A COMPUTERIZED DATA MANAGEMENT METHODOLOGY FOR THE MINUTEMAN INSTRUMENTATION SYSTEM

L. D. FOUST
Telecommunications Analyses Section
TRW Systems
San Bernardino, CA

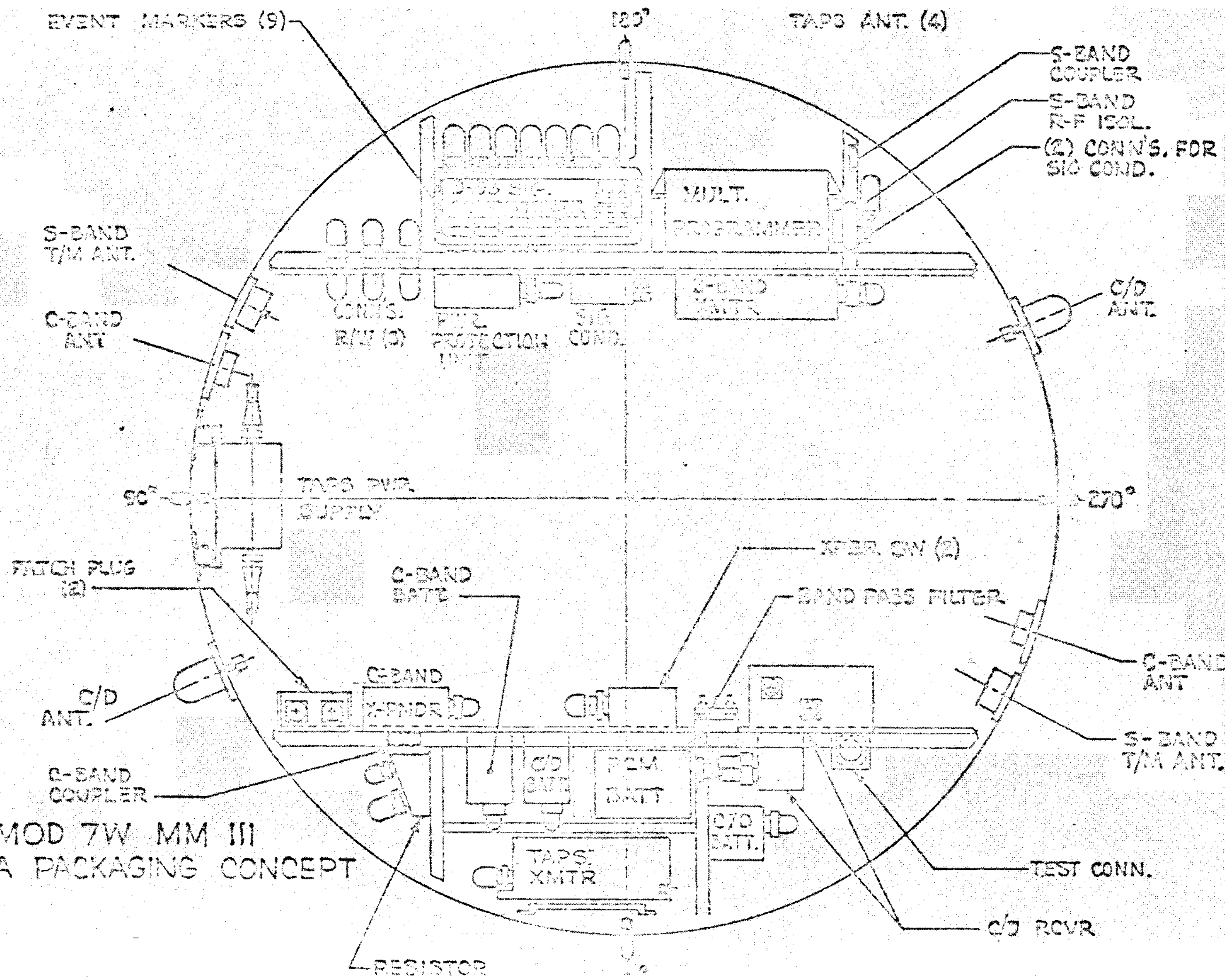
Summary The tasks associated with Development Management of complex instrumentation systems, from initial concept to production, involves the utilization of very large quantities of data. It is impossible to acquire, process, and analyze this data entirely by manual means, therefore, automated data management systems have been conceived to solve this type of problem. The computerized data system developed by SAMSO MINUTEMAN Instrumentation System Engineering Management is described and is further illustrated by presenting some of the specific applications of the system.

Introduction It is the objective of the MINUTEMAN Data Management System to optimize MINUTEMAN Instrumentation Management decisions by providing appropriate data upon which to base such decisions. Central to this system is a computerized data bank. Subroutines perform statistical manipulations of the data as well as provide specific report formats.

A brief description of the equipment which is developed by the MINUTEMAN Instrumentation Systems Program Office (SPO) is presented in order to provide the reader with a better understanding of the type of data which is processed by the Data Management System.

The system concept was developed with the user requirements being the paramount consideration. Computer program formats were constrained by a criteria written to reflect these user requirements. Manufacturers' data flows are presently being modified to further improve the compatibility of data formats and delivery schedules with the data user needs.

MINUTEMAN Instrumentation System The items of hardware which are considered to be part of the MINUTEMAN Instrumentation System are many and quite varied in type. The Airborne Instrumentation shown in Figure #1, is comprised of three major subsystems which include telemetry, metric tracking, and flight termination equipment. The basic telemetry system is a 345.6K bit PCM/ PM S-Band system which is



MOD 7W MM III
A PACKAGING CONCEPT

augmented by two FM/PM systems in the R&D configuration. A complex signal conditioner is included which provides electrical signals of appropriate voltage ranges to the multiplexer and serves as a buffer for data transferred from the Guidance Computer Accumulator to the telemetry system. The metric tracking subsystem is a C-Band transponder and a passive two element array antenna. The transponder receives the signal from a supporting radar and retransmits the signal with increased power to maximize the slant range at which the radar can operate. The flight termination subsystem is comprised of two command destruct receivers which are capable of detecting a tone modulated CW command from the range safety transmitters and initiating the flight termination ordnance. Included in this subsystem is a number of switches and timers which detect premature separation of propulsion stages and effect thrust termination on the leaving stage.

In total these equipments constitute a sophisticated system which acquires flight performance data, improves trajectory information, and provides the capability to terminate the flight of an errant missile.

The data acquired from the telemetry system is utilized to perform post flight analysis while the metric data is used as an input to the Range Safety System to allow the Range Safety Officer to make flight termination decisions.

A vital function of the Data Management System is to compile, summarize, and present data which determines the adequacy of these systems to fulfill each required function and to facilitate flight readiness decisions on individual flight units.

The airborne equipment is supported by over 100 end items of equipment ranging from adapter cables and test equipment to extremely complex repeaters and relay systems. A typical example of instrumentation support equipment is the large test sets which are provided at the manufacturers' facilities as well as at the test ranges to allow complete testing of the instrumentation system during production acceptance and flight readiness tests. This equipment must be so designed and utilized as to insure that proper testing is accomplished yielding accurate data and without degrading flight test performance. The Data Management System monitors the data developed on such equipment to insure that appropriate testing is being conducted and that no degradation in test equipment performance is experienced between calibration cycles.

Each of the airborne subsystems functionsare only a part of a total system during flight test operations. The telemetry and metric tracking subsystems must operate with ground based which are geog3nphically located over the entire test range. The overall operating characteristics of each of these sensors is evaluated to support assessment of end to end system performance. It is essential that these systems be viewed as a total system which includes both airborne and ground based equipment. A complete understanding of test range capability must be developed to predict current system performance or manage any cost effective development of new hardware.

Data Management System Development It was recognized by the MINUTEMAN SPO that the complexity of the systems being developed today required the formulation of a development management methodology of which, data management was a central part. In order to understand more fully the requirement for data management, let -us review the development cycle of MINUTEMAN hardware. This is essentially a process involving three distinct phases. The first or conceptual phase includes such activities as the conversion of general requirements into a formal system criteria, development of general test plans and the initial determination of test range capability. This is followed by the development phase which includes the formal design review sequence and initial hardware production flight proof testing is conducted and First Article Configuration Inspection is completed. The third and final phase is the application phase during which the test range interface is finalized and quantity production is begun.

It was intended that the data system would support management decisions during all three development phases. General requirements for data were established by discussions with performance analysts, system engineers, and SPO managers. The result was a expressed need for special data summaries in the traditional categories of cost, schedule and performance. Further, it was determined that the data originated in three sources. The first was classified as "Contractual Data" and included such information as hardware costs, production and test schedules, and the specific performance parameters found in formal criteria documents, specifications, standards and test procedures. The second source was the data accumulated from the hardware development, production, and flight tests. The third was "anomaly data" which was available from routine failure reports and quality assurance paper generated by the manufacturer.

The performance analyst, systems engineers and SPO managers each sought information from this data base but in a format unique to each function. These individual requirements were subjected to a detailed review and a set of standardized report formats were proposed which contained the requirements of each user. The reports were in conformance with another constraint which was that the reports be very concise summaries, and not simply a "dump" of all data available. The report formats proved to be satisfactory for most of the requirements of the users and were then incorporated in the system criteria document. Cost constraints associated with the development of this data system require the original implementation of this system to be accomplished on a machine of limited capacity and flexibility which made the standard report format seem even more attractive.

Data Management System Criteria The criteria document was formalized to provide a baseline for development of the data system. A system usage outline was developed and is presented below:

USE OUTLINE FOR THE MINUTEMAN DATA MANAGEMENT SYSTEM

1. General Data Bank

   Provide a central location for instrumentation system data which is easily accessible to data users.

2. SPO Management Data

   A. Provide recycle data and other information which describes activities resulting in unplanned cost.

   B. Provide parameter data which would indicate potential cost savings by relaxation or modification of identified parameter value limits in the specifications.

3. System Engineering

   A. Provide system, subsystem, and component performance history to data users from production acceptance through flight test.

   B. Provide parameter description and history of equipment type for comparison with in-process system parameters.

   C. Provide flags for parameters falling outside predetermined limits.

4. Performance Analysis

   A. Provide parameter statistical descriptions for inputs to trade studies.

   B. Provide updated parameter values and distribution information for use in system model.

   C. Provide data which will allow assessment of end-to-end system performance margin via ISMAP* computer program.

* ISMAP is a computerized RF system performance analysis program developed as part of the MINUTEMAN Instrumentation Management Methodology.

The contents of two standard data formats were delineated in the criteria. The specific data required in each report is given in the format descriptions given below.

DATA FORMAT "A"

This format shall provide historical data by equipment type (P/N). The data shall include:

1. Part nomenclature, part number
2. Total ordered on existing contracts
3. Total manufactured
4. Total accepted from Contractor (delivered to the field)
5. Total ground tests (including recycles)
6. Total failed in ground test (tests at this assembly level or higher requiring replacement of discrepant hardware to rectify problem)
    a. Airborne failure
    b. Test equipment failure
    c. List next lower assembly and portion of total failures attributed to each by P/N
7. Total flight tested
8. Total failed in flight test
    a. List next lower assembly and portion of total failures attributed to each by P/N
9. Total UER's (unexpected event records used to record test anomalies)
    a. Assembly level UER's for equipment shipped but not flown
    b. Assembly level UER's by number against each next lower assembly
10. Wafers (by SIN) not flight tested with parameters or test history still carrying an open flag
    a. Parameter value in first or last 5 percent of population distribution
    b. No confirmed failure in:
        1. Removed A/B equipment
        2. Replaced T. E. equipment
    c. Unacceptable repeatability
11. Data Dump for Past X Month Period
    a. ETR Flight Tested (by S/N)
    b. ETR Ground Tested (by S/N)
    c. ETR Failures and Subsystem Breakdown
    d. WTR Flight Tested (by S/N)
    e. WTR Ground Tested (by S/N)
    f. WTR Failures and Subsystem Breakdown

12. Equipment Type (P/N) Acceptance Ratio (A/R), Ground Tests i.e.

$$A/R \; \frac{\text{Tests Passed at this level}}{\text{Tests Conducted at this level}}$$

13. Histograms, median, and variance of selected parameters for equipment type population

Unit costs by PIN and date of effectivity

DATA FORMAT "B"

This format shall provide historical data by equipment S/N.

1. Part nomenclature, P/N and S/N, Subsystems P/N's and S/N's (present configuration)
2. Date manufacured
3. Test history
   a. Performance Acceptance Test date(s)
   b. Field Test date(s)
   c. Flight Test date
   d. Vendor Test date (due to recycle)
4. List Flags
   a. Open, indicate parameter and next lower assembly
   b. Closed, allow trace to lowest levels
5. Total failed in Ground Test (tests failed at this assembly level or higher requiring replacement of discrepant hardware to rectify problem.)
   a. A/B Failure
   b. T. E. Failure

6 All UER's against assembly and lower, including P/N and S/N for next lower assembly where applicable

7. Dump parameters for part as currently configured (list parameter and value for each test at this level.
8. Unit costs by PIN and date of effectivity
9. Configuration History
   a.. Original next lower assembly PIN, SIN
   b. Replacement assemblies PIN, SIN
   c. List UER's associated with (b) followed by indication of problem to allow further investigation
10. Indicate each parameter value location in population as (x) from median of equipment type distribution

The term “flag” is used to denote a special indicator found on the report which indicates that a previously determined test has been applied to the data and the specific data which formed the basis for this report was found in violation of that test. A specific example is the test to determine that a given parameter be of such a value as to lie within the range of the 5th to the 95th percentile of the established population distribution of that parameter. A value outside of that range is shown with the special indication or flag on the report.

Finally the criteria established two additional requirements which were to store data against a maximum of three levels of hardware assembly and provided that individual parameters be removed from the active data base after two years and retained only in statistical form for use in appropriate entries in formated reports. These requirements reflected practical limitations which established by trading user requirements against budgetary and machine constraints. The period’ of time during which data is retained in the program was easily calculated by the following equation:

$$\sum_{i=1}^{n} T R_i \quad C \quad \text{therefore,}$$

$$T = C / \sum_{i=1}^{n} R_i \quad \text{where,}$$

T	=	time data is retained
R_1	=	rate data is generated for System i
n	=	number of systems having data in the computer
C	=	total capacity of the data bank

A great deal of care was exercised in avoiding pitfalls encountered by others in data bank design. Experience in data system design points to two traditional shortcomings of these systems; a preoccupation which quantity rather than quality of data and a lack of structure which allows the user to absorb more than a fraction of the data available. The data quantity is limited in the MINUTEMAN Data System by carefully selecting and limiting the parameter value stored and provisioning for their removal as they become superceded by more recent data. User absorption is increased by the use of formated reports.

System Implementation Since the system criteria was developed with the machine limitations carefully considered, the computer program was written with relatively little difficulty. The primary problem encountered in achieving operational capability was a result of the complete lack of commonality in the formats in which the data was received from the various data sources. This problem is difficult to correct since many contractual data delivery constraints are in conflict with a standardized data format requirement. The present solution to this problem has been to manually compile the raw data, convert it to a standard format, and punch cards for entry into the data bank. This method has resulted in approximately 50 percent of the resources expended to date going for conversion and bank loading functions. Many contracts are involved but they are being modified as quickly as is practical to overcome this difficulty.

A typical format “B” report is partially reproduced below to illustrate the form of such reports. This is a synthetic report and does not contain actual MINUTEMAN Instrumentation System data.

DATA MANAGEMENT REPORT

Format “B” For S-Band Transmitter
P/N 25-19463-4, S/N 00164

S-Band Transmitter
P/N 25-19463-4, S/N 00164
Date Manufacturing 01/26/69

Flag Listing
Po, 02/19/ 69
Flag, “S-Band Po Repeatability”
Closed U157499
Ground Test Failures/Recycles 1 Count G to N/G transition. in test history

UER’s - U157499

T. E. Failures - 0
A/B Failure 1

All Critical Parameter

Iin	Po	Test Level	Date	GO/NO-GO	UER/N/A
5.6A	9.5W	BENCH	01/26/ 69	G	Mod 7E S/N 010
N/A	5.2W	PAT	02/19/ 69	G	
N/A	3.4W*	FIELD	04/ 03/ 69	NG	U157499
5.1A	3.3W*	BENCH	04/14/ 69	NG	
5.8A	9.4W	VENDOR	05/12/ 69	G	
5.8A	9.3W	BENCH	05/ 20/ 69	G	
N/A	9.1W	PAT	07/ 01/ 69	G	Mod 7W S/N 015
N/A	9.4W	FIELD	08/ 05/ 69	G	
N/A	N/A	FLIGHT	08/29/ 69	G	

* Out-of-tolerance parameter
UNIT COST
3/29/68, CONTRACT 00796, $25,000
9/01/68, VALUE ECP 07196, $21,500
NOTE: All underlined entries are unique inputs recorded into Format "B" after extraction from and/or manipulation by the MINUTEMAN Data Management Program

The MINUTEMAN Data Management System provides for special reports or data displays. These are generated to specific user requirements but are less efficient to use since detailed information must be provided and special subroutines written to produce them. A specific example of such a report is provided in Figure 2. This data format was used to examine the variations in C-Band transponder transmitter frequency during a series of production acceptance tests.

Conclusions After approximately one year of operation the MINUTEMAN Data Management System has proven to be a significant part of the system warrant elaboration. A capability to monitor trends or variations in parameter values during a series of tests has been most beneficial. The trend test is accomplished by establishing a set of test value limits, based on the parameter value recorded during the previous test and knowledge of the parameter variations experienced during past tests. These values are normally less than the specification acceptance limits reflected in the test procedures. Defective hardware has been identified by this data analysis technique and resulted in the replacement or repair of the defective part. These failures would not have been detected during routine testing and analysis since the values quite often do not exceed the specification limits.

The Data Management System has produced other benefits such as detected test procedure errors, isolated test equipment which was improperly calibrated and illuminated inconsistencies in test procedures utilized to conduct similar tests at different test sites. This system has shown that it does fulfill the primary objective of providing the maximum quantity of useable data into the system management activities thus making optimized decisions possible.

With the value of a data management system firmly established, an effort has been initiated to expand the initial capability. This activity is currently underway and includes a rewrite of the computer program and a transfer of the system to a new machine with expanded capacity and capability.

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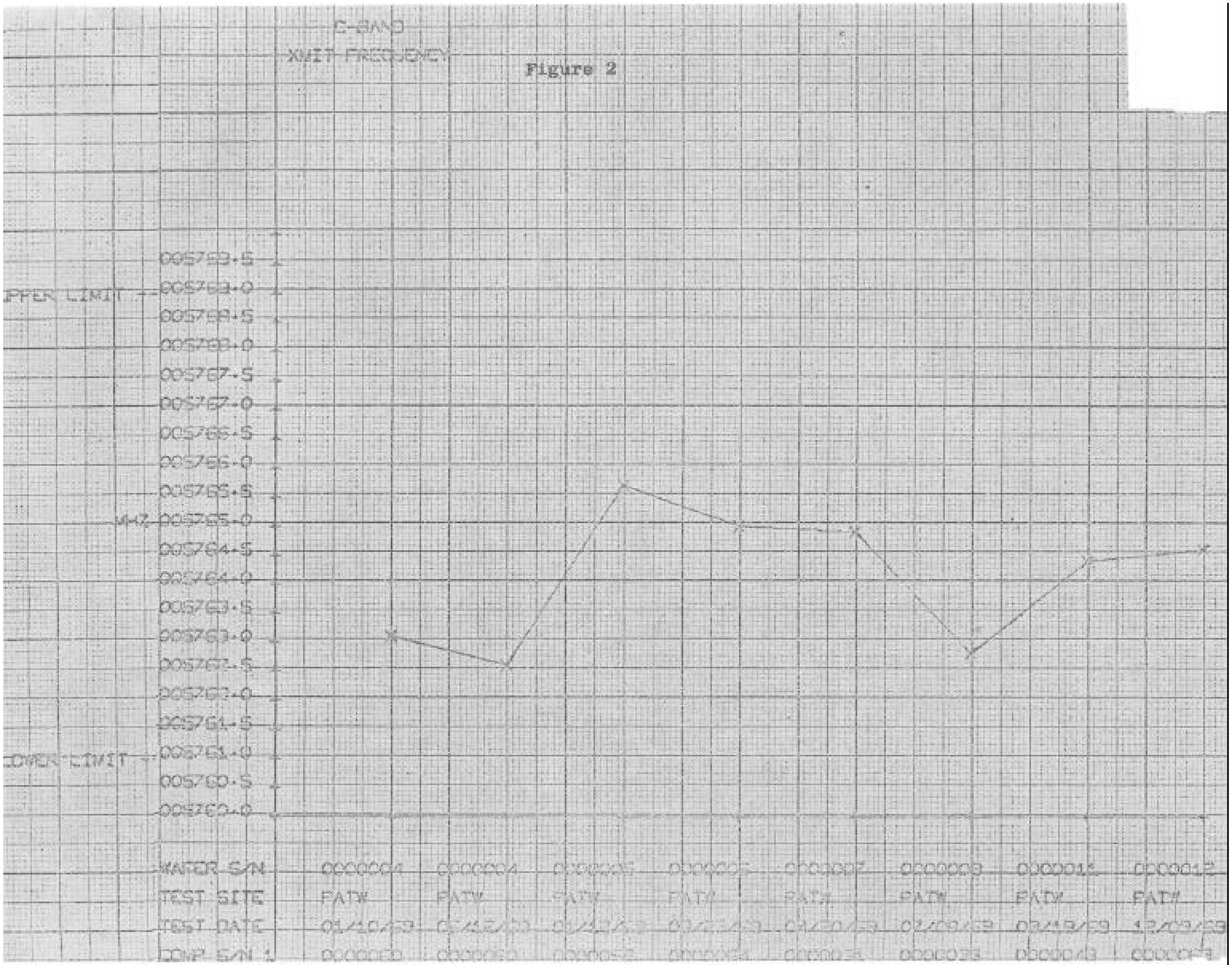
C-BAND
XMIT FREQUENCY
005769.5
UPPER LIMIT
005769.0
005768.5
005768.0
005767.5
005767.0
005766.5
005766.0
005765.5
MHZ
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005762.5
005762.0
005761.5
LOWER LIMIT
005761.0
005760.5
005760.0
WAFER S/N
TEST SITE
TEST DATE
COMP S/N 1

Figure 2