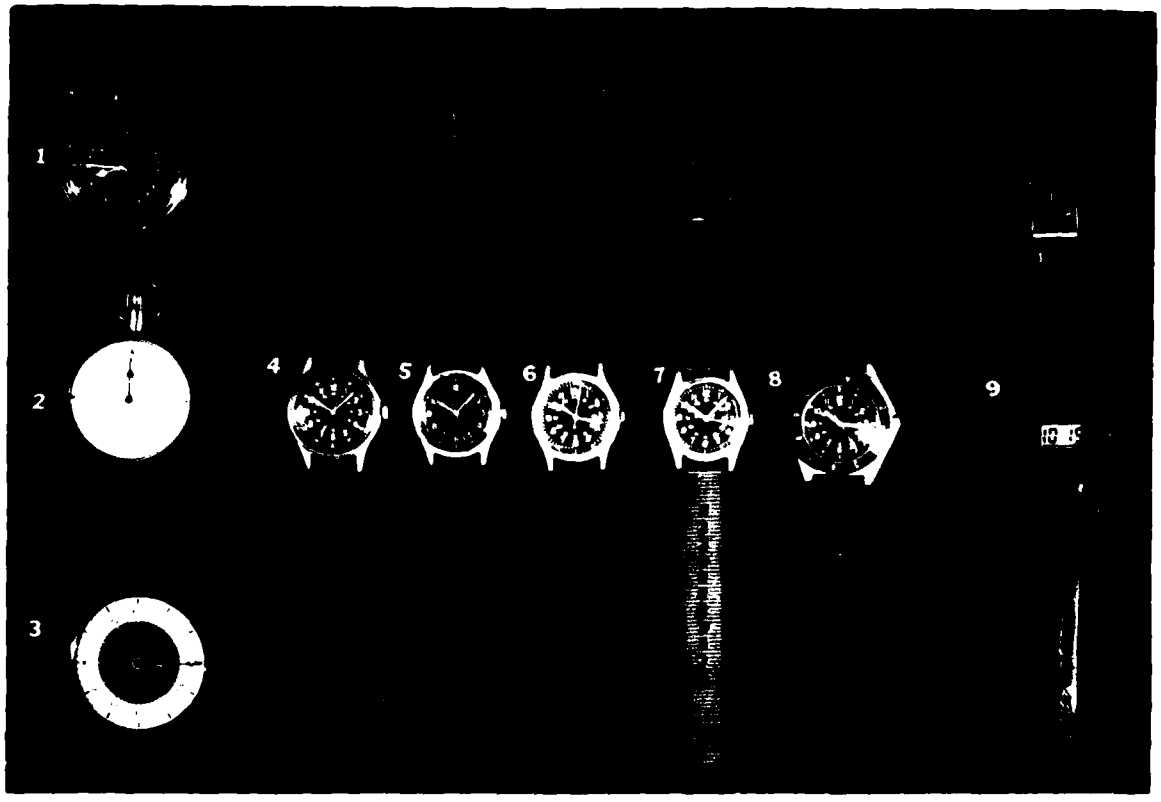


Figure 9 - Photo of Timepieces Used by the US Government

1. NSN 6645-00-526-7374
2. NSN 6645-00-250-4680
3. NSN 6645-00-126-0286
4. NSN 6645-00-420-6363
5. NSN 6645-00-719-8652
6. NSN 6645-00-066-4279
7. NSN 6645-00-952-3767
8. NSN 6645-00-225-1741
9. USAF Prototype Test Watch

Following the test use period of one to four months, the testers were asked to respond to a prepared questionnaire on the watch. Questions concerning five major areas of evaluation were asked: (1) evaluator's background, (2) watch design and construction, (3) assessment of digital display, (4) mechanical problems, and (5) overall assessment of digital watch. The category on the evaluator's background included his/her job title, rank, organization and a brief description of his/her duties. The watch design and construction section included questions on comfort, adjustment, size of buttons, crystal scratching, and case/buckle snagging. The section of digital display consisted of questions on visibility, size of display and mental adjustment to digital time. The part on mechanical problems had questions on mode/setting of buttons, watchband, buckle, case spring bars, accuracy of time, and the stopwatch function. The last section on overall assessment contained questions about whether or not the digital watch should be included in the USAF inventory. A sample questionnaire is included in the Appendix.

The questionnaires were analyzed in detail. This task included detailed data recording and a computer statistical analysis of the responses. The combined product is presented in the Evaluation Results Section of this report.

The fifty watches which were tested within the laboratory environment were evaluated as to hardware performance, The watches were subjected to the performance and environment requirements of the following military and federal specifications:

SECTION III
APPROACH

1. Evaluation Procedures

In the distribution of watches, emphasis was placed on providing test watches only to those personnel who are normally authorized a government timepiece in the performance of their job. Approximately 5% of the watches were evaluated by staff personnel who at one time were authorized a watch but are currently not authorized government issued timepieces. The watches and questionnaires were distributed to Major Commands or higher headquarters who in turn selected various bases and activities at locations throughout the continental U.S. Test monitors were appointed at each location to control the distribution of the watches and questionnaire. Each test monitor was provided instructions concerning the selection of test subjects and properly briefing the test subjects. Specific instructions included the following:

"The method of selecting personnel is important. Subjects should be randomly chosen at each activity or base from a variety of squadrons. If only one squadron is selected at a base, then the peculiar activities of that squadron could bias the test results. Subjects must not be chosen because they volunteer or because they are known by the test administrator.

It is also important that each subject be instructed not to discuss the watch with other subjects during the test because such activity could cause subjects to be influenced by others who have strong opinions.

The types of conditions under which the evaluator actually uses the watch is very important. Exposure to electronic equipment and electronic countermeasure equipment should be noted in the event such equipment affects the memory module or accuracy of the watch. Also, navigators should use the watch to navigate a number of night celestial, day celestial and radar missions as well as for a specified period of time."

Federal Specification GG-W-113A
Military Specification MIL-S-46383B
Military Specification MIL-W-46374A

The watches met or exceeded the requirements of these specifications.

2. Test Subjects

The specific DoD services and government agencies involved in the testing are as follows: US Air Force (ATC, AFSC, SAC, and ANG), US Army, US Navy, GSA, US Dept of Interior - Geological Survey, US Dept of Labor - Mine Safety and Health Administration, US Dept of Agriculture - Forest Service and US Dept of Commerce - National Bureau of Standards. The personnel tested the watch in everyday environment over a period of one to four months. These personnel had a variety of jobs. About two thirds of the personnel were aircrew members, pilots, navigators, loadmasters, refueling boom operators and flight engineers. Other testers had jobs such as flight test engineers, pilot and navigator instructors, operations officers, commanders, paratroopers, marines, field duty positions, miners, divers, survival training instructors, forest rangers and laboratory technicians. In all, 91.7% of the testers were military and 8.3% were civilians.

Questions 1 and 2 of the Questionnaire pertained to the personnel background, including a brief description of his/her job and the conditions under which the watch was used. This data is presented below:

QUESTION 1

Evaluator's Background:

Name, Rank/Grade:
AFSC and Position Title:
Major Command/Activity:
Base, phone:
Evaluation Dates:

COMMENT: Of the 425 questionnaires returned on the digital watch, 91.7% were military personnel while 8.3% were civilians. The rank/grade structure of these subjects is presented below:

4.0% - Jr. Enlisted or GS-1 - GS-4
22.8% - Sr. Enlisted or GS-5 - GS-8
45.7% - Jr. Officer or GS-9 - GS-12
25.1% - Sr. Officer or GS-13 - GS-16
2.4% - General Officer

The commands of ATC, SAC, and AFSC were represented by 25.6, 24.0 and 21% of the subjects, respectively. While the Navy, Army and Air National Guard were responsible for 10.6, 4.5 and .8% of the answers. The remaining questionnaires were submitted by a number of other interested organizations: GSA, AFLC, U.S. Readiness Command, Mine Safety, Geological Service and Bureau of Standards.

Pilots represented the largest percentage (30.5%) of those that tested the watch. Navigators ranked second at 18.1%, while field and staff duty personnel both ranked at 8.6%. Other jobs represented at small percentages included paratroopers, flight test personnel, load-masters, commanders, survival instructors, forest rangers, and miners.

The most common length of test time was 90 days. The 90 day test was performed by 40% of the subjects, while test periods of 120, 60, and 30 days only represented 6.8, 3.4, and 5.5% of the subjects, respectively.

QUESTION 2

Brief description of conditions/job position under which watch was evaluated; i.e., B-52 bomb navigator, flight nurse, airborne jumps, field duty, dusty or cold weather conditions, etc. The types of conditions

under which the evaluator actually uses the watch are more important than the length of the time of the test (e.g., a SAC navigator should use the watch to navigate on a number of night celestial, day celestial, and radar missions as well as for a certain specified period of time). If possible, specify the detailed conditions/ mission scenarios under which these will be tested.

COMMENT: From the answers to this question, a number of use and environmental categories were identified. Most of these categories have been developed into yes/no questions such as, "Was the watch worn in the water?" These categories were listed according to title, Table 1, and included the percentages of either yes, no or unknown responses. In those cases in which the subject's description of his/her job or use of the watch did not relate to a specific category, the response "unknown" was used. One category, entitled, "Temperature," did not fit the yes/no mode. In this case, 79% indicated the watch was used under normal temperature conditions while 12.5% indicated extreme cold use and 4.2% indicated use in very hot weather. The remaining 4.3% had exposes the watch to varying degrees of both hot and cold temperatures.

TABLE 1 - JOB ENVIRONMENTS IN WHICH THE DIGITAL WATCHES WERE EVALUATED

CATEGORY	PERCENTAGES		
	YES	NO	UNKNOWN
Exposed to vibration	23.4	47.4	29.2
Exposed to shock	40.3	32.6	27.1
Used at high altitudes	45.5	31.4	23.1
Used in water	19.1	48.6	32.3

CATEGORY	PERCENTAGES		
	YES	NO	UNKNOWN
Exposed to decompression	5.2	63.4	31.4
Used in brightness	77.2	1.3	21.5
Used at dusk	76.0	1.8	22.2
Used in darkness	75.1	23.7	1.2
Used in the office	8.3	81.5	10.2

SECTION IV

EVALUATION RESULTS

This section summarizes the responses of the evaluators to the questions contained in the PRAM Program Office questionnaire. The results of the statistical analysis are presented together with a summary of written comments on a question by question basis. Statistics and written comments were interpreted in every case. A total of 100 questionnaires was separately analyzed by HQ Strategic Air Command and not returned to the PRAM Program Office. However, the comments and statistics submitted by SAC were incorporated with the other responses whenever possible. Four hundred and fifty questionnaires were sent out and 425 responses tabulated in this report. The remaining 25 questionnaires were not returned in time to be compiled in this report.

This section contains an analysis of the test subject responses to questions 3 thru 6 of the PRAM questionnaire. These questions deal with the design and construction of the test watch, the test subject's assessment of the digital display, mechanical failures encountered, and the individuals overall assessment of the watch.

1. Design and Construction

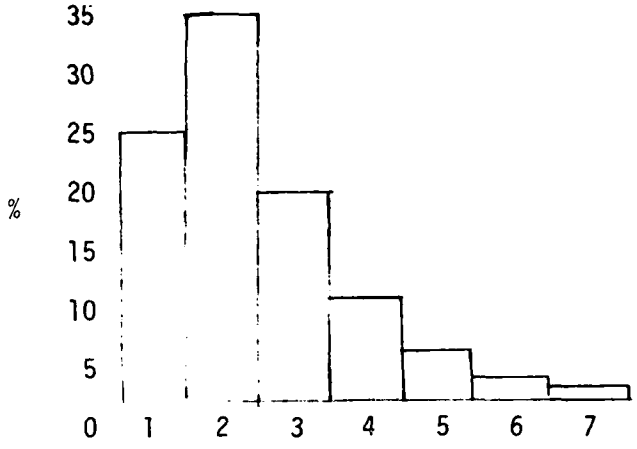
The watch design and construction section of the questionnaire included questions on comfort, adjustment, size and placement of control buttons, crystal scratching, and case or band catching. In general, the evaluation of the watch's design and construction produced favorable results with some exceptions as noted in the detailed comments pertaining to the individual questions.

QUESTION 3.a

Rate the watch's comfort by circling the applicable number below:

Extremely Comfortable	1	2	3	4	5	6	7	Extremely Uncomfortable

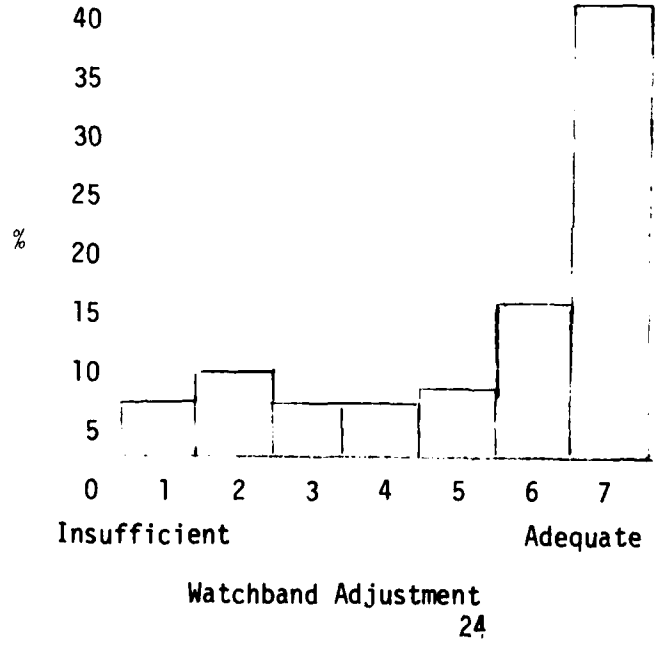
COMMENT: The evaluators rated the watch as very comfortable. The design and location of the battery seemed to cause the greatest degree of discomfort. This problem is due to the thickness of the module and battery which caused the battery to protrude beyond the case back (Ref Figure 6).



QUESTION 3.b. Rate the watchband adjustment by circling the applicable number below:

Does not have sufficient adjustment	1	2	3	4	5	6	7	Adjustment is adequate to fit wrist

COMMENT: The watchband adjustment was generally rated as being adequate. Some of the evaluators complained that the watchband was too small for their wrists or for wear over outer garments such as wet suits.



QUESTION 3.c. Does the band or case catch or hook on clothing or other objectives? If so, what could be improved?

Yes (32%) No (68%)

COMMENT: The most frequent complaint was that the buckle caught on clothing. Other complaints involved the thickness of the case and the sharpness of its edges. Suggestions made by the evaluators included: beveling or tapering the watch edges, indenting the buckle and making the catch pin flush with the buckle edge, switching to a round case and providing a thinner case.

Question 3.d. Are the buttons for control of digital display of proper size to provide for ease in adjustment time, date, or stopwatch feature?

Yes (84.5%) No (15.5%)

COMMENT: The comments from those wearing gloves (pilots and those exposed to cold weather) experienced difficulty in activating modes of the watch. One response indicated that the buttons were too close to the wrist and were easily activated accidentally. Also mentioned were that buttons were cumbersome to operate and perhaps should be on the right side.

QUESTION 3.e. If you exposed the watch to any type of pressure (or cabin altitude) changes, indicate the low and high extremes of the ranges experienced.

Low _____ feet; High _____ feet

COMMENT: The watch was used at altitudes ranging from minus 100 feet (Navy divers) to 40,000 feet (USAF pilots and navigators). Altitude and pressure did not seem to affect the performance of the watch. Underwater operations were affected by the action of salt jamming the action of the mode buttons rather than to any adverse pressure effect.

QUESTION 3.r. Does the crystal scratch easily?

Yes (44%) No (56%)

COMMENT: A significant number of the evaluators complained that the face crystal was easily scratched. Some respondents feel that the high incidence of scratching might be due to the elevated surface mounting and the plastic construction.

QUESTION e.g. Did you expose the watch to any type of shock or vibration? If so, describe any effect on the watch.

Yes (50%) No (50%)

COMMENT: The watch was exposed to numerous types of physical abuses, with no adverse effect, such as sports activities, airborne jumps, chopping and splitting firewood, flight "G" forces, and dropping on hard surfaces.

In a few cases, the stopwatch mode was activated by vibration. With the exception of flight "G" forces and airborne jumps, nearly all of the shock and vibration forces were encountered during off-duty activities. However, it should be recognized that the watch will be worn by individuals both on and off-duty and that off-duty damage to a watch will create an equal need for watch repair or replacement. In summary, the features of this watch which make is resistant to shock and vibration seem to be extremely effective.

2. Assessment of Digital Display

The section on the digital display consisted of questions concerning visibility during different lighting conditions, the size of the display, and mental adjustment to a digital time display. The assessment of the digital display produced generally favorable results. The display was judged to be very clear and legible under varying lighting conditions. Eighty-three percent of the subjects reported no problem with the size of

the digital display (the 15% that did report a problem were mostly navigators who complained about a lack of 24-hour clock and a lack of a continuous seconds readout). In comparison with the analog display, 75% thought the digital display was an improvement and 65% thought it took less time to determine time using the digital display.

QUESTION 4.a. For each of the conditions indicated in the left column, circle the number in the right column indicating how you rate the display images visibility.

CONDITION	VISIBILITY SCALE							
	Very Clear and Legible						Unclear, Not Legible	
	1 %	2 %	3 %	4 %	5 %	6 %	7 %	Mean Scale
With direct sunlight on display face:	30	30	15	10	8	6	1	2.7
Without direct sunlight on display face:	57	32	7	2	1	1	0	1.7
Under dawn work conditions:	44	30	13	5	4	3	1	2.2
Under dusk work conditions:	49	24	13	5	4	4	1	2.2
In artificial light work conditions:	49	36	8	2	3	2	0	1.9

COMMENT: The display was judged to be very clear and legible under different lighting conditions. The small percentage of low visibility ratings were primarily from higher ranking individuals indicating a relationship to age and perhaps poorer eyesight and/or difficulty in adjusting to the digital display.

QUESTION 4.b. If the size of the digital display is not adequate, what changes are needed?

No problem (82.6%) Too Small (2.8%) Other (14.6%)

COMMENT: Most unfavorable comments arose from the fact that the viewing angle was limited. The 24 hour military time versus A.M./P.M. was a desire of a few of the evaluators. Many navigators wanted

seconds displayed continuously and simultaneously with hours and minutes for celestial observations. There were some limited complaints about the glare from the watch face. The very favorable overall response to the digital display is possibly attributed to the large size of the digits.

QUESTION 4.c. Do you have any difficulty in mentally adjusting to the digital display in calculating specific time in relation to the hour; i.e., digital display of "9:47" versus reading 13 minutes to 10 on a regular (analog) dial? If so, what?

Yes (11%) No (89%)

COMMENT: Of the small group that had difficulty, most complaints centered on the person's inability to easily visualize time relationships with a digital display. This was true for both navigators and pilots, especially during flight when time compression is more severe. As with the display size, the unfavorable comments seemed to come largely from higher ranking, hence older respondents. Many of those who indicated that they had difficulty also noted that adjustment became easier after using the watch for longer periods of time. As a group, SAC FB-111 aircrew personnel who are used to digital display readouts almost unanimously favored the digital display watch.

QUESTION 4.d. Do you feel you consume more or less time calculating the time on a digital dial versus analog dial?

More (23.5%) Less (64.5%) Same (12%)

COMMENT: Higher ranking subjects seemed to require more time calculating the time from the digital display. A slightly higher percentage of navigators (34%) indicated that they took more time in calculating time with the digital dial. This may be due to the lack of a 24 hour feature.

QUESTION 4.e. Do you consider the digital dial an improvement over the conventional analog dial? Please explain.

Yes (75%) No (25%)

COMMENT: In general, the evaluators found a digital display easier to read, more accurate, and thought it reduced potential errors. Complaints included difficulty in approximating time relationships, the lack of a 24 hour display feature, the limited viewing angle, and the inability to use a digital display as a makeshift compass for survival and escape and evasion. The major and most frequent complaint was that the digital display did not include a continuous readout of seconds simultaneously with hours and minutes for use especially during navigational related tasks. Because of the emphasis placed by many navigators on the need for a continuous display of hours, minutes and seconds and on the need for a 24 hour display, a more detailed analysis was accomplished. The results are tabulated in Table 2.

TABLE 2 - COMPARISON OF WATCH FEATURES DESIRED BY TEST SUBJECTS

	Navigators	Pilots	Other
Sample size	62	110	151
Require/desire continuous display of seconds	79%	17%	8%
Require/desire a 24 hour display (versus 12):	50%	15%	11%
Require/desire a longer stop function	32%	26%	15%
Require/desire dual time readout	16%	0%	0%

The data indicates that there is a strong requirement for a continuous seconds display for navigation duties. The navigators also require a capability to quickly switch from Greenwich Mean Time to local time which drives their desire for the 24 hour display, a longer stop-watch function with a memory capability to allow switching back and forth between modes, and/or a dual time display of some sort.

3. Overall Assessment of Digital Watch

This section of the questionnaire identifies mechanical problems. It also investigates the acceptability of the instructions for setting and operating the watch. Finally, each subject was asked whether or not the digital display watch should be integrated into the USAF.

QUESTION 5.a. Were there any mechanical problems associated with the following? If so, explain.

	PROBLEMS(%)	NO PROBLEMS(%)
Mode/setting buttons:	24.8	75.2
Dial illumination:	23.8	76.2
Face crystal:	24.0	76.0
Watchband, buckle and case spring bars:	28.0	72.0
Battery:	9.0	91.0
Accuracy of timekeeping:	5.9	94.1
Back popping off:	0	100.0
Stopwatch function:	21.8	78.2
Month and date function:	7.5	92.5

COMMENT: The majority of personnel indicated they had no mechanical problems in the above mentioned areas.

Mode/setting buttons. The problems identified by the 24.8% included the following: stopwatch was activated/inactivated easily by accidental pushing of left button, the watch was cumbersome to set the time back, mode setting buttons adversely affected by salt water, buttons too small, and buttons poorly positioned.

Dial illumination. Although not purely a mechanical problem, two-thirds of those expressing a negative opinion, said the watch was too bright. The other one-third of those expressing a negative opinion said the watch was not bright enough in dusk and bright sunlight environment.

Some comments concerning the "too bright" statements came from survival instructors. They indicated that the watch's brightness could reveal the location of an aircrew member in an escape and evasion environment.

There was a similar comment from a Marine indicating that the watch was not suitable in a tactical situation because it would reveal the wearer's position at 30 meters.

Face crystal. Of the 24% who indicated a problem with the face crystal, 94% said it was the fact that the face scratched too easily and subsequently made legibility of the display slightly more difficult.

Watchband, buckle, and case spring bars. One-third of the 28% who expressed a problem in this area said the buckle snags on clothing. Others commented that the band was uncomfortable, as it was too stiff, not sufficiently perforated, causing perspiration and that it was too short.

Battery. Of the 9.1% expressing a problem with the battery, one-half said their batteries went dead within three months. The others complained of intermittent operation.

Accuracy of timekeeping. One-half of the 5.9% indicating a problem with accuracy said the watch lost more than four seconds a month. The remaining said it gained around four seconds per month. Overall, the vast majority commented that the watch was extremely accurate.

Back popping off. No one expressed any problems in this area.

Stopwatch function. Of the 21.8% who identified problems, only one-fifth indicated that they were mechanical problems. The mechanical problems related to difficulty in starting and stopping this feature. The remainder commented that 15 minutes was not a long enough period of time and/or that a memory mode would be desirable.

Month and date function. Those few who responded negatively desired a day of the week presentation. No mechanical problems were identified.

QUESTION 5.b. In reference to the instructions, which explain the setting and operation of the watch, do you feel these instructions are clear and provide adequate information?

Yes (65%) No (35%)

COMMENT: Only 20 percent of the evaluators outside Strategic Air Command encountered significant difficulty with the instructions. For some reason, the SAC statistics were reversed with 82% of the evaluators reporting that the instructions were vague, confusing and hard to understand. The most frequent complaint was the length and complication of initial setting procedures, difficulty in hacking the watch, and the inability to rapidly reset the watch in flight with frequent time zone changes. Another recurring comment was that when initially looking at the watch with a blank display there are no markings or indication of which is the top or bottom, left or right. There was some indication that evaluators not familiar with digital watches had more difficulty than those who had prior exposure to this type of timepiece. It should be noted that most digital watches are sent out from the factory already running. The watches in this survey were not running and had to be started by the individual evaluator - a much more difficult task. The instructions did not include a few sentences at the beginning describing the basic features of the watch.

QUESTION 5.c. Do you feel that the digital dial quartz crystal style of watch should be integrated into the USAF?

Yes (85%) No (15%)

COMMENT: Overall, the vast majority of the evaluators recommended that a digital dial quartz crystal watch be integrated into their respective government agency. However, only 15% of the evaluators indicated that this watch be selected without modifications. Over 53% indicated desired changes (simultaneous seconds display, 24 hour clock, longer stop function, etc.).

QUESTION 6. If a new watch were introduced into the USAF inventory, would you also like the watch to be available on the commercial market (stores, base exchange, etc.) in order that you could purchase your own watch in the event you were no longer authorized a watch in a future job?

Yes (78%) No (22%)

COMMENT: This question was included in the questionnaire because of the high volume of watches procured annually by the military departments indicates a possible problem with pilferage or failure to turn watches back into the logistic system when no longer required/authorized for the military member in performance of their job. The availability of identical watches in the exchange stores may reduce annual buy programs of government issued watches. A majority of those responding yes indicated they would only desire to purchase the watch if the price in the exchange stores was comparable to the price paid by the government in the annual bulk procurements.

SECTION V

CONCLUSIONS

The digital display watch was very favorably received by most of those who participated in the evaluation. The most favorable comments concerned the extremely precise accuracy of the watch, the clarity and easy visibility of the digits under varied lighting conditions, and the continuous readout function. These latter two features provide for hands-off operation and hence, the watch does not hinder normal aircrew operations. Another feature of this type watch which was very favorable received was the stopwatch function. From the analysis of the evaluators responses and comments, it is strongly concluded that the digital dial quartz crystal style of watch can and should be integrated into the US Government inventory. The particular watch under evaluation, however, may not be acceptable without some modification. The following paragraphs summarize the comments noted in the analyses.

a. Watch design and construction

(1) The degree of comfort, although not a serious problem, could be improved by adapting advanced technology to reduce the thickness of the case.

(2) Watchband adjustment adequacy problems as well as problems associated with the buckle catching on clothing could be overcome by adapting the watch to accept the current Mil Spec nylon web strap in lieu of the plastic test band.

(3) The black watch finish, which was evaluated as a good color for military/government use, should be improved to prevent chipping on the backside when removing the case back and wear through of the finish especially at the corners and edges.

(4) The problem of accidental activation of the mode buttons, although infrequent, could be avoided by moving the buttons to the upper right and/or left-hand corners of the octagon-shaped case. On some commercially available watches, the buttons are placed on the slanted portion of the upper end cover opposing corners rather than on the sides perpendicular to the wrist. It should be noted that the buttons on the test watch are larger than those on most other digital watches and are pushed rather than turned to activate modes (as opposed to the need to turn the stem on an analog watch).

(5) A "push in) setting button would be more responsive to rapid setting and "hacking" than the existing procedure which requires the setting button to be rotated 180°. A "push in" button would also be easier to operate for individuals wearing gloves or those with short fingernails.

(6) The face crystal should be recessed or hardened to reduce scratching. After examining a number of the watches, it was concluded that the problem may not have been greater with the test watch (on an absolute scale) than scratching on the face crystal of an analog watch. However, the scratching effect may be more noticeable on a digital display.

(7) The shock and vibration features of the test watch were excellent and should be retained.

(8) The watches were extremely accurate and far surpass current military/federal specifications on government timepieces.

(9) The watches were evaluated by Explosive Ordinance people against nonmagnetic Mil-Spec MIL-M-19595B which requires a device to read less than five gamma at a distance of 4 1/2 inches. The watches were tested as per this Mil Spec and were found to read greater than 200 gamma. One watch was disassembled and the following readings were taken on each part:

Buckle	200 gamma
Battery	25 gamma
Strap Spring Pin	17 gamma
Push Button	7 gamma
Electronic Module	0 gamma
Case without Push Buttons	0 gamma

Items such as the buckles, strap pins, and push buttons could be made of a nonmagnetic material such as brass. Batteries made of non-magnetic materials are currently available at a higher cost than standard silver oxide watch batteries.

b. Digital Display

(1) An hours-minutes-seconds continuous display is required for navigation tasks, bombing time tolerances, underwater use, and a few other selected activities. For most other activities, a display of continuous seconds is not a necessity.

(2) A 24 hour display is essential for celestial navigation and is a desirable feature for many military activities due to the extensive use of Greenwich Mean Time as a standard.

(3) The stopwatch function was very favorably received but should be redesigned to provide for a longer time duration, i.e., one hour versus 15 minutes. For divers, this function should be

increased to at least three hours. Additionally, the stopwatch function should incorporate a memory circuit that would allow uninterrupted operation when changing between the stopwatch mode and the hours-minutes-seconds mode.

(4) The Tritium backlighting may not be acceptable for ground combat operations or during escape and evasion attempts. It is desirable, however, for most other military activities. The escape and evasion problem could be overcome by training individuals to remove and either cover it (place it in a pocket) or bury it. The problem for ground combat operations is more severe and would present a more continuous danger. A different type of backlighting with a shut-off feature might be the answer. A thorough review of the statistics concerning tritium illuminated watches by survival training personnel indicates the disadvantages of the tritium should not prevent the USAF from these style watches.

SECTION VI

RECOMMENDATIONS

1. It is highly recommended that the development and procurement of the digital display watch, for use by military and civilian personnel who normally use a government issued watch, be adopted.

2. A commercial item description would be satisfactory for the general purpose watch. This instrument should include the following features:

   a. Continuous display of hours and minutes (the addition of simultaneous, continuous seconds should only be considered if the size of the digits remain large enough for easy viewing from any angle).

   b. Call-up feature for seconds and date function.

   c. The 24 hour display. (This feature is desired, but not mandatory.)

   d. The call-up stopwatch function with displays down to whole seconds, one hour duration, and a memory circuit.

   e. Water resistance to three atmospheres.

   f. Shock resistant.

   g. Tritium backlighting.

3. A separate style watch with a commercial item description may be necessary for Army and Marine combat operations use.

4. A separate specification should be written for the navigator/diver watch, since it requires capabilities beyond that required for other government functions. These specifications should include the following features:

a. Type I - Navigation watch.

(1) A six digit continuous display of hours, minutes and seconds.

(2) A 24 hour display.

(3) A stopwatch function which can be called up, displays down to 1/10 or 1/100 of a second, has a duration of at least one hour, and has a memory circuit which permits changing mode without losing the stop function.

(4) Tritium backlighting.

(5) Water resistant to at least three atmospheres.

(6) Shock resistant.

b. Type II - Submersible (Diver) watch.

(1) Same as Type I except for the following items.

(2) Increase the stop function to at least three hours (the 1/10 second display may not be necessary for divers).

(3) Water resistance to at least five atmospheres.

(4) All materials must be non-magnetic.

5. The incorporation of a longer stopwatch capability with a memory circuit should largely eliminate the need for separate procurement of pocket style stopwatches. Users of stopwatches which require accuracy down to 1/10 or 1/100 of a second could utilize the more expensive military specification navigators/divers watch as discussed in paragraph 4 above.

6. It is recommended that the Mil Standard - Specification 46383, nylon web strap be procured for use with all government watches in lieu of other commercial bands.

7. The face crystal used with the digital display watch should be hardened or redesigned to minimize the adverse visual effects due to surface scratches.

8. Repair

Most digital watch modules are not designed for repair. In digital watches, nothing moves and there are not parts to wear out. According to the watch industry, case related problems and battery replacements account for a majority of the problems. Most of the other failures result for manufacturing problems either of the component or the completed module. The result is that the failure of a digital electronic watch module is much more probable during the first year than it is for the next nine years. Since most manufacturers warrant their watches for one year, the digital watch which exceeds the one year warranty period should be an extremely reliable product except for battery failures. It is therefore recommended that any watches procured have a one year warranty and that the government should not provide repair of digital watches.

9. Although there are over 125 types and styles of power cells used in watches, the silver oxide high drain 1.5 volt cell is most commonly used in liquid crystal display watch. Watch manufacturers normally guarantee their batteries for one year period with the expectation that the batteries will last from 1 1/2 to 1 3/4 years using tritium backlighting. The battery failures experienced by manufacturers during the first year vary between 2 and 10 percent. (NOTE: Our test results show 9.1% battery failure in test watches.) Because of the wide variety of batteries utilized by watch manufacturers, it is recommended that watch batteries should not be stock listed in the government logistic system at the present time. Each government agency could purchase the type, style and quantity of watch batteries utilizing local procurement procedures or in accordance with the Armed Forces Procurement Regulation (ASPR) or the Federal Procurement Management Regulation (FPMR).

An alternative to the silver oxide battery is the recently introduced lithium solid electrolight cells to power LCD watches. Lithium batteries offer energy densities on a volume of two times that of a conventional silver oxide cell and have a confidence life of 5 to 8 years or more. However, lithium batteries required a differently designed - higher voltage watch module which is not yet commonly used in the commercial watch industry today. Although lithium powered watches are on the threshold of being introduced throughout the commercial watch marketplace, their higher cost does not presently offer a cost effective alternative for use in watches by the US military.

10. Shelf Life of Watches

In most instances, government procurements of watches will be in bulk quantities for storage by government "wholesale" depot activities and ultimately distributed to government "retail" or using activities. This process could result in watches being stored within the government logistic system between 1 and 9 months before actual issue to the using organization or individual. Accordingly, the life of the watch energy cell could be severly shortened by the time the individual is issued the watch. A few of the commercial watch modules are designed to permit the watch to be shutdown in order to eliminate a drain on the battery while in storage. However, most watch modules do not have this feature and the watches are distributed by the manufacturer to wholesale and retail activities with the watch in an operating or running mode. It is recommended watch procurement documents (specification or commercial item description) specify the watch to have a shutdown capability or the manufacturer include a spare battery with the watch.

APPENDIX
TEST AND EVALUATION
OF USAF DIGITAL WRISTWATCH

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OBJECTIVE

The objective of this evaluation is to investigate the acceptability of a digital time display and determine the feasibility of replacing the mechanical, stem wind analog dial wristwatch, currently utilized by USAF, with the quartz crystal movement digital display wristwatch. It is desirous to have the watch evaluated by a wide variety of personnel with Air Force specialties which are authorized watches in the USAF Table of Allowances. It is recognized this watch is only a prototype test model and doesn't incorporate all the features which may be available (at increased prices) on the final watch.

TEST INSTRUCTIONS

The current test runs from until . Please complete and return this questionnaire together with the watch to your test monitor as per instructions listed below:

In order to insure complete objectivity, each evaluator is requested to refrain from discussing the watch with any other person who is also evaluating a prototype USAF wristwatch.

Feel free to take full advantage of this unique opportunity to make as many additional comments as you desire. Please precede all comments with the relevant questionnaire item number. If you need more "comments" space, use any available paper and attach it to the back of this questionnaire.

If you have any questions concerning the watch or questionnaire, please contact your test monitor or inquire directly to ASD/RAO, Wright-Patterson AFB, OH, 45433, AV 785-6632/6841.

QUESTIONNAIRE DIRECTIONS:

This questionnaire attempts to gather facts about the feasibility of using electronic movements in USAF watches and the feasibility of using digital displays in lieu of the analog (conventional) display. Be as accurate and objective as possible, because your evaluation will determine the type and style of future watches to be adopted in the Air Force.

Please remain familiar with the questionnaire items throughout the test period. This will allow you to make comments concerning specific items when they occur.

INDIVIDUAL ASSESSMENT OF USAF PROTOTYPE DIGITAL, QUARTZ WRISTWATCH

1. Evaluator's Background:

Name, Rank/Grade:

AFSC & Position Title:

Major Command/Activity:

Base, Phone:

Evaluation Dates:

2. Brief description of conditions/job position under which watch was evaluated; i.e., B-52 Bomb Navigator, Flight Nurse, Airborne Jumps, Field Duty, dusty or cold weather conditions, etc. The types of conditions under which the evaluator actually uses the watch are more important than the length of the time of the test (e.g., a SAC navigator should use the watch to navigate on a number of night celestial, day celestial, and radar missions as well as for a certain specified period of time). If possible, specify the detailed conditions/mission scenarios under which these will be tested:

3. Design and Construction:

a. Rate the watch's comfort by circling the applicable number below:

Extremely Comfortable	1	2	3	4	5	6	7	Extremely Uncomfortable

b. Rate the watchband adjustment by circling the applicable number below:

Does not have sufficient adjustment	1	2	3	4	5	6	7	Adjustment is adequate to fit wrist

CIRCLE ONE

c. Does the band or case catch or hook on clothing or other objects? If so, what could be improved? YES NO

d. Are the buttons for control of digital display of proper size to provide for ease in adjustment time, date, or stopwatch features? YES NO

e. If you exposed the watch to any type of pressure (or cabin altitude) changes, indicate the low and high extremes of the ranges experienced:

Low _____feet; High _____feet

f. Does the crystal scratch easily? YES NO

g. Did you expose the watch to any type of shock or vibration? If so, please describe any effect on the watch. YES NO

4. *Assessment of Digital Display?*

a. For each of the conditions indicated in the left column, circle the number in the right column indicating how you rate the display image's visibility.

CONDITION	VISIBILITY SCALE						
	Very clear and legible						Unclear, not legible
With direct sunlight on display face:	1	2	3	4	5	6	7
Without direct sunlight on display face:	1	2	3	4	5	6	7
Under dawn work conditions:	1	2	3	4	5	6	7
Under dusk work conditions:	1	2	3	4	5	6	7
In artificial light work conditions:	1	2	3	4	5	6	7

b. If the size of the digital display is not adequate, what changes are needed?

c. Do you have any difficulty in mentally adjusting to the digital display in calculating specific time in relation to the hour; i.e., digital display of "9:47" versus reading 13 minutes to 10 on a regular (analog) dial? If so, what? YES NO

d. Do you feel you consume more or less time calculating the time on a digital dial versus analog dial? MORE LESS

e. Do you consider the digital dial an improvement over the conventional analog dial? Please explain. YES NO

5. Overall Assessment of Digital Watch:

a. Were there any mechanical problems associated with the following? If so, explain.

Mode/setting buttons:

Dial illumination:

Face crystal:

Watchband, buckle and case spring bars:

Battery:

Accuracy of timekeeping:

Back popping off:

Stopwatch function:

Month & date function:

b. In reference to the instructions, which explain the setting and operation of the watch, do you feel these instructions are clear and provide adequate information? If no, please explain. YES NO

c. Do you feel that the digital dial quartz crystal style of watch should be integrated into the USAF? YES NO

6. If a new watch were introduced into the USAF inventory, would you also like the watch to be available on the commercial market (stores, Base Exchange, etc.) in order that you could purchase your own watch in the event you were no longer authorized a watch in a future job? YES NO

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