

INNOVATION AND RELIABILITY OF ATOMIC STANDARDS FOR
PTTI APPLICATIONS

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ABSTRACT

Over the past 20 years, the U.S. Government has been the largest single customer for hyperfine frequency standards and clocks. In this same period the government directly and indirectly has provided financial support of extensive research, development and manufacturing methodology efforts in industrial and government laboratories.

The GPS/NAVSTAR Program requirements for a spaceborne clock has provided new impetus and development monies to generate multiple sources of reliable frequency standards and clocks with life expectancies of 5 to 7 years. These multiple sources will produce significant economies and performance improvements to PTTI users in the U.S.

The GPS/NAVSTAR designs should result in units with improved stability and environmental tolerance that will provide U.S. systems planners with strategic advantages in the PTTI field.

I would like to address the subject of innovation and reliability in hyperfine frequency standards and clock systems. Hyperfine standards are defined as those precision frequency sources and clocks which use a hyperfine atomic transition for frequency control and which have realized significant commercial production and acceptance. I refer to the cesium, hydrogen, and rubidium atoms and exclude references to other systems such as thallium and ammonia since these atomic standards have not been commercially exploited in this country.

In the late 50's and early 60's several companies pioneered in the development and production of atomic standards. In the mid 60's statistically significant quantities of cesium and rubidium standards were produced, sold, and put into service by PTTI user agencies. The reliable performance established by the Hewlett Packard hyperfine standards in the 1960's stimulated government interest in additional system applications and further development of the hyperfine family of standards.

In the early 70's the Department of Defense issued military specifications (MIL F 28734 & Elex F 105) which defined four types of cesium standards. Our industry saw the issuance of these MIL specifications as a clear signal by the government that there was a growing opportunity in cesium and hyperfine clocks for system applications.

Until the 1970's government support of hyperfine standards was focused on research and technology development. In the 70's the emphasis shifted and intensified toward the development of specific hardware with direct application to major systems concerned with navigation, communications, Very Long Baseline Interferometry (VLBI) and space experiments. The GPS/NAVSTAR need for development of a spaceborne clock provided great impetus for innovative activities in all three hyperfine clocks. New companies and new concepts advanced rapidly in this period producing new miniature rubidium standards, small long lived cesium standards, and prototype passive H masers. The strong levels of government funding matured these new designs and spawned a broad series of commercially available products.

In the late 70's and now into the early 80's, our industry continues to benefit and mature from both continuing government support and an active commercial marketplace for quality hyperfine standards. Contractual funding from the Department of Defense is directed toward higher system performance and multiple sources of cesium, rubidium, and hydrogen clocks.

To summarize this development activity the following table describes the companies who have been recipients of government funding and a parenthetical estimate of this funding (to date) in millions of dollars.

| <u>CESIUM</u> | <u>RUBIDIUM</u> | <u>HYDROGEN MASER</u> |
|----------------------|-------------------------|--------------------------|
| Atomichron, Inc.* | Autonetics - (Rockwell) | Applied Physics Lab./JHU |
| Freq. Control Corp.* | Collins - (Rockwell) | Hewlett Packard* |
| FEI | Efratom | Hughes Research Lab. |
| FTS | E G & G | Jet Propulsion Lab. |
| Hewlett Packard | General Radio* | NASA Goddard |
| Kernco, Inc. | General Technology* | NBS |
| NBS | Hewlett Packard | Sigma Tau Corporation |
| National Radio* | Tracor* | Smithsonian Astro |
| Pickard & Burns* | Varian Associates* | U. S. Naval Res. Lab. |
| Varian Associates* | | Varian Associates* |
| | | Universities: Harvard |
| | | Laval |
| | | Williams |
| (20 - 25) | (15 - 20) | (25 - 30) |

*No longer active in this business

The figures support public statements made that there is more support and more work available than the hyperfine companies can ingest. Many companies in this field have doubled over the past two years. Perhaps this preoccupation with growth in this period of prosperity has caused a diversion of industry attention from the issues of performance and reliability.

The U.S. Government, as a customer, has had a vested interest to develop both improved clocks and competitive sources for them. The hyperfine technologies have enjoyed strong levels of direct and indirect customer support these past ten years and must now address the question of customer payback. Current programs to qualify several suppliers for GPS/NAVSTAR clocks should favorably impact both the economics and the stability of the source(s) of supply.

The payoff to the government customer is rooted in the fact that for the first time in our business qualified competition exists in all the hyperfine standards. It is no longer adequate for the manufacturer to certify his design, build, and verify by test that the equipment initially meets all applicable acceptance specifications. In the future it should be necessary for the manufacturers both to guarantee and to demonstrate that the customer will actually realize the called for lifetime expectations. Demonstration of the lifetime cost parameter must be an integral condition for a manufacturer to receive future business.

Let me suggest a valid signal that development is truly complete when a manufacturer releases a quantity of commercial products directly spawned from the government sponsored development effort and assumes a significant commercial warranty obligations for these commercial units. It is then that the government customer, after paying for the development, has a right to expect a stable price structure, continuing product improvement and a purchase price that is less than ten times the price of the commercial unit.

The specific point I wish to make today concerns innovation and reliability in hyperfine physics packages. The intensive developments now underway would not be necessary if our industry had achieved the equipment which the government customer(s), some 90% of the market, funded to bring into being.

The technology base for hyperfine physics packages had been established and remained locked away under a "proprietary information" label by a few companies. Government scientists and engineers did not have the opportunity to participate in and evaluate the underlying design and processing philosophy of the physics packages. Nor have the manufacturers revealed the details of factory and field failure history of the design. Only by customer-supplier discussion and analysis of such data can specific problems be quantified and user insights applied to yield simple environment compatible solutions to engineering or processing weaknesses.

This lack of physics package 'know-how' and the lack in the visibility of data make it difficult for a user to evaluate whether a given supplier can consistently meet his lifetime and performance requirements. Usually the customer can provide verification that the electronic components are procured, screened and assembled to a specified practice. When it comes to the physics package used in the equipment, the PTTI user must accept company assurance that the 'proprietary unit' was built according to strict process specifi-

cations and in facilities unique to the system requirements. Then, screening and in-house unit testing will do the rest of the reliability and performance job.

Until recently the development sponsoring agency could not purchase cesium or rubidium physics packages without buying the whole standard or clock. In my opinion what remains to be done is for the Department of Defense customer to conduct specific in-house testing and make design appraisals of the hyperfine physics package. By establishing end user data concerning the reliability and lifetime performance of a given design, in a government laboratory, the customer could compare results with data provided by the manufacturer.

The tests to be performed by the government laboratory can include several tests usually conducted by the manufacturers and can be expanded to include tests which reveal the design limits of the device.

PHYSICS PACKAGE TESTS FOR DESIGN CHARACTERIZATION

- o Accelerated Life Testing
- o High/Low Ambient Temperature Runs
- o Irradiation
- o Over Voltage Testing
- o Temperature Gradient Induction
- o R.F. Power Shift Stimulation
- o Spectral Sensitivity

The appearance of multiple manufacturers in the GPS/NAVSTAR hyperfine marketplace will provide economic and performance benefits to the whole of the PTTI community. It now remains for the U.S. Government to establish an in-service capability for the assessment, evaluation and lifetime testing of the physics units utilized by these manufacturers. With data and the institution of manufacturing controls and safeguards the government's support can finally produce an economic and performance return on investment.

QUESTIONS AND ANSWERS

DR. HELLWIG:

Maybe just a comment on the availability of physics packages for testing. If I remember right, Varian was willing and able to sell tubes in the '60's. I think Hewlett-Packard did so in the early days -- 1970's -- and FTS has sold tubes over the past years to the U.S. government. That is not a question of lack of availability.

It is a lack of focus on this problem which I totally agree with you, Bob. I think this is one of the major problems.

CHAIRMAN STOVER:

Well, there seems to be a common thread through the papers we have heard so far of need for more cooperation between industry and government. We will see if that continues with our other two papers.