# CONCEPT AND ADVANTAGES FOR PTTI INTEGRATION OF TIME ORDERED SYSTEMS

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The question: To what degree is the Naval Observatory concerned with distribution of precise time to the lowest level of each individual user? This is really a question of policy and of basic decisions. It brings up, of course, the problem of fundamental distribution philosophy which will be answered in as much detail as possible.

The Observatory is in a period of transition. What it does now, of course, is not perfect. It sends traveling clocks to individual centers of activities--for example, to Oahu, where the Naval Astronautics Group operates a time reference station, Detachment Charlie (see Figure 1). This station also furnishes data for adjustments of more local time services. In other words, a concept of "trunk-line" timing is used.

This, of course, can only be considered an interim solution and it may even be considered an economical solution as long as there are only a few users, but it should not be the final one. One, therefore, has to ask what the concepts should be for the organization of PTTI distribution (see Figure 2).

First is the concept of <u>economy.</u> It appears unnecessary to have one specific system for the distribution of time, as long as so many systems are available which are capable of distributing time as a piggyback operation. This makes PTTI available on navigational or communication

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# PRECISE TIME SYNCHRONIZATION SERVICE (PTSS)
# WORLD DISSEMINATION

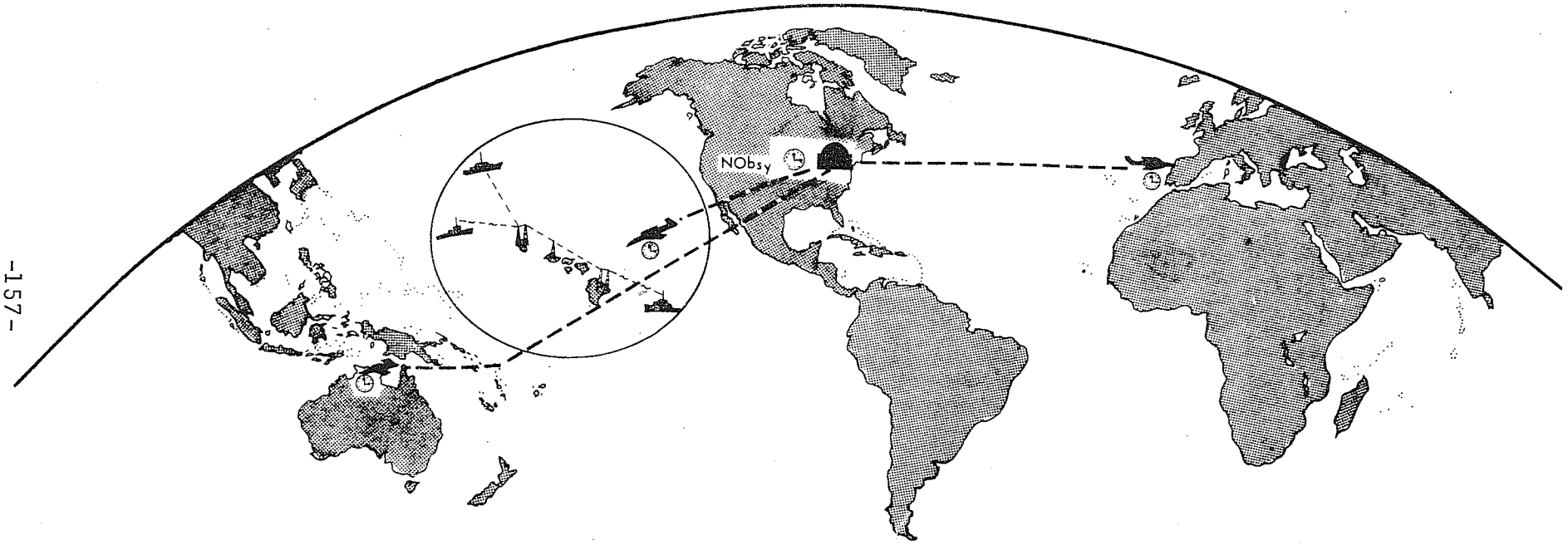



FIGURE 1

# DISTRIBUTION

CONCEPTS

1. ECONOMY: SUPERPOSITION OF PTTI ON NAV & COMM. SYSTEMS
2. REDUNDANCY: USE DIFFERENT SYSTEMS, IF ECONOMICAL
3. ORGANIZATION: HIERARCHY — ONE SOURCE - "TRUNK LINE" TIMING TO PTRS

SPECIFICATION OF NEEDS

1. PRECISION OF SYNCRONIZATION
2. FREQUENCY OF ACCESS TO SYNCRONIZATION
3. QUALITY OF CLOCKS USED (RELIABILITY X PERFORMANCE)

WITHIN SERVICES: ARMY-NAVY-AF CALIBRATION SYSTEM

BY AREA: GLOBAL-INTERMEDIATE-LOCAL SERVICES

BY SYSTEM: PROPAGATION PTTI WITHIN EACH SYSTEM, INTERFACE WITH OTHERS AS BACK-UP

EXAMPLES OMEGA USES INTERNAL SYNCH. AND USES LOR-C AS EXTERNAL BACK-UP

MANY LOR-C CHAINS CAN BE LINKED DIRECTLY, BUT MUST USE SATELLITES AND PORT. CLOCKS FOR CHECKING

FIGURE 2

systems. That principle is far superior to the design or implementation of a specific time distribution system, because it offers as a second benefit, the necessary redundancy. Different systems should be used simultaneously, since only incremental costs have to be spent to provide that additional service.

PTTI incremental cost is sometimes exceedingly small. To put time signals on the VLF high-powered transmitters requires an expenditure only for the clocks--an expenditure of approximately $30,000 or $40,000 per station, with some redundancy, compared to the millions of dollars of investment for the station itself. Redundancy will become more important in the future, since there are several time frequency systems under development, and these may require more reliable access to synchronization sources.

As to organization, Figure 2 in Mr. Stone's presentation (page 123) exploits the principle of hierarchy. There is one source--trunk-line timing to Precise Time Reference Stations (PTRS)--which provides the nodal points for regional distribution of time. For the specification of needs, precision of synchronization is only one parameter, and frequency of access is another very necessary parameter. The payoff to be decided is where to put the money, either in the quality of clocks or in the frequency of access to synchronization.

The overall principle of organization would be very simple if it were not for other complicating factors. There are calibration services within the Army, Navy, and very extensively in the Air Force. Evidently, needs for certification exist here which are in direct conflict to such an organization. In addition, there are geographical facts; there are systems which provide global synchronization or intermediate range or local services; and there is synchronization within each system. It would be a grave mistake for any system designer who proposes to use time frequency technology not to provide for some synchronization capability within the

system. In addition, however, it is necessary to provide for an interface to satisfy the requirements of redundancy and invulnerability against jamming or spoofing. Such an interface must be provided, therefore, with other systems as a backup. That appears to be the real crux of the whole concept of PTTI. There is no justification for going to more expensive clocks and less frequent access, if these considerations do not make a system less vulnerable and more reliable. (That is a point of greatest importance, not only for military systems, but also for any kind of civilian time frequency system.)

Figure 3 shows the capabilities of the standard transmitting stations. The high-frequency time signals are of continuing necessity. There are approximately 50 reliable time signal standard transmission stations distributed over the earth which are synchronized to about 1 msec. They all cooperate in the BIH system of coordinated time which has, at the present time, a tolerance of 1 msec. Within the United States or in the Eastern Pacific, one will listen to WWV, WWVH, and in addition, on the East Coast, the excellent Canadian time signal, CHU. From these stations, time is transmitted very reliably and very simply to 1 msec precision, or greater. The day-to-day variations of the WWV signals which we observed in Washington, D.C. are on the order of 0.2 msec, if the precaution is taken to make the same measurement, on the same frequency, at the same time every day. Any PTTI user should have access to a $50.00 communication receiver, and one must compare that kind of timing capability with other concepts which have previously been discussed.

The CIRR has consistently neglected to consider possible improvements in the high-frequency time signal emissions. These improvements cannot be incorporated because of the limitations to 5-kc bandwidth. If time signals were radiated in a bandwidth of 20 kc and the number of stations was reduced in favor of bandwidths, there would be a distribution

# DISTRIBUTION

1. HF RADIO TIME SIGNALS: 1 ms GLOBAL
2. PORTABLE CLOCK: $\frac{1}{2}$ $\mu$ s GLOBAL
3. VLF-OMEGA: 1-3 $\mu$ s PHASE TRACK (RELATIVE)
4. LORAN-C: $\frac{1}{2}$ $\mu$ s NORTHERN HEMISPHERE EXCEPT WESTERN U. S.
5. SATELLITES:
   - A) DSCS: 0.1 $\mu$ s "TRUNK LINE" } 2 WAY
   - B) TACSAT: 0.5 $\mu$ s "INTERMEDIATE" } 2 WAY
   - C) TRANSIT: 10 $\mu$ s GLOBAL } SILENT (ONE WAY)
   - D) DNSS: 0.1 $\mu$ s GLOBAL } SILENT (ONE WAY)
6. EXOTICS: R&D (VLBI, POWER LINES ETC)

   TV FOR LOCAL SERVICE

   UHF BEACONS: ——————"——————

   $\mu$ WAVE: LOCAL LINKS

FIGURE 3

system in which each mode of atmospheric propagation could be clearly distinguished by time of arrival. There would also be a stability of these modes either the same or nearly the same, as the skywave propagation of LORAN-C; namely, better than 50 μsecs. The stations could be reduced in number very easily, since some were built only for reasons of prestige. Some crowding may occur in the future when all the developing nations insist on a radio standard time system. To summarize, radio time signals will continue to be required by navigators as well as many others.

The exact opposite system with respect to numbers, costs, etc., is one which has already been mentioned--the portable clock. It is a system which has been called a counsel of despair, but it is one which can be implemented immediately. Inasmuch as there are only 100 to 200 users, it is still, by far, the most economical way to bring time to any location of the surface of the earth with better than one-half usec precision.

Many people propose $5 million or more for systems to satisfy five or ten users. Such expensive designs can no longer be considered. With regard to VLF or OMEGA, PTTI capability for a very small cost exists, and I am amazed that VLF seems to be completely out of fashion with many users.

Relative phase track can be performed today with great reliability without danger of loss of coherence, and it gives everyone located anywhere on earth a timing capability of a 5-μsec precision. The situation is different only by an order of magnitude from what there is in LORAN-C; the same thing will be true at OMEGA. The local setup must be calibrated to extract 1 μsec, because other effects enter. Antenna problems are not important for navigational applications, because differences are measured; however, for timing applications they are essential and may be a primary limitation. The LORAN-C is really the best existing operational distribution system with a capability exceeding 1 μsec. Unfortunately, it is not available everywhere.

With regard to satellites, the future situation may utilize the Defense Satellite Communication System and possibl TACSAT with a mutually compatible PTTI modem. This will yield a timing precision certainly in excess of 0.1 μsec, as referenced in the very conservative presentation by Mr. Stone and Mr. Murray. There was nothing in Mr. Murray's data to indicate that the present limit of performance is not entirely due to the limited resolution of the measurement equipment. The figure of 1 μsec is excellent for timing precision. The system will soon be in operation. The concept has been approved both by the Joint Chiefs and by DCA and efforts are well under way to provide an operational capability to the major centers of activity. Hawaii will, of course, be the first, with other stations to follow. The concept contains a link between the East Coast and the West Coast of the United States.

Of the next two systems--TRANSIT and TIMATION--the major advantage is the fact that they are "passive." TRANSIT is an existing capability which is not being exploited. There are five TRANSIT satellites in the air, and there are replacements scheduled in an operational way. It is a full-going system, and it will continue to operate for a long time. It is a pity that the TRANSIT capability has not been utilized for PTTI except by the French, who have demonstrated it very surprisingly.

There are "exotic" systems for PTTI which have been mentioned. But there are also at least 100 different navigational concepts for electronic navigation, and each one would be a useful concept for the dissemination of time.

The question appears to be not what <u>can</u> be done but what <u>should</u> be done. Where should the money be spent? Which compromise would be the best, both from the present point of view and for the foreseeable requirements? The use of television stations is of great importance wherever they are available for local dissemination of high-precision time.

Several concepts have been discussed in previous talks and should be reviewed briefly. The first one is the utilization of the television signals in a differential way. The differential system was first exercised and demonstrated by Tolman and has been used for a couple of years between major timing centers. It does not require any investment at all on the part of the television stations, not even a stabilized carrier emission. One just selects a pulse and makes differential measurements.

The second system, which is the present "line 16" system, or the one which was proposed and designed by Mr. Davis of the National Bureau of Standards, is one which would be of use for application as a local system for dissemination of time. With regard to the "network" dissemination, some essential additional comments are in order. Namely, that although it is true that microsecond stability from day to day over larger distances (almost continental distances) is available, it is also true that the service is continuously being interrupted. The same objection exists against the HF timing signal. That system should also be tested by the same standards and there may be an operational difficulty. More importantly, the propagation delay through the network from time to time changes violently.

There has been a proposal made by the Air Force, Newark, which has great merit, and which is outlined following this discussion. Briefly, they propose to use all three networks; however, people should not immediately jump into a sole reliance on this method because very serious difficulties could arise. At least, "caution" is a very good adjective here until more operational experience has been gained. The television system's great usefulness for local distribution would be of interest anywhere. Wherever there are centers of activity, there is a need for entertainment, and there will be entertainment stations not only in the

United States but in other areas as well. Such a system is very easy to set up and it offers terrific resolution at very little investment. The system has merit; however, the Observatory is faced with a dilemma, in view of some differences of attitude and interest between it and NBS, which evidently is interested in having a very wide general use of the system at a modest accuracy. The Observatory's interests are to use the system to the very highest possible precision in those areas of activity where there is the greatest demand.

This dilemma is posed because the Observatory still has to work out a design which would be compatible with both purposes, because otherwise, approval from the FCC will be difficult to obtain. The FCC, for very good reasons, has to move cautiously in its approval of any such system. Such compatible designs are possible and, such systems should be put into operation immediately. There is some danger that the common R&D syndrome to develop forever and to never become operational will prevail.

The Observatory is at the present time making an extensive effort to improve its own capabilities (see Figure 4). The improvements of the capabilities go on in every area--in the provision of a very stable, very reliable time base and in the determination of astronomical time where a small improvement by a factor of two to five can be squeezed out. Some of these capabilities will not be of use in PTTI, but in related areas like polar variation, etc.

The greatest problem at the moment is to provide funding for high-precision synchronization of all LORAN-C chains, which means that direct synchronization will obviate the need to use corrections, as mentioned by Cdr. Potts. The program has been approved by the Secretary of Defense and is now in the reliable hands of the fiscal people where it will be solved. The next great interest and effort is in making use of the DSCS

# PLANS

1. IMPROVEMENT OF USNO CAPABILITIES
2. HI-PREC. SYNCH. OF ALL LORAN-C
3. USE OF DSCS OPERATIONALLY FOR TRUNK-LINE TIMING TO PTRS
4. UTILIZATION OF FSK SYNCH ON VLF
5. OMEGA SYSTEM
6. USE OF DNSS PROTOTYPES
7. LINK-UP OF MAJOR USERS BY TV, $\mu$ WAVE, ETC.

FIGURE 4

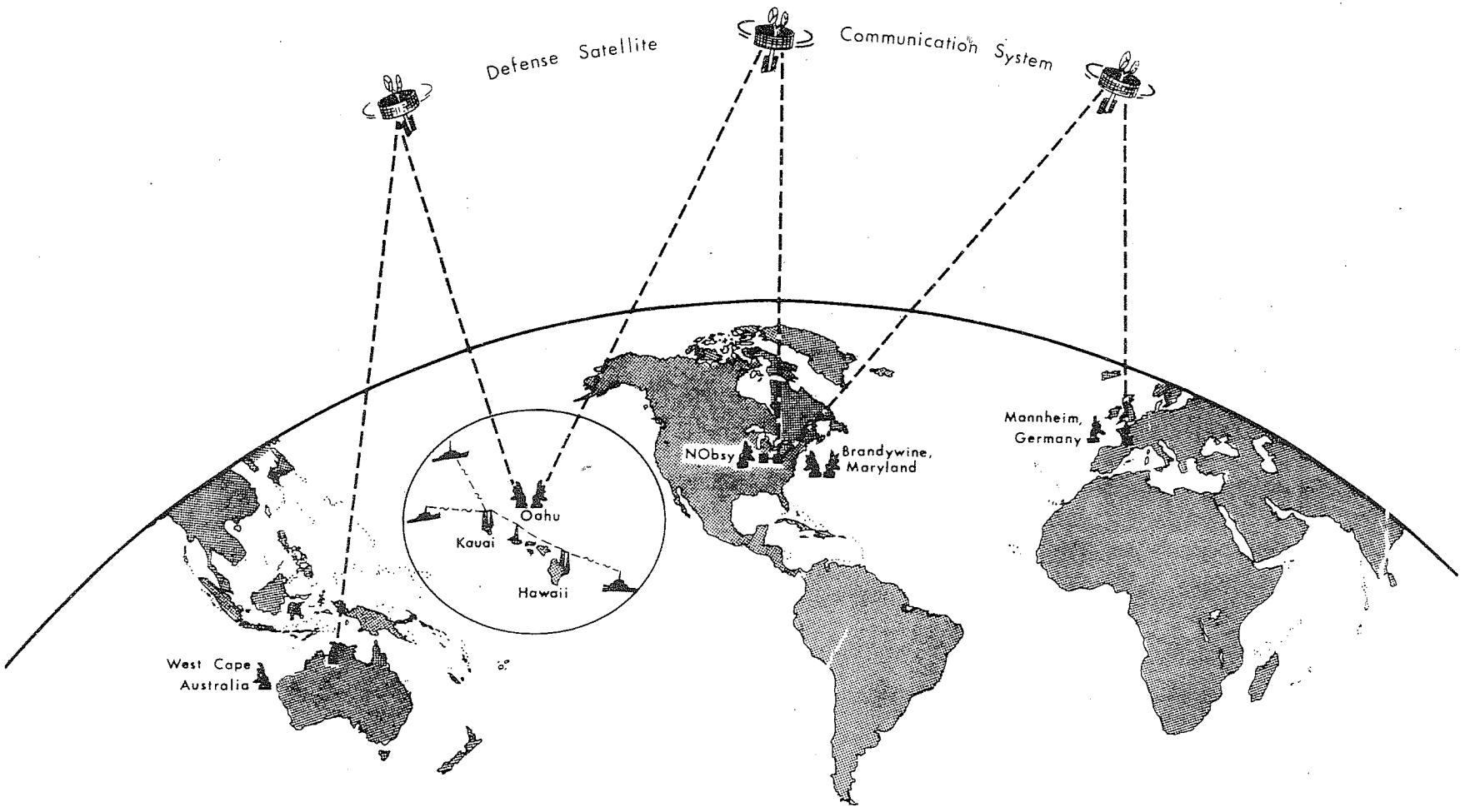
capabilities for trunk-line timing, not only with the precise time reference stations, but also with a number of additional stations--particularly in the Air Force where there is an interest to link-in with that system. It can be done, and there is general agreement that this is very desirable.

Another item of interest concerns the DNSS prototypes. TIMATION II can already be utilized for time purpose dissemination. The numbers which you have seen on the Alaskan LORAN chain frequencies are examples of what can be expected for operational use.

Finally, a point of concern is the link-up of major users by television or by microwave. If a hierarchical organization of time distribution is accepted as an overall strategy, there should be no serious objection for the reasons and the various principles which have been previously listed. But if that is accepted as a primary concept, then it is clear that access possibilities should be provided to regional or local sources of synchronization while more detailed requirements and their justifications should be left to the user or the user system. The Observatory does not have the capability to even consider organizational details; however, it should know about problems and such requirements.

Most people, and particularly those good system designers who have kept in mind the principle that each PTTI system must provide internal synchronization, evidently feel that this is what they need; they have provided for all of their needs and they see no benefit in interfacing with anyone else. That question points to an identity crisis within the PTTI community, because where and why does the need exist to single out this field of interest activities and coordination efforts? How far should we go, and what are the main benefits? They simply have to do with hardening operations of all systems and with economy of operation.

Figure 5 shows the new, high precision "trunk-line" distribution system. For the immediate future, the Observatory will replace a great number of portable clock trips to major centers by satellite links.




**PRECISE TIME AND TIME INTERVAL (PTTI) – WORLD DISSEMINATION**

FIGURE 5