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A REVIEW OF THE U.S. NAVY'S PRECISE
TIME AND TIME INTERVAL (PTTI)
PROGRAM

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ABSTRACT

In September 1975, the Navy's PTTI Program experienced a restructuring of its internal management. Since that time, the Program has undergone significant redirection.

This paper briefly outlines in broad terms:

- (a) The history of the Navy's PTTI Program
- (b) The Navy's current and projected PTTI requirements and capabilities
- (c) The current and projected Program efforts

The United States Navy's Precise Time and Time Interval (PTTI) Program is a Navy-wide effort to provide Navy platforms with PTTI information traceable to the U.S. Naval Observatory (NAVOBSY).

At the Ninth Annual PTTI Applications and Planning Meeting, Rear Admiral Fowler briefly outlined the Navy's early dependency on time for navigation and the need for improved timing as ships' speeds increased with the conversion from sail to steam propulsion. He also outlined the NAVOBSY's very early involvement with timekeeping in support of this timing requirement and the consequent evolution of the NAVOBSY as the nation's timekeeper and a leader in today's international PTTI

community.

The Naval Research Laboratory (NRL) is another, more recent, example of the Navy's participation in the fields of timing and PTTI. NRL's involvement with crystal oscillator and frequency synthesizer technology, its' experiments in transferring time via the Defense Satellite Communications System (DSCS) and the development of the Hawaii Test Bed, both in conjunction with the NAVOBSY and the Naval Electronic Systems Command (NAVELEX), and its' recent efforts with atomic standard developments under the Global Positioning System (GPS) Program have resulted in numerous advances in PTTI.

In recognition of this early Navy leadership in time-keeping and timing developments, the NAVOBSY in 1956 was directed to provide the Standards of Time and Time Interval for the U.S. Department of Defense (DOD). Further, in 1965, by DOD directive, the NAVOBSY became the single DOD component responsible for PTTI management control functions.

Then, in 1972, the Chief of Naval Operations (CNO), tasked the NAVOBSY with maintaining the Time and Time Interval Standards for the Navy and assigned the Chief of Naval Material (CNM) as "The single Department of the Navy Manager responsible for PTTI."

CNM then designated the Commander, Naval Electronic Systems Command (COMNAVELEXSYSCOM) as the "Department of the Navy Manager for PTTI."

The current Navy PTTI Program and its associated program management organization, depicted in Figure 1, are the direct result of these various directives and taskings.

After establishing an official program organization and responsibilities, CNO, in September 1975, issued a draft Operational Requirement (OR) for Timing and Synchronization (PTTI). The draft OR described the operational problem as follows:

There is a present and future need for precise time and time interval traceable to the U.S. Naval Observatory.

Currently, each warfare sponsor provides his own precise time and time interval using methods which range from crystal oscillators to atomic clocks.

PRECISE TIME AND TIME INTERVAL (PTTI) PROGRAM ORGANIZATION

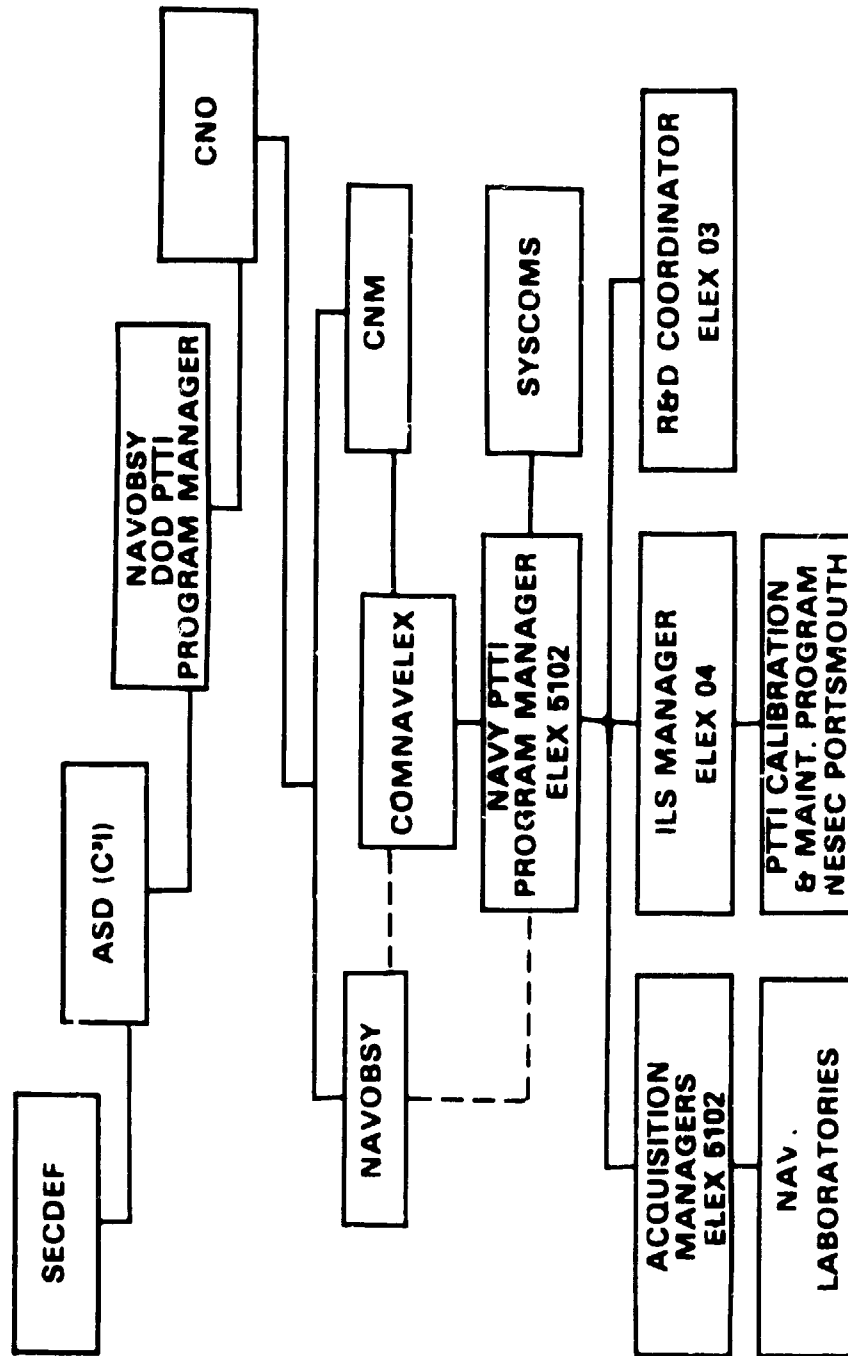


FIGURE 1

. This proliferation is neither economical nor technically sound in design and use.

The draft OR also stated that the operational requirement was for:

. The worldwide dissemination of precise time and time interval traceable to the NAVOBSY.

. Cost effective distribution systems for the various platforms to support their designated missions.

Based on that draft OR, the Navy's PTTI Program objectives are:

. To quantitatively determine the PTTI requirements of the various Navy Platforms through the 1990 time-frame.

. To review the status and capabilities of existing dissemination systems to determine if the platform requirements can be met.

. To design, as necessary, a dissemination system to meet the platform requirements.

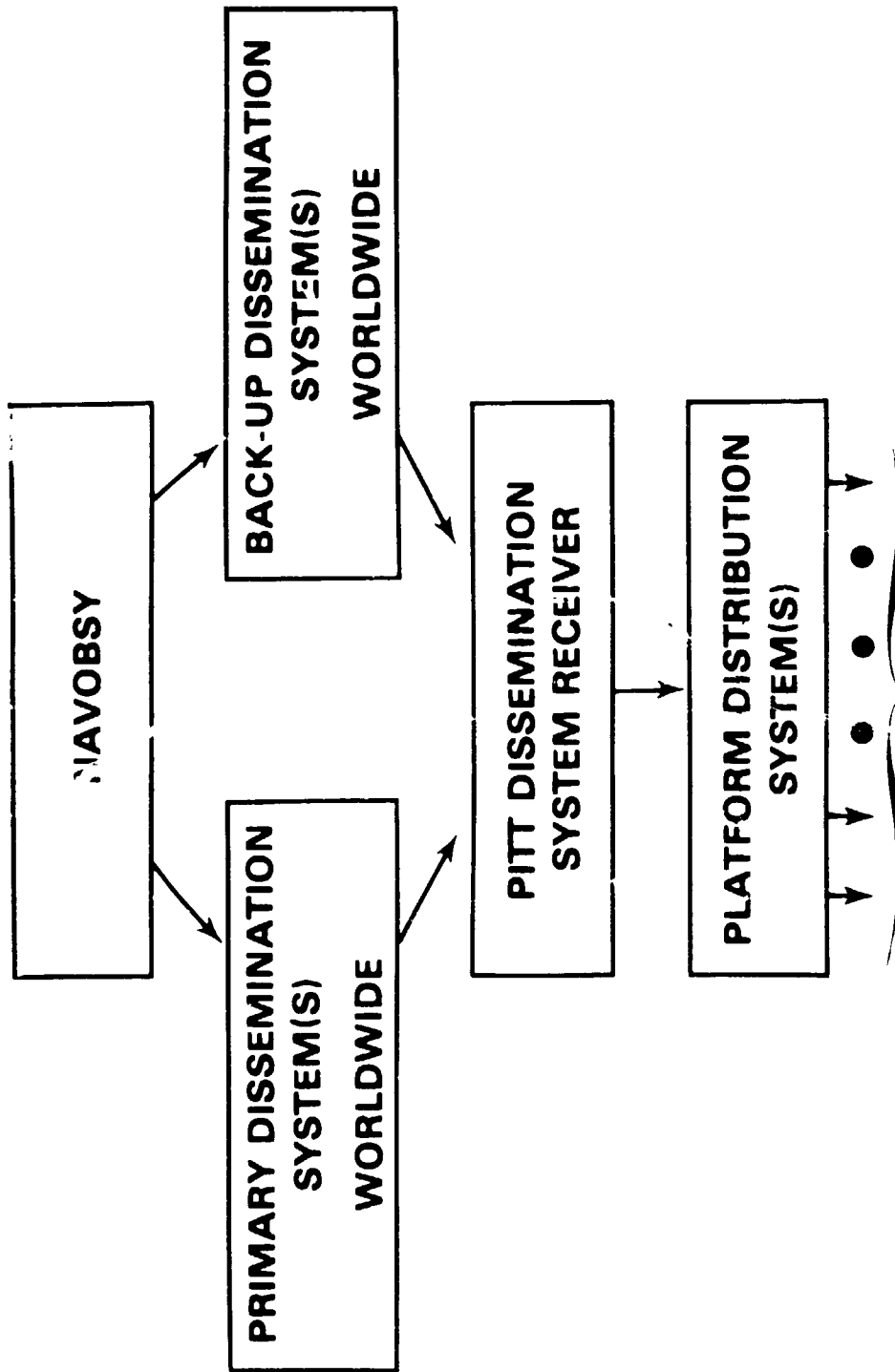
. To design platform distribution systems to satisfy platform requirements in a cost-effective manner subject to survivability and operational constraints.

A PTTI Program Master Plan to meet these objectives, was published on 1 June 1976 and forwarded to CNO for approval.

In the Program Master Plan, a PTTI System concept, as shown in Figure 2, was outlined. That PTTI System concept is based on a dissemination system, see Figure 3, which uses, to the maximum extent possible, existing dissemination systems and a platform distribution system, see Figure 4, which also uses, to the maximum extent possible, existing equipments.

Because of an inability to obtain internal approval of the draft OR, CNO requested that NAVELEX perform an analysis of the Navy's PTTI requirements as outlined in the Program Master Plan and that the plan be resubmitted upon completion of the requirements analysis.

NAVELEX did perform the PTTI Requirements Analysis. It was completed in July 1978 and the Final Report was



PRECISE TIME AND TIME INTERVAL

FIGURE 2

PRECISE TIME AND TIME INTERVAL (PTTI) PROGRAM DISSEMINATION SYSTEM

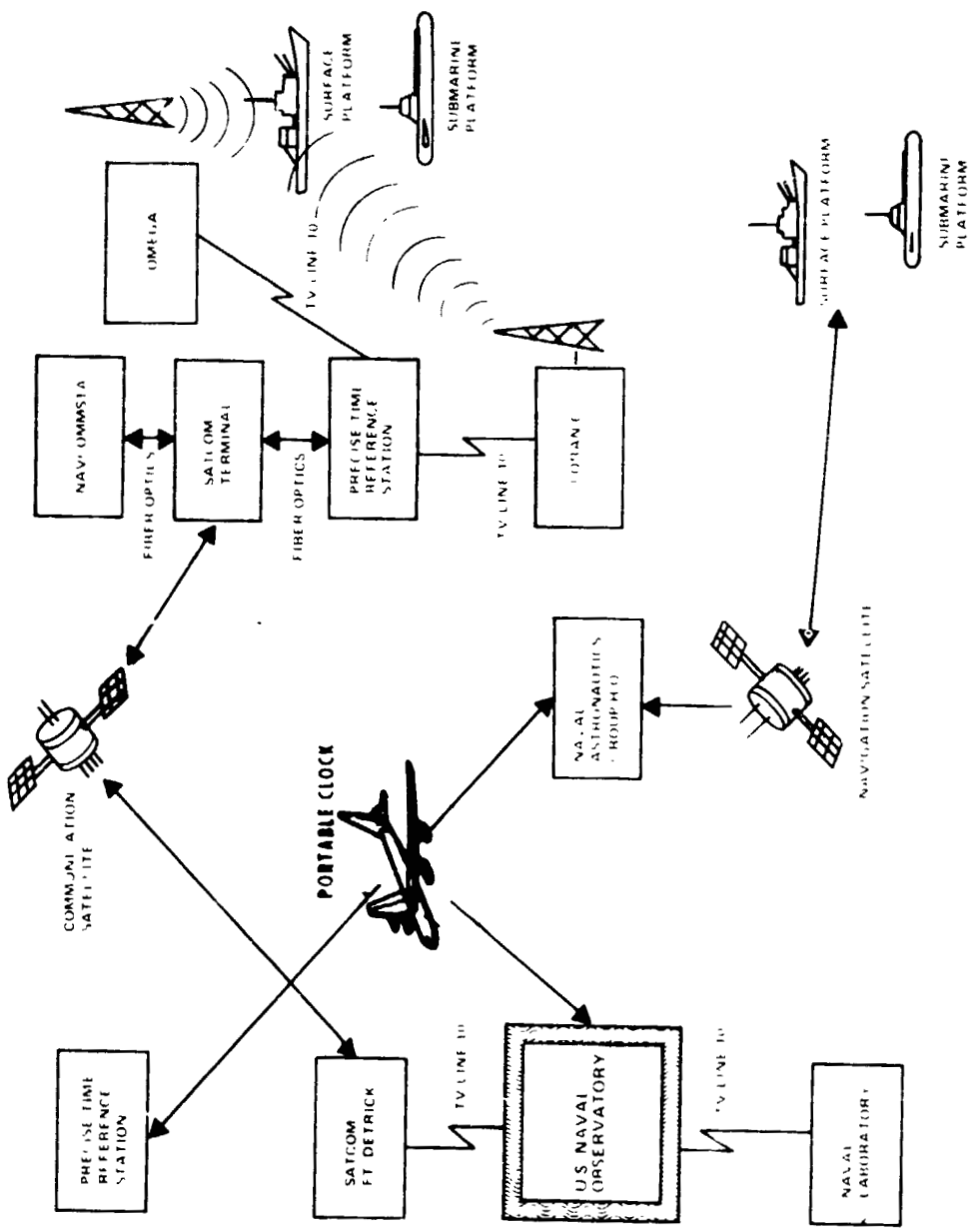
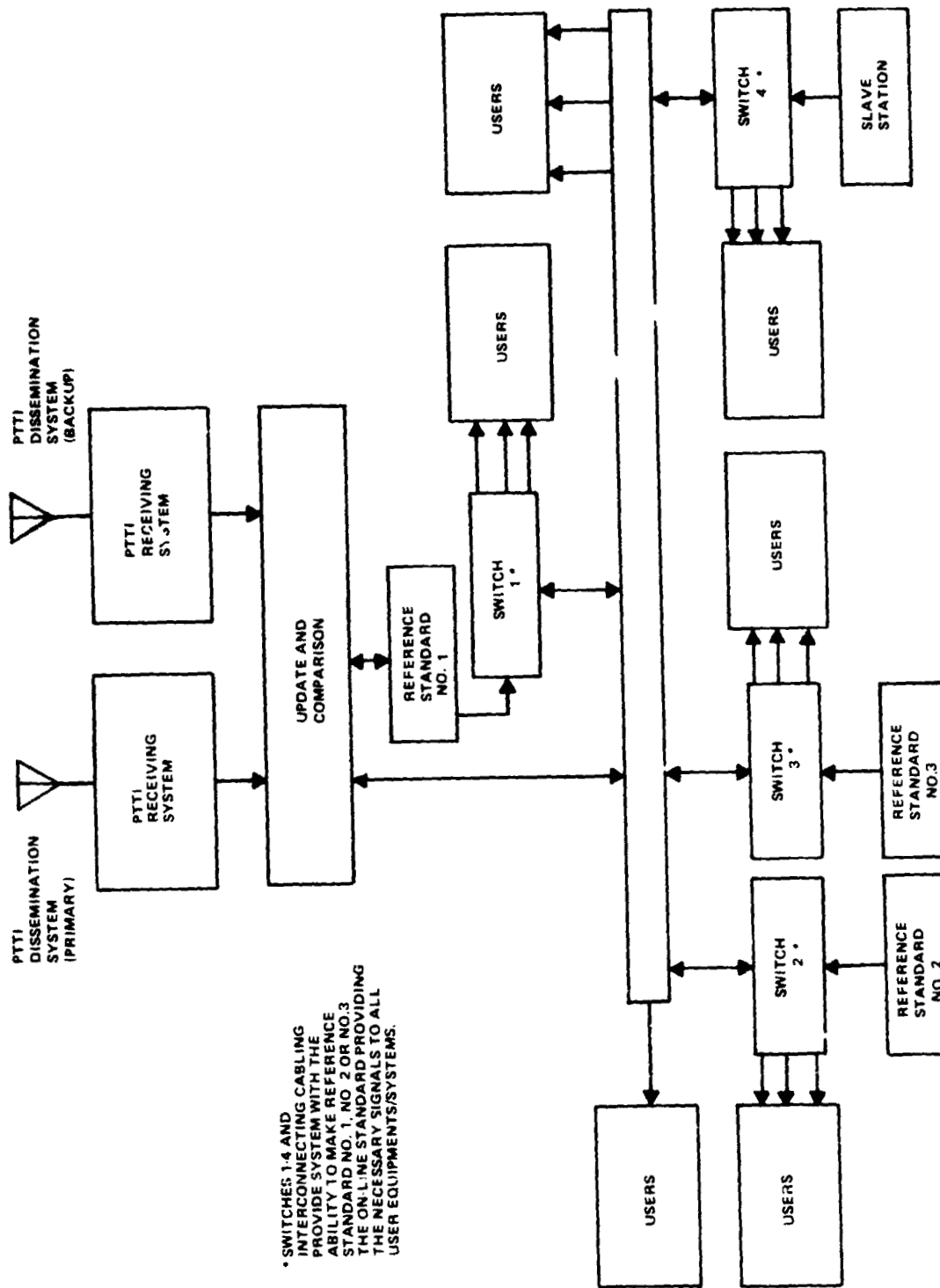


FIGURE 3



* SWITCHES 1, 4 AND INTERCONNECTING CABLING PROVIDE SYSTEM WITH THE ABILITY TO MAKE REFERENCE STANDARD NO. 1, NO. 2 OR NO. 3 THE ON-LINE STANDARD PROVIDING THE NECESSARY SIGNALS TO ALL USER EQUIPMENTS/SYSTEMS.

Figure 4 PTTI PLATFORM DISTRIBUTION SYSTEM CONCEPT

delivered to CNO for validation in November 1978. The Analysis indicates that there will be a dramatic increase in the number of platform communication, navigation and weapon systems requiring increasingly stringent PTTI information; e.g., while today the Navy's platform requirements for time are primarily limited to the submarine fleet and are in the 100 microsecond region, the typical Naval Platform, afloat and ashore, requirements in the 1980 to 1990 time frame will be in the one to ten microsecond range with one future system identified which may require a platform to maintain time to within ± ten nanoseconds or less.

Some of the major conclusions in the Requirements Analysis were that:

- . Platform requirements for PTTI are currently being met.

- . Based on current planning, surface platforms especially will be unable to meet future PTTI requirements.

- . Those platforms requiring PTTI would benefit from a "Standardized" Platform Distribution System (PDS).

- . With proper planning, all current and future platform requirements for PTTI can be satisfied by at least one current or future PTTI dissemination system.

- . There is no identified need for the development of additional PTTI dissemination systems.

Some of the major recommendations in the Requirements Analysis were to:

- . Develop a PTTI PDS utilizing a modular concept and standardized equipments.

- . Consider the PTTI Requirements Analysis recommendations regarding the PTTI Dissemination System in any PTTI PDS development effort.

Based on the requirements analysis, CNO is developing a new PTTI OR. Also, the PTTI Program Master Plan is currently being updated and will be resubmitted to CNO for approval in February 1979.

Some of the major on-going efforts to be covered in

the updated Program Master Plan include the:

- . PTTI Maintenance and Calibration Program.
- . SSN-637, SSN-688 and POLARIS/POSEIDON Class PTTI PDS Developments.
- . NAVOBSY Master Clock System Upgrade.
- . AN/URQ-23 Frequency Standard.
- . GPS Time Transfer Unit.
- . PTTI Technology Program.

The PTTI Maintenance and Calibration Program at the Naval Electronic Systems Engineering Center (NESEC), Portsmouth is a continuing program. Responsibilities under this program include portable clock trips to various Navy and DSCS earth terminal sites and the repair and maintenance of all Navy rubidium and cesium beam frequency standards. Beginning in FY-79, this program will also have full responsibility, including budgeting, for the VERDIN 0-1695 Cesium Beam Frequency Standard Depot.

NAVELEX, in May 1977, developed a system level specification for a PTTI PDS for the SSN-637, SSN-688 and POLARIS/POSEIDON Class Submarines. This effort originated with an urgent need for PTTI on the SSN-637 Class Submarines. The specification calls for an automatic, no break system and for the use of common equipment in all of the classes with reconfiguration to meet the needs of each particular class.

NAVELEX is currently developing platform distribution systems for the SSN-637, SSN-688 and POSEIDON Class Submarines. The SSN-637 Class PTTI PDS depicted in Figure 5 is an automatic, no-break system. The PTTI PDS for the SSN-688 and POSEIDON classes, which is depicted in Figure 6 will essentially be in accordance with the original May 1977 specification, except that the need for an automatic, no break system has been eliminated by the program sponsor.

NAVELEX has also been tasked by CNO with upgrading the NAVOBSY Master Clock System, see Figure 7. As stated previously, the PTTI Requirements Analysis has indicated that current Navy requirements are in the 100 microsecond region and that future requirements will be in the one to

SIMPLIFIED DIAGRAM OF SSN-637 CLASS PTTI PDS

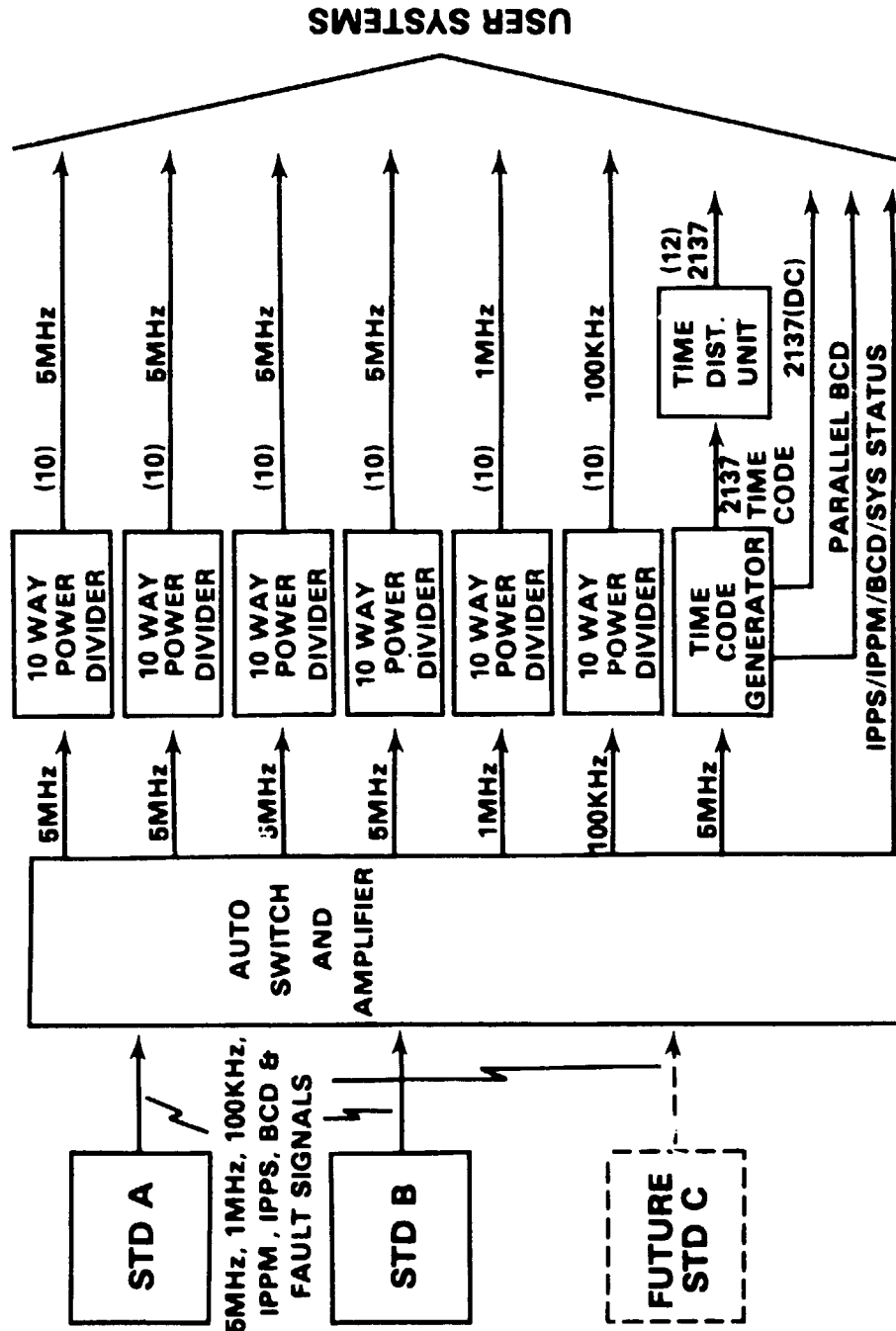


FIGURE 5

PCIP & SSN-688 PTTI PDS

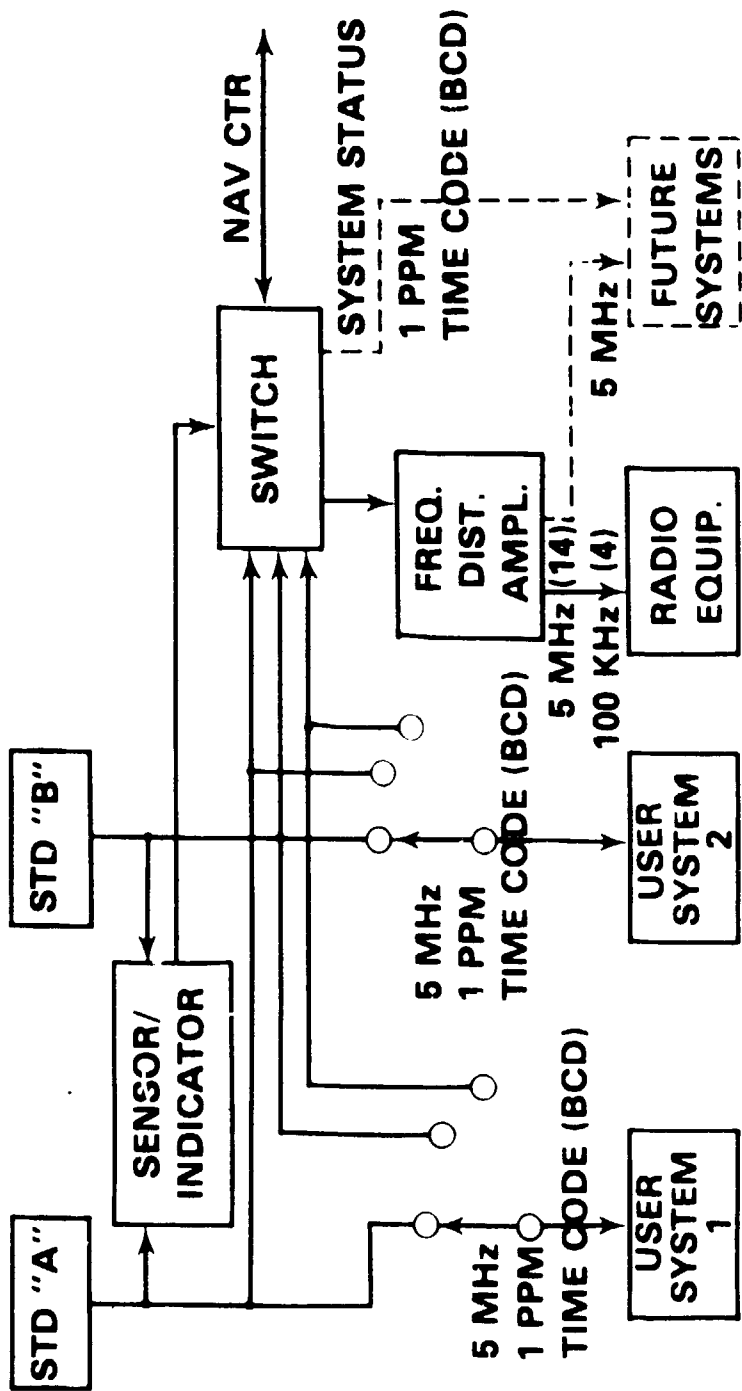


FIGURE 6

U.S. NAVAL OBSERVATORY MASTER CLOCK SYSTEM

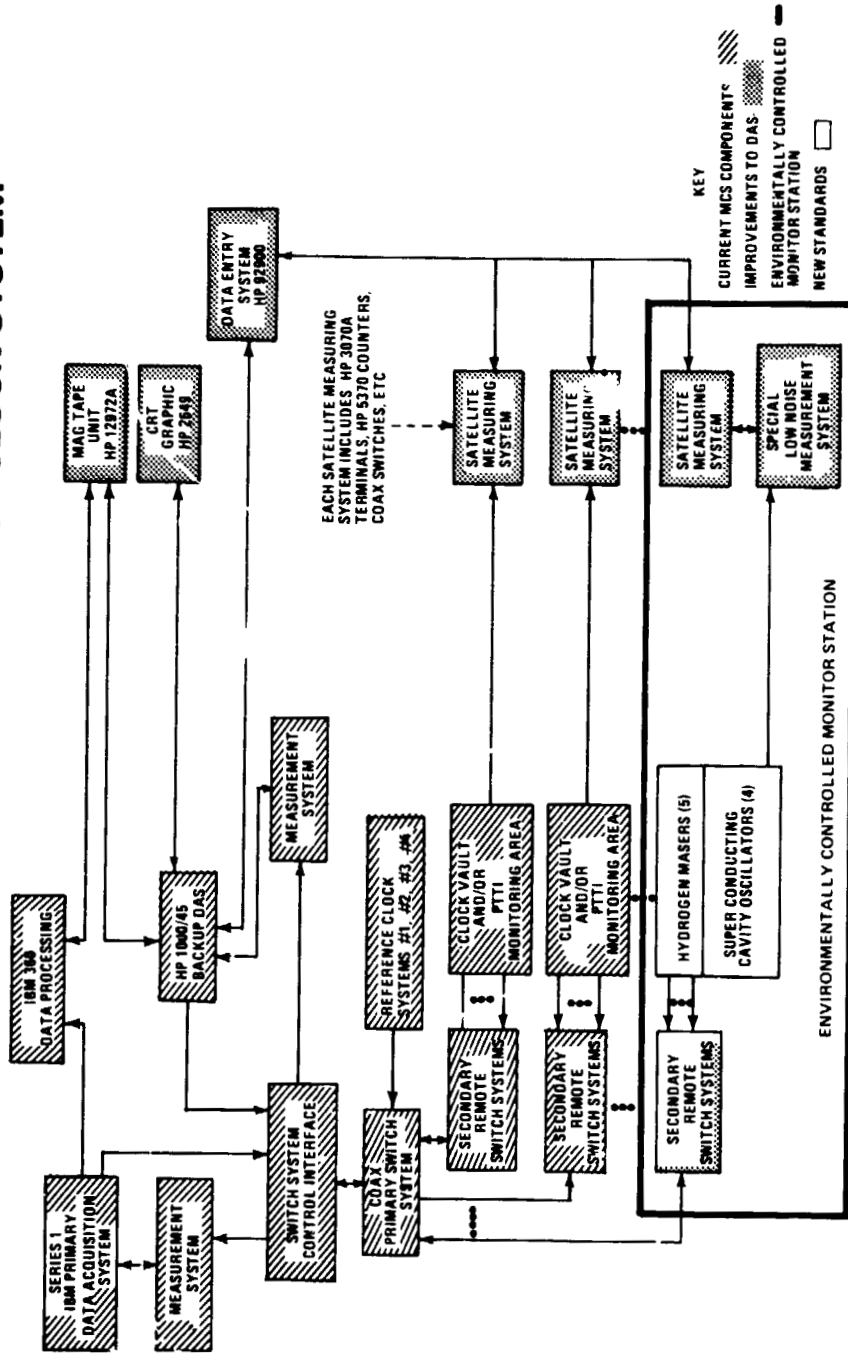


FIGURE 7

ten microsecond range with one requirement possibly in the + ten nanosecond region.

A similar increase in PTTI requirements for other DOD components is also projected, e.g. while the NAVOBSY, under its assigned responsibilities as the single DOD component responsible for PTTI management control functions, currently maintains the Master Clock System which also serves as the DOD Master Clock and provides the National Security Agency, the Air Force Calibration Laboratories and the DSCS with time of day in the 0.1 to 10.0 microsecond range, it has projected requirements to provide time of day in support of the GPS and the Transit Improvement Programs to within 10 nanoseconds or less and to provide the Very Long Baseline Interferometry Program with a frequency stability of one part in 10^{14} or less.

While the present system provides time accurate to within 1 nanosecond per day and exhibits an exceedingly good long-term stability of two parts in 10^{14} , it will not meet the projected Navy and DOD user system requirements. In order to support those requirements, the future Master Clock System will be required to maintain time accurate to within 1 nanosecond per ten days and a frequency stability of 1 part in 10^{15} or less.

This will be accomplished by the introduction and integration of the latest, state-of-the-art technology and improved reference standards into the current Master Clock System to maintain and display near real time in the sub-nanosecond accuracy region.

This upgrade will enable Navy and other DOD components to meet their projected PTTI requirements and it will maintain the NAVOBSY's preeminent role in the national and international PTTI community.

While these basic documentation, program planning and early development efforts are taking place, there are still, however, real on-going operational needs of the fleet which must be met. For example, the AN/URQ-10 and 10A are the reference frequency standards of the fleet today. They are approximately ten years old. Although they still meet the majority of the Navy's current PTTI requirements, spare parts are becoming increasingly expensive and unavailable and handling procedures for maintenance are out of date.

The AN/URQ-23, disciplined time and frequency standard, which will be a direct replacement for the AN/URQ-10 and 10A was granted Provisional Approval for Service Use in September 1977. It offers an improved frequency stability and timing information which the AN/URQ-10's do not. More significantly, however, is the fact that the AN/URQ-23 can be calibrated in four hours vice the approximately 30 to 60 days required for the AN/URQ-10's. This calibration feature alone should yield significant savings for the fleet.

The AN/URQ-23 is currently undergoing First Article Testing at NRL and full Approval for Service Use is expected in June 1979.

Also, at the direction of CNO, NAVELEX is procuring a GPS Time Transfer Unit (TTU) Feasibility Model, see Figure 8, for the NAVOBSY via the Space and Missile Systems Organization (SAMSO).

The GPS has an inherent ability to disseminate PTTI information. The Time Transfer Unit, on which a paper was given at the Ninth Annual PTTI Applications and Planning Meeting (1), should provide fixed platforms with a low cost means of extracting that information and updating their local clocks to within 100 NS of GPS time which in turn is referenced to the NAVOBSY.

Finally, NAVELEX was recently notified that the Naval Material Command (NAVMAT) is partially funding the PTTI technology effort outlined in Figure 9. Informal discussions with NAVMAT and the NAVOBSY indicate that the PTTI technology effort has enough potential impact on, for example, future atomic clock developments and PTTI dissemination via satellite clocks to warrant its continuation.

NAVELEX is, therefore, currently developing a PTTI Technology Program, with particular emphasis on (1) relativity effects on satellite clocks, (2) laser reflectometry for increased time dissemination accuracy via GPS and (3) super crystal technology, in support of both current and projected Navy PTTI Program requirements.

That completes the review of the most significant, on-going PTTI efforts. Some of the projected PTTI efforts to be addressed in the updated PTTI Program Master Plan include the:

GLOBAL POSITIONING SYSTEM TIME TRANSFER UNIT

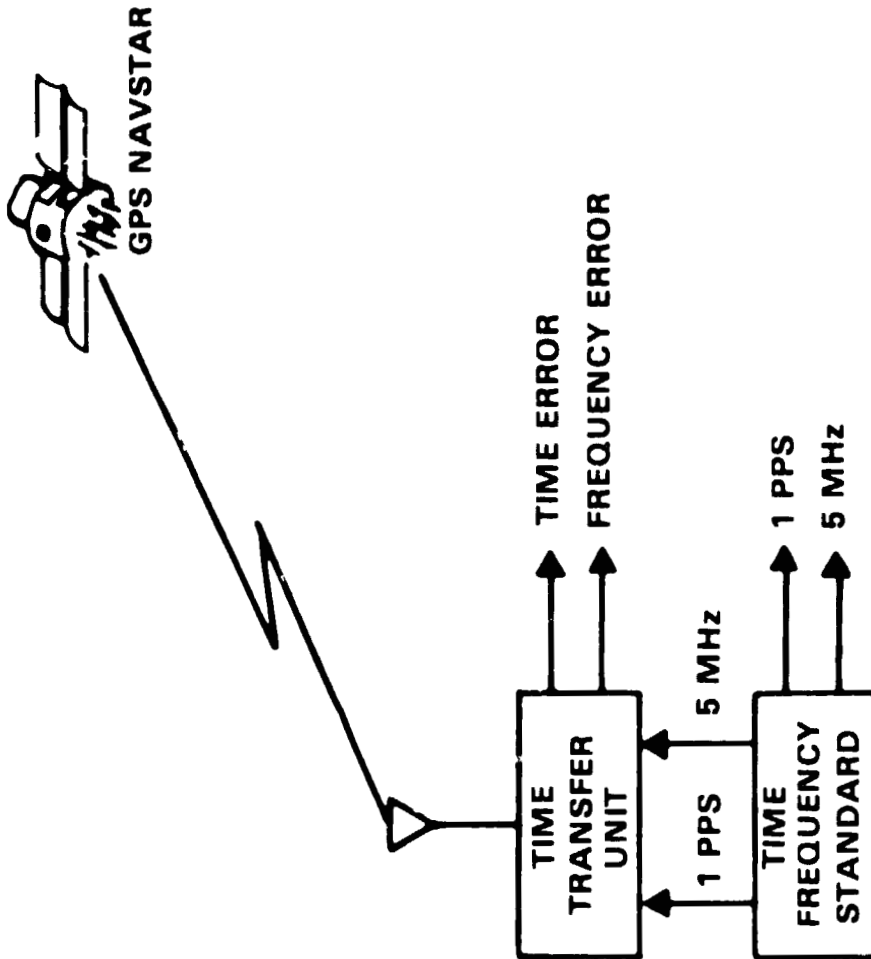


FIGURE 8

**MAJOR PTTI
TECHNOLOGY R&D PROGRAM EMPHASIS**

- **RELATIVITY EFFECTS ON SATELLITE CLOCKS**
- **LASER REFLECTOMETRY FOR INCREASED TIME
DISSEMINATION ACCURACY VIA GPS**
- **SUPER CRYSTAL TECHNOLOGY**

- . 0-1695 Cesium Beam Standard
- . Rubidium Standard Development
- . "Standardized" PTTI PDS Development
- . "Standardized" PTTI PDS Preliminary Design and Cost Analysis
- . PTTI via DSCS

Under the VERDIN Program, NAVELEX several years ago developed the 0-1695 Cesium Beam Frequency Standard and a complete support system. Within the last year, however, agreement has been reached that cognizance of the 0-1695 and its previously mentioned depot responsibilities properly belong under the Navy's PTTI Program. NAVELEX is currently planning for that transition in FY-79.

The Naval Air Systems Command (NAVAIR) is currently preparing to develop a rubidium frequency standard in support of the TACAMO Program. NAVELEX under a previous program was funding for the development of a rubidium standard. NAVAIR has been contacted to see if the NAVELEX rubidium standard effort will meet the TACAMO requirements. If so, it is felt that substantial savings in development costs can be accrued by the Navy.

The "Standardized" PTTI Platform Distribution System Development, depicted in Figure 10, is a FY-80 new start effort to provide all Navy platforms, surface, subsurface, air and shore, which require PTTI information with a modular distribution system comprised of "Standardized" equipments which can be reconfigured to meet the needs of a particular platform.

The "Standardized" PTTI Platform Distribution System Development will take advantage of any outputs from the previously mentioned submarine efforts by incorporating them, to the maximum extent possible, into the "Standardized" system.

The first task under the "Standardized" PDS effort is a preliminary design and cost analysis to provide answers to some of the questions raised as a result of the PTTI Requirements Analysis; e.g.

- a. How much standardization of equipment components

can be achieved between surface, subsurface, shore and air platforms?

b. How much utilization of existing assets is practical?

c. How much savings, in the area of logistics support, could be accrued by the Navy from the standardization of PTTI component equipments?

The final projected effort to be discussed is the PTTI via DSCS effort, see Figure 11.

The Joint Chiefs of Staff (JCS) on 17 March 1976 authorized the dissemination of PTTI via all DSCS terminals equipped with specialized modems capable of transferring time. The JCS further requested that CNO develop an implementation plan for the dissemination program.

The implementation plan was developed by the Naval Telecommunications Command (NAVTELCOM) in conjunction with the NAVOBSY and NAVELEX in May 1977. It designates the CNM as the executive agent for procurement and logistics support for this tri-service effort. CNO approved and forwarded this implementation plan to JCS for approval in September 1977. NAVELEX is currently planning for the assumption of these responsibilities upon the approval of the Implementation Plan by JCS.

As the preceding discourse indicates, the Navy's PTTI Program has, in three years, been defined and given direction. As Figure 12 indicates, however, the Program's major development and procurement efforts are still to come.

While there are problems associated with some of these efforts, e.g. the AN/URQ-10 maintenance problems, solutions have generally been identified and are being pursued.

The estimated impact of the outyear hardware procurements resulting from the platform distribution system development efforts and the JCS approval of the DSCS Implementation Plan will be significant. NAVELEX, CNO OPS 952, the PTTI sponsor, and 986, and COMNAVTELCOM are working together to absorb that impact.

The overall picture for PTTI has already improved significantly in the past three years; e.g. with the

TIME TRANSFER BY COMMUNICATION SATELLITE

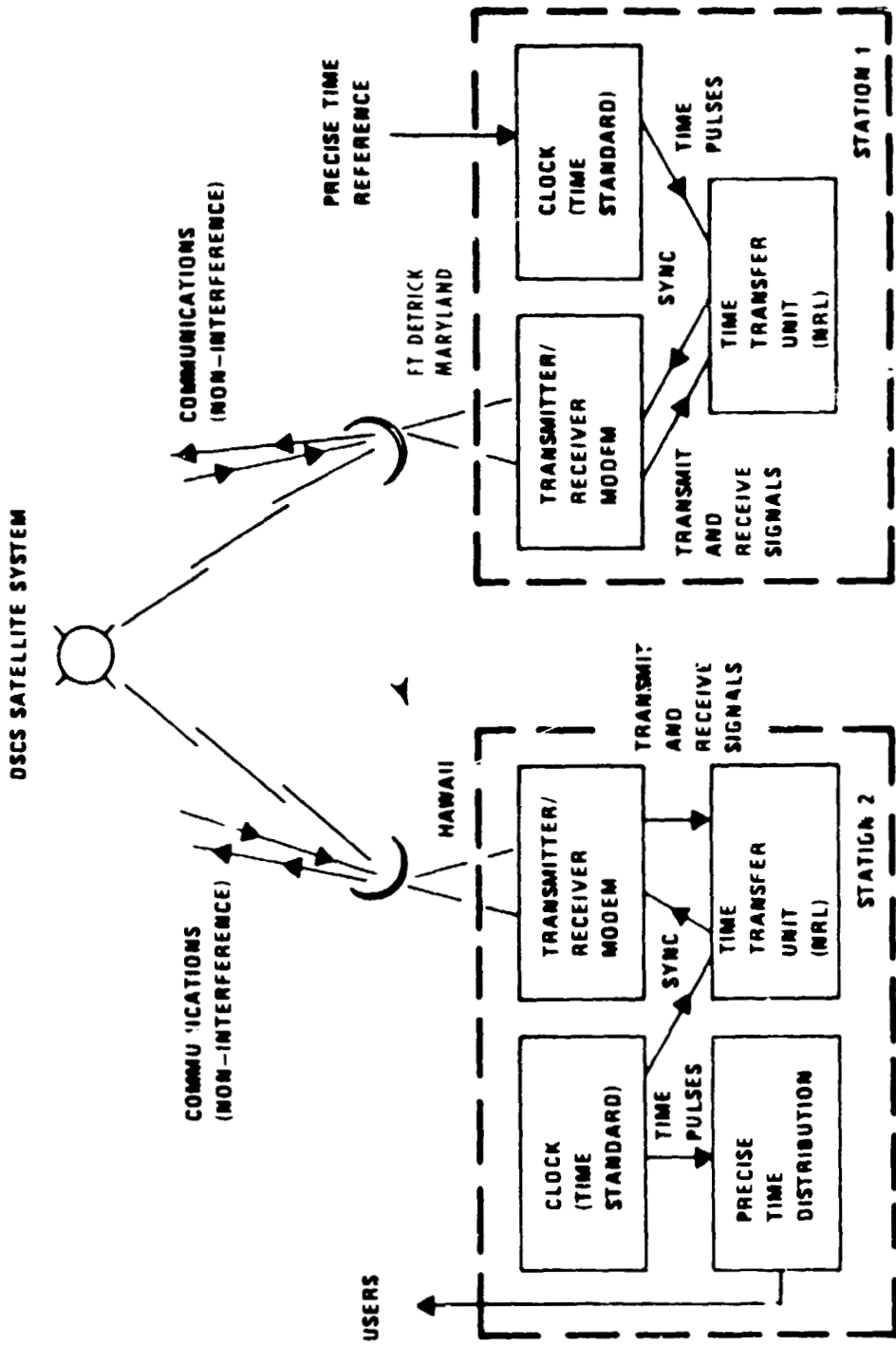


FIGURE 11

MAJOR PTTI PROGRAM MILESTONES

CY 77	CY 78	CY 79	CY 80	CY 81	CY 82	CY 83	CY 84
1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4

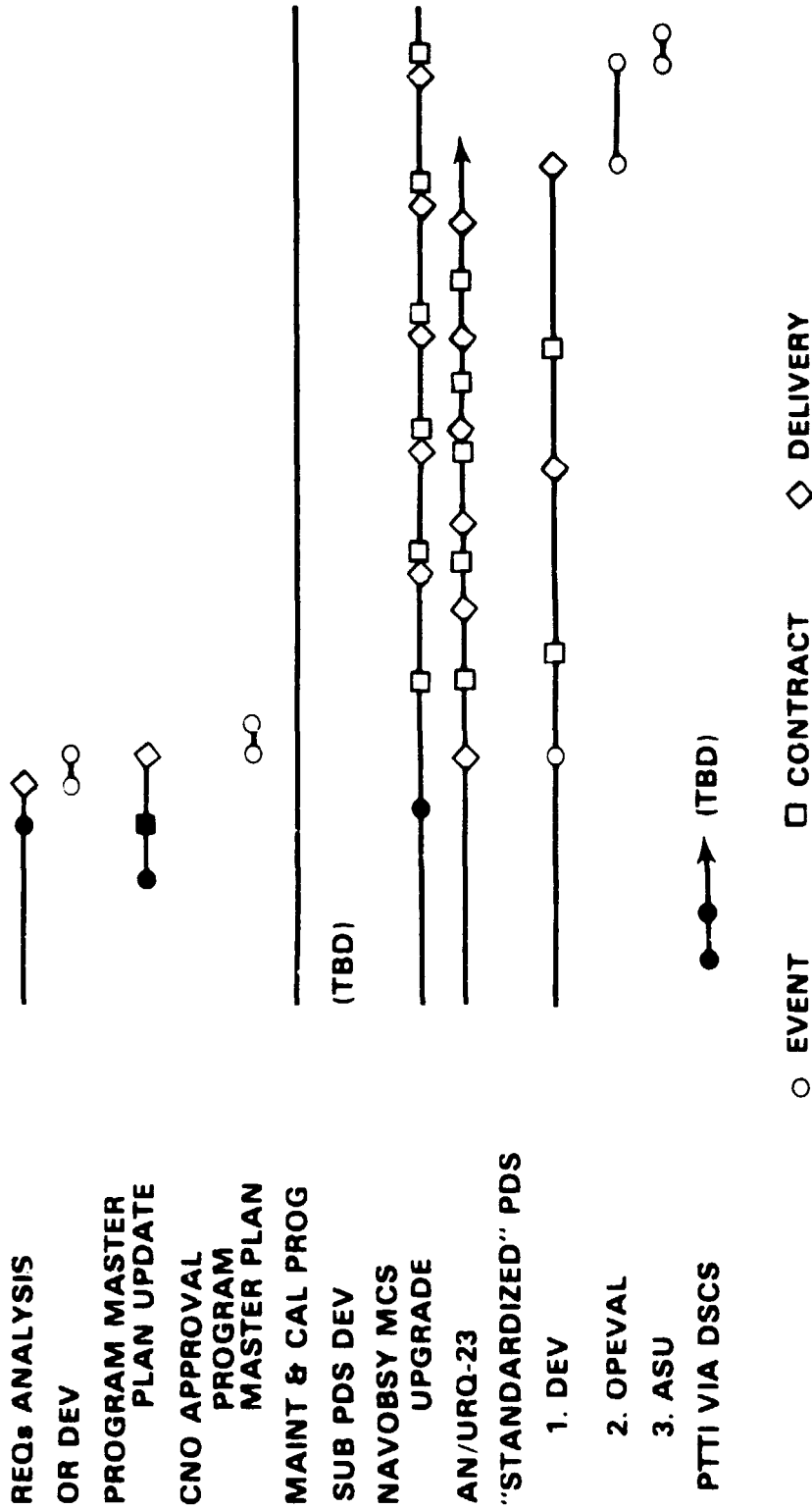


FIGURE 12

advent of the PTTI Program Master Plan, the PTTI Requirements Analysis and the assistance of OPS 952 and 986, the "Standardized" PTTI Platform Distribution System Development has moved from a new start in FY-82 to FY-80.

Again, in summary, the Navy's PTTI Program has, in three years, been defined and given direction. Program schedules and funding have improved and solutions have been identified for problem areas such as the AN/URQ-10. Overall the future of the program looks good. It is now being recognized by Navy Headquarters and Field Activities, the Fleet and other DOD Activities as attempting to solve the PTTI problems of today and to plan for the PTTI needs of tomorrow.

REFERENCES

1. Witherspoon, Jackson T. and Schuchman, Leonard, "A Time Transfer Unit for GPS," Proceedings of the Ninth Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting, March 19, 1978.

QUESTIONS AND ANSWERS

MR. HARRY PETERS, Sigma Tau Corporation:

I don't know how appropriate this is, but a couple of years ago there were ongoing efforts by Hughes Aircraft Company, RCA, Naval Research Labs, Smithsonian Astrophysics Lab, to get PTTI using hydrogen masers. Now we haven't heard much about that lately, nor do I see very much here about the future of this effort. I wonder if you could elaborate on that?

MR. ALLEN:

I believe those efforts are under the GPS program. And they are not directly under the PTTI program. We are trying to absorb more and more of the PTTI efforts in the Navy and bring them under one single program. But, again, this is not a GPS effort right now. Someone from the GPS program office would have to address those development efforts.

MR. CLARK WARDRIP, NASA Goddard Space Flight Center:

When do you see these GPS timing receivers becoming available?

MR. ALLEN:

The feasibility model is supposed to be delivered, I believe, next June to the Naval Observatory. And I don't see a unit being available much before a year after that.

MR. WARDRIP: Can you give an estimate of the cost?

MR. ALLEN:

No. Estimates have ranged anywhere from about \$25,000 to \$50,000, but I think until we have the feasibility model and do some testing, we really won't be able to put a price on it.

MR. DAVID ALLAN, National Bureau of Standards:

It is interesting that at the one nanosecond level on a global basis the relativistic effects become extremely important. And to date, internationally, a particular coordinate system that would be useful for this has not been agreed upon. And so this is a separate issue outside of this audience that needs to be flagged and watched. I am glad to see that you are very conscious of that in your considerations.

DR. CERNOT M. R. WINKLER, U. S. Naval Observatory:

That is exactly why you have seen in this program a combination of relativity concerns.

MR. ALLEN: Yes.