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MINICOMPUTER MAINTENANCE AND OPERATIONS CENTER OPERATIONS GUIDE

MINICOMPUTER MAINTENANCE GROUP

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Prepared by the Information Management Services Division,
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1. INTRODUCTION

1.01 Purpose

This practice provides an operations guide for the Minicomputer Maintenance and Operations Center (MMOC). It contains descriptive information for each nonmanagement job in the Minicomputer Maintenance Group (MMG). It is not intended to be an in-depth troubleshooting guide.

1.02 Reasons for Reissue

This practice is reissued due to divestiture and the addition of section 10 "MMG Force Sizing".

2. GENERAL

The work functions of an MMOC are divided into two categories; (1) Minicomputer Operations, and (2) Maintenance. Each category is normally cared for in one of two subgroups, the Minicomputer Operations Group (MOG) or the Minicomputer Maintenance Group (MMG). The MOG and MMG in a model MMOC are joined under common management. The specific level they are joined is dependent on the magnitude of the organization, span of control, and local practices.

The MMG is responsible for conducting preventive maintenance (PM) routines and for performing corrective maintenance (CM) of computer subsystem hardware. This includes the processors and peripherals (disks, tapes, etc.) and terminal equipment associated with the computer system (console terminal). It is responsible for stocking spare parts, managing the spare parts inventory at efficient levels, and maintaining an inventory of installed hardware components. The MMG is also responsible for the installation and administration of field changes, the reflection of these changes in the records, and where necessary and possible, installing these changes in stocked spare parts.

3. WORK FUNCTIONS

This defines the specific work functions and accompanying work flows for all nonmanagement personnel in the MMG. This information will guide MMG personnel in performing their work functions. There are six major work functions assigned to nonmanagement personnel in an MMG. These functions are:

(1) **Minicomputer Corrective Maintenance (MCM):** Personnel assigned to perform CM on all minicomputer hardware under service agreement with the MOG and remote computer systems within the MMG geographical region (Figure 1).

(2) **Minicomputer Preventive Maintenance (MPM):** Personnel assigned to perform PM on a scheduled basis to avoid hardware malfunctions that might occur during normal usage before it adversely affects system performance or user operation (Figure 2).

(3) **Minicomputer Hardware Change (MHC):** Personnel assigned to perform the application of all MHC orders on maintained systems. These personnel provide feedback to the MMOC Support Group (MSG) when problems are encountered after the application of a Field Change Order (FCO) and assist MSG personnel in resolving MHC problems (Figure 3).

(4) **Spare Parts Management (SPM):** Personnel assigned to ensure proper stocking of spare parts to support the MMG. This includes provisioning, stocking, tracking minicomputer spare parts, shipping, receiving, and inventorying these parts. The SPM personnel are responsible for parts shipments to the vendor for repair and for emergency parts ordering from the various vendors when parts are out of stock (Figure 4).

(5) **Module Repair (MR):** In companies performing circuit board repair, personnel assigned to the MR work are responsible for repairing defective circuit boards to the component level. These

personnel also repair subassemblies when an entire subassembly (e.g., disk drive or tape drive) is removed from the system (Figure 5).

(6) **Minicomputer Maintenance Administration (MMA):** Personnel assigned to perform the day-to-day administrative procedures in the MMG. This includes answering and directing phone calls to the appropriate MMG personnel; processing bills, vouchers and time reports (using proper general instructions); typing correspondence; filing, and routing mail (Figure 6).

4. MINICOMPUTER CORRECTIVE MAINTENANCE

When a trouble call is received, the MCM manager opens the trouble report log and loads the trouble to an available CM technician (Figure 1).

If the technician is on site, troubleshooting procedures may begin immediately (Figure 1). The CM technician confers with the operator of the system with the problem to find out what type trouble symptoms the operator has experienced (e.g., on-line system software diagnostic failure, error log printouts, system crashed and operator cannot boot, etc.). When the system operator cannot identify the cause of the trouble, the CM technician must begin fault isolation.

The fault isolation process begins with a determination of whether or not there is a power problem. If there are no obvious indicators of a power problem (e.g., blown fuse, circuit breaker tripped), the technician checks regulators for over/under voltage. All voltages are adjusted, using a digital voltmeter, to recommended vendor specifications. Next, the technician, with the aid of an oscilloscope, checks all voltages for noise and replaces any regulators which do not meet vendor tolerances.

After power is eliminated as the source of the problem, the fault isolation sequence proceeds:

(1) Check basic processor

(2) Check internal options (e.g., cache memory, memory management, or floating point)

(3) Check main memory.

These components are checked in the following sequence:

(1) Access internal registers by "toggle in" procedures and run basic diagnostics until the complete central processing unit (CPU), its options, and its memory are thoroughly tested and pass all diagnostics.

(2) Test each peripheral device, one at a time, and run any communications devices.

(3) Run vendor system diagnostics and/or operating system on-line system diagnostics (e.g., UNIX* operating system edit program).

The CM work flows are referenced at the "Find Trouble" decision point (Figure 1). After a predetermined period of time (previously agreed upon by the MOG/MMG managers), if the trouble has not been found, it should be escalated to the MSG. The MSG will then assist the CM technician in correcting the problem.

The CM technician may have completed all troubleshooting and arrived at the "No Trouble Found (NTF)" condition. In this case, the technician returns the system back to the MOG, goes to Step 2 of

* UNIX is a trademark of AT&T Bell Laboratories.

the work flow, and completes the procedures indicated.

If the fault is found to be in the circuit board (module) during troubleshooting, the technician must determine the availability of replacement units and decide when the defective parts should be replaced.

The spare parts manager must be contacted for parts availability. At a site with clustered minicomputers, spare parts may be stocked. Otherwise, the technician may have to return to a stock location to pick up parts if the parts cannot be delivered. In all cases, the parts used for repair must be logged out of the MMG spare parts inventory.

A delay in repairing the system will occur if parts are not available. Delay may also occur if a standby system is activated and the trouble could be repaired at a time more convenient and appropriate for the MMG, MOG, and the user. A simplex system with multiple peripherals could be reconfigured and run in an impaired state until parts arrive. However, this arrangement must be agreed to by the MOG, MMG, and user managers and a repair schedule established.

If the technician is able to fix the system now, the repair and checkout of the device can begin immediately. After defective parts are replaced, appropriate tests and diagnostics are run to verify that the trouble has been eliminated. The CM technician then tells the system operator to boot the system with the application software.

After a predetermined period of time has elapsed to ensure proper system operation, a decision must be made as to its performance. If the problem recurs, the trouble should be escalated to the MSG. If system failure is due to a different source of trouble, the technician should begin troubleshooting on the new trouble symptom. When the agreed-upon repair time has elapsed, the MOG/MMG managers must decide whether the CM technician should continue troubleshooting or escalate to the MSG.

When the system is operational, the CM technician turns the system over to the MOG. The CM technician now completes all logs and reports (i.e., system activity report, trouble report, spare parts removal log, etc.). After completing all reports, the CM technician returns all spare parts used and attaches a repair tag stating the status of each part (e.g., for repair with description of trouble symptoms and diagnostic failure printout attached for test only or for FCO, etc.). The CM technician is now ready for the next job.

Refer to the CM flows at the "Tech on Site" decision point (Figure 1). If the technician was not on site when the job was loaded, another consideration must be taken into account. Are there remote diagnostic capabilities (e.g., remote console unit [RCU], etc.)? If "yes," the system should be diagnosed remotely. If diagnostics run without failure, the CM technician should ask the system operator to boot the system, using the operating system software. Once system operation is verified and the "System Still OK" is "yes," the CM technician can complete all reports as shown in the flows. If the system fails again, the CM technician is dispatched to the site with the problem. Depending on the system type and the location, the CM technician should consult with the MMA manager and SPM manager to determine exactly what tools, test equipment, and spare parts should be taken to the site.

If the remote diagnostics fail and isolation to a specific device is accomplished, the CM technician needs to take only the spare parts and/or test equipment for that specific device. If the failure cannot be isolated, the CM technician has to take all required spare parts for the system in trouble.

If there are no remote diagnostic capabilities, the MMG must rely on the computer operator for information and assistance in isolating the problem cause of trouble. With operator analysis of the trouble the CM technician can determine what spare parts, tools, and test equipment are needed to do the repairs. This will eliminate carrying parts and equipment that are not needed, making these parts available to other CM technicians. This contributes to better control of tools and test equipment and reduces spare part levels of stocking. After the CM technician arrives on site, normal troubleshooting may begin by following the same procedures previously discussed.

5. PREVENTIVE MAINTENANCE

Preventive maintenance (PM) is the physical inspection of a system and the application of diagnostic tests and procedures to detect and correct problem or potential problem conditions. These conditions, if not corrected, could progressively degrade system operation and ultimately result in a system failure. It includes locating, repairing, and recording troubles (service affecting or not) that result from scheduled routine work. It also applies to troubles that are discovered by any manually-initiated diagnostic program.

Establishing a PM schedule for each system involves total cooperation and understanding of the MOG, MMG, and system managers responsible for each system, since performing PM generally requires taking the system out of service. The schedule should be adhered to as much as possible. There are uncontrollable circumstances that require schedule flexibility (e.g., loading a new data base, various types of reliability studies, conflicts from CM, etc.). If PM cannot be performed on schedule, it should not be dropped for that particular period but rescheduled.

The PM routines are usually set up on specific time intervals (e.g., weekly, monthly, quarterly, semiannually, and annually). Some weekly and monthly PM is performed by the MOG operator (e.g., cleaning tape/disk heads, cleaning filters and prefilters, etc.). The various vendors publish PM guides and procedures for each device or option manufactured. These publications may be used as a reference guide to establish scheduling and procedures unique to each system (see Practice 007-560-309).

On large systems with numerous disk and tape drives, too much time is needed to do a complete PM on the entire system. In this case, PM is on a partial basis (e.g., all tape drives or all disk drives), at one time. Doing PM in this manner ensures compatibility between all drives and decreases the downtime for the system. If systems are clustered at one location, PM could be done on all the disk/tape drives during the same week. Using the same technician and exactly the same test and alignment equipment also tends to maintain better uniformity between adjusted system components.

On small systems or remote systems, it may be desirable to do complete PM on the entire system. If extensive travel time is required to reach a remote site, it may be beneficial to do total PM even if it requires more than one day to complete.

The MMG should maintain an accurate inventory of each minicomputer system it maintains. This includes the total number of systems and devices within its geographical region. The inventory enables the spare parts manager to initiate purchase orders for expendable parts necessary for PM routines to cover the entire year (e.g., various type of filters, belts, fans, etc.). This enables the spare parts manager to order bulk quantities of expendable items and receive a greater discount on the price of these parts. This minimizes the number of purchase orders for PM parts and assures that parts are available every time a PM is due.

In Figure 2, at the "PM Work Loaded to Tech" point, the MMA should have checked with the system manager to ensure the following:

(a) The system is available.

(b) No problems have occurred on the system requiring CM since the last entry in the maintenance activity log for that system.

The MMA will also open MMG logs, and mark the PM type - partial or total system. The PM technician decides from the type of PM and vendor documentation which tools and test equipment are necessary for the job. The technician also determines what parts are required for PM and ensures that appropriate replacement parts (e.g., fans, filters, power supplies, etc.) are properly packed for the trip to the site. The technician checks the status of the system for any FCOs and determines parts required to apply these while the system is down for PM. The PM technician is ready to travel to the site.

When the PM technician is on site, all logs for the system should be checked to verify satisfactory performance since the last time a maintenance activity was logged. The technician should check with the MOG manager and operators to verify system performance. If any problems (e.g., system errors, crashes, or intermittent problems such as occasional read/write errors from a disk or magnetic tape drive) have recently occurred, the technician must decide whether the problem can be taken care of during PM. If not, the technician should perform CM first and then start on the PM after eliminating any existing problems.

When turning the system down for any reason, the PM technician should have the system operator ensure that the data base is backed up on more than one type of media before starting the PM (e.g., one copy on disk, one copy on tape). This will provide current system backup that is especially important if many recent software changes or activities have occurred. A copy of the data base on disk and tape will also be helpful when a total PM is done or a partial PM on all the disk drives or all the tape drives. After the system operator has completed a system backup, the system may be taken out of service and turned over to the PM technician. This activity should be scheduled so that the PM technician is not required to wait at the site before being able to begin the PM.

The technician is now ready to start either partial or total system PM. The recommended procedure for doing a total PM starts at the basic CPU. All filters should be cleaned and/or replaced. All cooling fans are then checked for proper air flow.

Powering the system down while watching how long it takes for the fan to stop rotating is one way to check the fans. Another way is rotating the fan by hand with the system powered down. The fan should spin freely. If it is difficult to turn or the fan stops rotating almost immediately, it should be replaced.

After all fans are checked, the technician should check the power supplies and regulators. The voltage output should be checked and adjusted with a digital voltmeter to the recommended vendor specifications. If the voltage cannot be adjusted to the recommended tolerance, the unit should be replaced. When all power regulators have been adjusted and/or replaced, each output should be checked with a high quality oscilloscope to ensure that the noise level is well below the recommended tolerance.

A physical inspection should now be done on all cables, power harnesses, backplanes, etc., to check for bent pins, frayed cables, poor mating of connectors, or improper module seating.

Next, the lamps on the front console of the CPU should be replaced. There are times when a technician or an operator encounters an error when loading a diagnostic or the operating software. The address or data displayed on the front console are used to aid in fault isolation. If a lamp is burned out in the address or data lights, many hours may be spent looking for the trouble using erroneous data collected from the front console. Lamps should be checked and replaced every time a site is visited and the system is turned down, regardless of the type maintenance to be performed.

The technician should now run the appropriate diagnostics. The basic CPU diagnostics are run first. Referencing the PM flows (Figure 2) at the top right marked "1," if all tests pass (ATP), continue PM on the next device or option interval to the CPU (e.g., memory management, floating point, memory expander, cache memory, etc.) until all of the CPU and its associated options are tested. Main memory should then be tested, followed by an instruction exerciser that tests all of the CPU, and its internal options.

If diagnostics fail, the technician should first check PM procedures. One of the steps in doing the PM may have skipped or an adjustment made incorrectly. Errors in alignment procedures are a common occurrence, especially on peripheral devices (e.g., disk or tape drive). Many diagnostics require the technician to set switches on the CPU front console or ask questions pertaining to the exact type of device (e.g., address and vector, device number, data transfer, etc.).

Inputting the wrong information will also cause the diagnostic to fail. The revision level of the diagnostic may be at an earlier or later revision than can be run on the system. This can also cause diagnostic failures. A hardware engineering change (FCO) may need to be added. If everything appears all right, the diagnostic should be run a second time for fault verification. A read error, that occurs occasionally, can cause the diagnostic to give false errors while being run.

After reloading and the diagnostic, the PM technician should troubleshoot the failure using the CM work flows and begin fault isolation and repair of the defective device. If ATP on the PM, the technician continues PM until all diagnostics are complete and all are ATP.

After completing the PM on the processor, its options, and all of its memory, the PM technician can expand to each peripheral (e.g., all disk drives, all tape drives, etc.).

Any time a disk or tape drive is aligned or a defective module is replaced, the possibility exists that data previously written on the disk or tape drive may not be readable. After alignment of a disk drive, it is always necessary to reformat the disk pack, exercise the drive with a diagnostic, and then reformat the pack if ATP. Data can then be dumped back to the disk and verified. When aligning all disk and tape drives, make backup copies of the operating software on each medium. Align the tape drive first, run all diagnostics to be sure it is working properly, then dump from disk to tape. After all tape drives have been aligned and copies made from disk to tape, the disk drives may be aligned, tested, and the disk packs formatted. Data should then be dumped from tape to the disk drives and verified.

The last devices for PM are the communication devices and any special devices (e.g., alarm and display panels, etc.). *Care should be taken when running diagnostics on these devices because they often require the use of special loop-around test connectors and/or special switch settings to run the diagnostics.*

If the system is large (e.g., a duplex system) or at a remote location requiring extra travel time, total PM may require two or more shifts to complete. This would require the PM technician to halt the PM and resume the next scheduled day. In this case, the technician should stop at a point where the system could be turned back up for service. For example, the PM should be completed on a particular peripheral device before interrupting the PM for that shift.

After the PM is complete, the technician checks for any FCOs that need to be installed. If FCOs are required, they should be applied following the processes detailed in the FCO work flows (Figure 3).

Referring to the PM flows (Figure 2), after the technician has completed the total PM (or has not) and must return on the following scheduled tour, enough time must be given to boot the system and wait for the system to run for a predetermined time period. This ensures a normal system operational mode. After normal system functions have been verified, the technician should complete all logs and reports (e.g., system activity log, trouble report, etc.). If any spare parts were used, a repair tag and spare parts usage report must be filled out. The technician may not turn the system over to the MOG.

6. MINICOMPUTER HARDWARE CHANGE OR FIELD CHANGE ORDERS

The installation of FCOs has historically been a problem for MMGs. It is recommended that MMGs keep up with the latest revision (REV) levels and install all FCOs. This should aid the MMG in its efforts to incorporate FCOs in the systems it maintains.

There is no recommended way to install FCOs that can be applied to all situations. Geographical areas, number of systems, number of personnel, MR facilities, etc., must all be considered before selecting the proper method that meets the requirements of a particular MMG. Examples of the different methods used are as follows:

(1) **Vendor Installed:** If an MMG has relatively few systems to maintain, few technicians, and no circuit board repair facilities, the vendor may be used to install FCOs. This will require taking a module from the MMG spare parts kit or inventory shelves, and sending it to the vendor for installation of the FCO. After receipt of the module from the vendor, a schedule is made for the installation of the FCO module into a system. The module that was removed from the system can now be sent to the vendor for installation of the FCO. This method continues until all systems and the MMG spare parts have the FCO installed. The module swapping that takes place can be scheduled as part of PM or if time does not permit, a technician can be assigned specifically to the FCO installation.

(2) **MMG Internal FCO Installation:** An MMG which has module test and repair facilities can schedule FCO installations internally. The FCO can either be installed by the module swapping method or by assigning a technician to field installation of the FCO. The latter method has the disadvantage of requiring the FCO to be installed and tested on a working system rather than being pretested at the MMG.

(3) **MMG Centralized FCO Installation:** In multistate Bell Operating Companies/Information Distribution Companies (BOC/IDCs) having several MMG locations, there should be a single centralized location that provides component level test and repair of modules. They should also provide a centralized stocking location of spare parts for the other locations. The centralized location can schedule FCO installation by individual area or all areas at one time. This method is very efficient since a centralized repair facility can justify the purchase of specialized tools and test equipment necessary to perform FCO installation. They can also order FCO components, documentation, etc., in bulk quantities providing dollar and time savings. They should be equipped with the necessary test benches to do pretesting of FCO modules. Therefore, problems that may occur because of FCO application may be identified more quickly.

The rules to be followed when incorporating FCOs to ensure high quality results are as follows:

(1) Only well-trained, experienced personnel should be assigned the job function of FCO installation.

(2) Equipment used in the installation of FCOs should be of high quality. This is particularly true of soldering/desoldering units. Basic soldering/desoldering units, attachments, and options can be added as the MMG needs grow, including miniature portable units that can be carried in a tool kit to the field. There should be several sizes of wire wrap tools for adding or removing wiring changes to backplanes. Module cleaning equipment used to wash dirt and residue from boards after installing an FCO adds significantly to high quality standards.

(3) Many FCOs from the vendor require only a small number of components to apply. Usually, the FCO requires the purchase of a kit which includes procedures, updated engineering drawings, and parts needed to install the FCO.

(4) Accurate records must be kept on all FCOs installed. These records should reflect the up-to-date information, including system name and serial number, location, FCO number, etc. A report should be generated periodically to identify any system or part that does not have an FCO installed by a predetermined time period.

Refer now to the Field Change Order Work Flows, starting at the top of the page at "FCO Job Loaded to Tech" (Figure 3). Anytime a maintenance activity occurs, the MMG logs are opened and the type of maintenance being performed is identified. The next step is to determine the method of incorporating the FCO. This will be done in one of two ways; module swap or the FCO must be installed on site. On rare occasions, both methods will be used (e.g., module swap with a backplane wiring change).

Tools, test equipment, and necessary parts have to be obtained. A parts inquiry to the spare parts manager is required and any parts needed should be logged out of the MMG parts inventory records. An inquiry to the minicomputer maintenance administrator is necessary for any documentation needed to install an FCO (e.g., the FCO procedure, updated engineering drawings, new revision diagnostics, etc.).

The FCO technician is now prepared to travel to the site. At the site, the FCO technician should ensure that the data base is backed up before removing the system from service. After the data base backup, the operator should remove the system from service and turn it over to the FCO technician. The FCO technician should always run all diagnostics on a device on which an FCO is to be installed. If the device does not pass diagnostics, CM should be performed before FCO installation. The diagnostic may fail because the FCO is not installed.

If the device passes diagnostic testing, the technician may install the FCO. This could require swapping the module or changing backplane wiring, etc. Next, do any adjustments called for in the FCO. After completing the required adjustments, rerun the old diagnostics or (if specified), run any new diagnostics stated by the FCO.

If diagnostics pass, the technician can continue FCO installation. If no other FCOs are required, the technician can have the operator boot the system and wait for the predetermined period of time to ensure the system is operating properly. If the system cannot be restored to an operational state, go to Step 5 on the CM flows (Figure 1) and begin troubleshooting the system.

When the system is operational, the FCO technician can update inventory records, maintenance logs, and upon arrival back at the MMG office, return all parts to SPM and tag all modules used. These modules may then have the FCO added at the MMG repair facility or be sent to the vendor for installation of the FCO. After completing all logs and reports at the site, the FCO technician can turn the system over to the MOG.

If, after installation of the FCO, the system cannot be restored, an error may have occurred while the FCO was being installed. In this case, go to "Check Procedures." A step in the FCO may have been overlooked or the device being worked on may not have been adjusted correctly. The adjustment procedure may also have been changed with the addition of the FCO. If the procedures are okay, then check documentation. Sometimes the documentation is misinterpreted. Finally, check the diagnostics.

Sometimes the vendor produces an FCO in order to correct a condition which causes the diagnostics to fail. Application of an FCO may cause an existing diagnostic to fail after it is installed. In these cases, a new diagnostic should accompany the FCO. If the checks do not correct the problem, remove the FCO if possible (e.g., swap out the new FCO module with the old module and rerun the diagnostic). If backplane wiring is involved, it may not be practical unless there are only one or two wiring changes.

If the system cannot be restored after performing the previous steps, the MSG should be contacted. The MSG should contact the vendor to clear the problem as quickly as possible. If the problem is resolved by performing the previous steps, the technician can go to Step 3 of the FCO flows (Figure 3) and continue installing FCOs or boot the system, etc. The procedures on the flows should be followed until complete.

7. SPARE PARTS INVENTORY AND ADMINISTRATION

The job of handling spare parts is a very important part of an efficient MMOC operation. Personnel assigned to this job must be well trained in maintaining meticulous records on spare parts inventories, shipping and receiving transactions, billing, purchase orders, etc. The spare parts personnel need a thorough understanding of vendor coding of spare parts and the hardware configuration of each system maintained by the MMG. A detailed understanding of system configuration is essential to eliminate duplicate ordering of spare parts resulting in wasteful overstocking.

Personnel assigned the spare parts job function are required to interface with many different organizations (e.g., engineering departments, various vendors, electronic component suppliers, and MSGs or other headquarters staff organizations). A good working relationship with all of these organizations must be established and open lines of communication must be maintained. This relationship is necessary to keep up to date on the latest information on new systems being developed, products, price changes, equipment changes, etc.

The results are lower operating costs, efficient stocking levels of parts, and assurance that the right parts are on the shelf before the new system is installed and operating.

Refer to the Spare Parts Management job function work flows (Figure 4). The first items to be covered are the following administrative responsibilities:

- Spare Parts Inventory and Changes
- Billing Verification
- Purchase Ordering
- Disbursal Forms
- Serialization of Parts
- Trouble Tickets
- Vendor Documentation
- Parts Availability, Inquiries, and Tracing
- Monthly Transaction Reports.

Each of these categories is described in the following paragraphs 7.01 though 7.09.

7.01 Spare Parts Inventory and Changes

The most critical administrative function of the spare parts personnel is to keep meticulous inventory records. This is especially true in an organization that has several MMGs with local, on-site, and central stocking locations. In multistate companies with multiple stocking locations, it is important to ensure that administrative procedures are established to prevent confusion between parts at these stocking locations. A simple method of identifying what location owns what parts is to use some type of color coding label or dots.

7.02 Billing Verification

Another important job of the spare parts administration is the proper classification, verification, and tracking of bills. Proper accounting codes must be used when filling out the paperwork required for payment by the accounting department. Errors on these forms cause accounting errors and requires the bill to be reprocessed.

Verification of each bill is also a necessary function. There may be instances when parts are ordered under a specific purchase order number. The vendor may have been contacted to change the part number or numbers and when the bill arrives, those changes are not reflected. The result is payment for parts never received. Careful tracking of purchase orders with the receipt of parts will eliminate these problems.

7.03 Purchase Ordering

Purchase orders for spare parts, repair components, packaging material, etc., are initiated by the personnel under the spare parts manager. When spare parts personnel initiate, track, and log all purchase orders for the MMG, a more efficient flow of paperwork through the organization is provided and duplicate effort is eliminated.

7.04 Disbursal Forms

When a nonexempt part is unrepairable, a disbursal form must be filled out. It is important that proper accounting procedures be followed to ensure parts are disbursed properly and accurately.

7.05 Serialization of Parts

Serialization of stocked parts and components in operational systems in the field is required for accurate inventory management and FCO administration. It calls for the establishment of comprehensive and extensive methods and procedures and periodic audits to verify the integrity of the records. A mechanized system to perform this function will probably be required to administer serialization of spare parts.

7.06 Trouble Tickets

Spare parts personnel are responsible for initiating trouble tickets for new parts received from the vendor. A stocking location that sends a new part must be verified if a company has multiple stocking locations. This ensures that replacement parts are returned to the proper location and accounting records are kept accurate.

7.07 Vendor Documentation

Spare parts personnel need to refer to many types of vendor documentation (e.g., spare parts catalogs, configuration sheets, new devices, etc.) in order to keep inventories at satisfactory levels. Many vendors offer this documentation at no charge or at a yearly fee. The information is usually updated on a quarterly basis. Spare parts personnel are responsible for collecting, updating, and distributing this information to the MMG for use in ordering spare parts.

7.08 Parts Availability, Inquiries, and Tracing

This is necessary any time parts are ordered from the various vendors. The vendor usually gives a confirmed ship date for any part inquiry with an estimated lead time. Spare parts personnel occasionally request a trace for a part that was shipped but never received.

7.09 Monthly Transaction Reports

Many reports can be generated by spare parts personnel that provide useful information for the MMG. Monthly transaction reports give the quantity, system, and use of each part. This type report can aid the spare parts administration and MMG management. The report can be used to determine stocking strategies, poor performance of a particular system, need for more training for MMG personnel, etc. The report also generates more detailed accounting records on consumption by location. Inventory records by part number and quantity, system inventory, and tools and test equipment inventory are all maintained by the spare parts personnel and provide valuable information for all departments involved in minicomputer maintenance.

There are two other major categories to be discussed. Refer to the Spare Parts Management job function work flows (Figure 4). The first is receiving parts from the field for test or repair. This requires the spare parts personnel to fill in the appropriate information on the trouble ticket (e.g., date received, initials of person receiving the part, etc.). The trouble ticket should have a portion of it filled out by the technician sending the board in for test or repair. The next item is to check the shipping records for location of part, (e.g., part belongs to the central stocking location, MMG stock, or if a clustered site with on-site spares, if the part belongs to the site). The shipping records must be checked against the trouble ticket to ensure accuracy of ownership.

If the MMG is involved in serialization of parts, assign a serial number if necessary. The last item is to move the part to the repair area for test and repair. The spare parts personnel can now go back to Step 1 on the flows for the next function.

When the part is returned from the repair bench, the spare parts personnel must complete the trouble ticket. This may only involve adding the return date or filling in the comments section. Check stocking location (e.g., if from central spares stock, place it in its proper location on the shelf). If from another MMG or at a clustered location with on-site spares, package for shipment to the location. If from central stocking location or the spare parts personnel maintains the inventory records for other MMG locations, then update inventory records.

If unrepairable, see the spare parts manager and fill out a disbursal form. Remove disbursed part from inventory records and reorder replacement part.

The final function in the receiving of parts is the new or repaired part from vendor. Again, the spare parts personnel must check shipping records and purchase orders against the parts received packing list. If a new part, then update inventory records, assign a serial number, and record. Whether the part was new or repaired, fill out a trouble ticket and move the part to the repair area for test or to the stock location if it cannot be tested. Many parts ordered as spares are mechanical or electrical in nature and cannot be repaired (e.g., electromagnetic coil assembly or spindle on a disk drive, brakes on a tape unit, etc.). If the part is not repairable or requires an excess amount of time to test, make a thorough physical inspection and place the spare in the stocking area.

The last portion of the spare parts personnel responsibility is administrating the shipment of parts to and from various locations. The three major types of shipping are normal, to vendor, and emergency shipments from vendor.

For the normal type of shipment to a location, the first step is to open stock inventory records to check if the part or parts are in stock and change the inventory records to reflect a decrease in the inventory. The spare parts personnel log the shipment, showing the location the part is being shipped to, the name of person requesting the shipment, serial number of part, etc. The parts are then packed and shipped to the location needing the part. During the time the part is in transit, the spare parts personnel must contact the destination and provide details to the person requesting the part, the estimated time of arrival, name of the company used to ship the part, a way bill or air bill number, etc.

If the estimated delivery time has elapsed and the part still has not arrived, the spare parts personnel should be notified by the personnel at the destination point. When parts are received, the personnel receiving the part call the spare parts personnel so they can complete logs and records associated with the transaction. This information should include the exact time the carrier delivered the part. This is necessary to ensure the best and quickest carrier is being used for shipping. The name of the person receiving the part and the condition of the part is also necessary in case of damage during shipping.

If the parts are not received when expected, the spare parts administrator should receive calls from the destination point. At this time, the spare parts manager begins to trace parts. This is done by contacting the carrier used in shipping the part. The way bill or air bill number must be given and the number of packages sent. The carrier is then responsible for tracing the part. A little time is usually required, but generally the carrier locates the part and calls back with the new expected arrival time. The spare parts personnel maintain contact with the destination until the part is received. Another part may have to be shipped until the first part arrives. After the part has arrived, complete the required logs.

The next type of shipping on the flows describes returning parts to the vendor. This may involve the return of parts for repair, application of FCOs, or to return a part shipped in error. The first step is to open shipping logs. Information as to who, what, where, when, and why the part is being returned to the vendor is entered in the log. Next, spare parts personnel should make out a purchase order. The vendor usually assigns a purchase order number; the assignment of two purchase orders is a good method for tracking when a purchase order is lost or misplaced. The vendor also assigns a return authorization (RA) number when the parts are shipped to expedite shipping to the proper repair department within the vendor organization. The spare parts personnel can now package the part and ship it to the vendor, completing this work flow.

The final type of shipping is the emergency shipment from vendor. This type of shipment generally occurs when all other resources have been exhausted in trying to locate a part for an inoperative system. Again, the spare parts personnel must open shipping and purchase order logs. It is necessary to record all information for vendor use. This includes the serial number of the system that is down, the exact location of the destination, the name of the person receiving the part, and a phone number for the contact. The vendor generally requests the type of service desired in shipping the part (e.g., next flight out, hold at airport, deliver to door, etc.).

The vendor usually requires a period of time to locate and package the part, determine the best shipping method, and initiate the transaction before the spare parts personnel can expect vendor response. If the response is "Part Available," spare parts personnel will provide all the necessary information for shipping. The next activity is to contact the field and give all the details on the time of arrival, air bill number, etc. Then, complete logs, using the information given by the vendor and MMG personnel at the computer location. Spare parts personnel must now wait for the expected time of delivery to elapse and again contact the field to verify that the part was received. If the response to "Parts Received" is "yes," close out logs and start on the next job. If the response to "Parts Received" is "no," spare parts personnel should escalate to the spare parts manager to contact the vendor to expedite the problem.

If the part is not available from the vendor, spare parts personnel must look for an alternate source. There may be an alternate supplier who could be contacted or spare parts personnel may be required to contact other BOC/IDCs. This will involve escalating to the spare parts manager to arrange for a temporary loan of a part, etc.

In companies performing module repair, spare parts personnel should determine if a needed part is available but awaiting repair. This requires escalating to the spare parts manager and arranging for test and repair of the needed part. If no parts are awaiting repair, the last resort may be to appropriate parts from the test bench or administrative computer, if available. In this case, the defective part must immediately be sent for repair.

8. MODULE REPAIR

This provides information to MMGs that perform component level module (circuit board) repair (MR).

Establishing an MR facility using technicians already assigned to CM and/or PM, etc., requires consideration of the following factors:

- Systems Maintained
- Board Repair Personnel
- Board Repair Equipment
- Replacement Parts
- Floor Planning.

These factors are described in paragraphs 8.01 through 8.05.

8.01 Systems Maintained

The first and most critical item to be taken into consideration is the number of systems being maintained. Starting an MR facility equipped with the proper tools, test and repair equipment, and personnel requires that the MMG be able to repair a sufficient number of circuit boards to make this activity a cost effective venture. An economic analysis of costs versus savings is essential when considering eliminating vendor charges.

8.02 Board Repair Personnel

Personnel assigned to circuit board repair must have specialized training. A thorough knowledge of electronic theory is necessary to do component level troubleshooting. This often requires training in addition to that received in vendor maintenance curricula.

8.03 Board Repair Equipment

Initially, very little test or repair equipment was available to minicomputer maintenance forces for the purpose of performing component level repair. The various vendors were using specially-built test equipment with limited capabilities. Component level repair was accomplished by using a test bench minicomputer system configured with options installed in the field. Today, there are many different types of automatic test equipment (ATE) available to perform component level troubleshooting. Much of this equipment is designed for production areas where very high volumes of one particular board are tested before being installed in a new system. The ATE method is efficient but is economical only when large numbers of boards need testing. The ATE may require extensive software programming or coding. There may also be the cost of building special adapters to plug in each board. Some ATE requires a minicomputer or microcomputer.

Minicomputers can also be used as a test bench. This arrangement has the advantage of allowing the MMG to perform static and dynamic testing. That is, the module is being tested using the vendor diagnostics and operating system software in the module's normal operating environment. Using the combined ATE/minicomputer test bench method provides the highest degree of reliability possible for quality control of module repair.

8.04 Replacement Pairs

The MMG must ensure that only quality replacement parts are used in repairing modules. Replacement parts should be an exact vendor replacement or of the same manufacture if it is an industry standard part.

Replacement components, like spare modules, also require bulk purchasing and advance planning since many have excessive lead times (up to 6 or 8 months). Careful tracking of high failure rate components, especially those which are in limited supply, is critical to keep the flow of modules being repaired running smoothly. If component shortages are anticipated, it is beneficial to purchase a larger number of the part expected to be in short supply. The threshold for minimum reorder level should be increased for that part. This will aid adjusting for the excessive lead times.

8.05 Floor Planning

Planning floor space for a repair area requires some consideration. Floor space is needed for test benches and tools and test equipment, plus enough space for a clear walkway wide enough for carts, mobile test equipment, etc., to pass. Space must also be provided for storing engineering drawings, maintenance manuals, microfiche readers, etc., as close to the test benches as possible for easy access by the repair technicians. Space for work benches, board washers, and equipment cabinets, within easy reach by all technicians, is also necessary.

Power for the various test benches should be planned in such a manner as to allow for movement or the addition of the test benches with easy access to receptacles and outlets. The use of raised flooring or overhead power runs adds versatility to a repair area and minimizes the addition of new power runs.

Refer to the MR job functions work flows (Figure 5). Once the job is loaded to the technician, the first thing for the technician to do is to get the part and check the status of the part. This is done by checking the trouble ticket shipped with the part.

If the module is new or for test only, a physical inspection is made. The technician checks for broken components and for solder splashes that may have occurred during manufacturing.

Making a thorough physical inspection of each module for solder shorts, splashes, broken components, etc., before placing it in a test unit can help eliminate physical damage to a module and to the device used for testing the module.

The technician then cuts any jumpers or sets switches for proper configuration, if any exist on the module. If a module does contain switches and/or jumpers, test this module configured to the exact settings that would be used if the module were being used in the field. The module is then installed and all appropriate diagnostics run.

If all tests pass (ATP) for all diagnostics, the technician should remove the module from the device used for testing. The technician then completes the trouble ticket, work logs, etc., and returns the part to the shipping area.

If the module did not pass all diagnostics, the technician checks the part status to see if the module was from the field or if it is a new part. If it is a new part, record failure or trouble symptoms for future use. Is the part under warranty? If yes, then attach the information on the failure for use by the vendor when the module is sent back for warranty repair. Close out the trouble ticket with remarks for use by the spare parts personnel to use when returning the module to the vendor, complete work logs, and return the module to the shipping area so the module can be returned to the vendor for warranty repair as quickly as possible.

If the part is not under warranty, the technician begins test and repair of the module. If the part that failed is not a new part but was sent in from the field, then the trouble symptoms are recorded and the technician again begins test and repair of the module.

Is the part repairable? This is the first decision to be made. Some parts are not repairable. These include disk and tape heads, severely damaged modules, and mechanical parts. If the part cannot be repaired, the technician should fill out a trouble ticket and log, with remarks as to the nature of the trouble and why it cannot be repaired. If the part can be repaired and ATE is available, the technician should set up the module, run in ATE, isolate to the defective component, and repair. After the module has been repaired and cleaned, it should be rerun in the ATE equipment until the defective part is found and ATP is "yes." The technician then installs the module and runs in computer test bench.

Refer to the flows at "ATE Available" point (Figure 5). If the answer is "no," the only way to test the module is to run in the computer test bench, isolate the trouble, and repair it. Run the vendor diagnostics on the defective module and isolate the trouble with the aid of an oscilloscope, an integrated circuit (IC) comparator or any other test equipment the repair area has for locating defective components. After the module is repaired and tested, return it to the shipping area.

There are times when the cost of continuing the troubleshooting and repair of some modules becomes cost prohibitive. If diagnostic, troubleshooting, repair time, or cost of replacement components exceed the cost of the module, it should be replaced and not repaired. If the determination is made to halt repairs, the technician should fill out a trouble ticket and log, stating the reason that repairs were halted, and return the part to the spare parts manager for disbursal.

Referring to the top center of the flows at "Status of Part" (Figure 5), the final function of the repair technician is the installation of FCOs. This function often coincides with a module coming in for repair or test only. The revision (REV) level or Engineering Change Order (ECO) level of every module coming into the repair area must be checked and, if needed, must be brought up to the latest revision for that particular module. Documentation from the various vendors on FCO status is available on a subscription basis and contains current information which would be readily available to all module repair personnel.

Even though a module is placed in repair for FCO application only, the repair technician should first install the module in the computer test bench and run all diagnostics to ensure that the module is functioning normally.

If the module fails preliminary diagnostics, a check of the vendor documentation may reveal the cause to be an FCO. If this is not the case, the module is probably defective and needs repair. If the answer to diagnostic failed due to missing FCO is "yes" or if the module passed preliminary diagnostics, the repair technician can begin FCO installation.

With the documentation and necessary parts on hand, the repair technician can now install the FCO. When the FCO is installed, the technician can place the FCO module in an ATE or test bench computer and run all diagnostics. If the answer to ATP is "yes," the technician can update the revision level on the part itself. Then, update inventory records, complete the trouble ticket, and log. The part may now be returned to the shipping area.

If the module fails diagnostics after FCO application (e.g., the answer to ATP was "no") the technician should remove the module from the testing device and check installation, procedures, and documentation. The technician should also check diagnostics. Sometimes after installing an FCO, the diagnostic will fail due to incompatibility between the new revision of the module and the diagnostic itself. If "Procedures OK" is "yes," the installation of the FCO may have caused a trouble. The repair technician should begin repair procedures.

If FCO procedures or documentation is found to be in error, the repair technician should escalate to the MSG. The MSG should report the error in the documentation or procedures to other MMGs and the vendor in order to halt any further implementation of the FCO in the field and assist the vendor in correcting the problem as quickly as possible.

The repair technician should work with the MSG to aid in eliminating the problem. This may involve installing the FCO on other modules if possible or reinstalling the FCO on the original module. For this type of problem, all organizations should work together in order to correct the FCO as quickly as possible.

9. MINICOMPUTER MAINTENANCE ADMINISTRATIVE (MMA) JOB FUNCTION - NONMANAGEMENT

The administrative function of minicomputer maintenance is an area of responsibility that impacts the effectiveness and efficiency of all MMG functions. The administration functions of the MMG is difficult since it requires the interpretation and use of non Bell Operating Companies/Information Distribution Companies procedures and documents. However, it is important to the daily performance of the MMG.

Discussion of the MMA job function/work flows is general, without the use of decision blocks (Figure 6). This is because of variations in accounting guidelines, forms used to classify and pay bills, time reports, etc., that are specific to particular systems and/or vendors.

The MMA function provides a centralized point for administration and control of MMG expenditures. It assists MMOC supervisors in managing expenses.

The following are part of the MMA functions:

- Bills and Vouchers
- Travel Arrangements
- Time Reports and Payroll Information
- Typing and Dictation
- Answering Telephones and Taking Messages
- MMG Mail
- Publications and Documentation
- Filing and Documentation.

These areas of involvement are described in paragraphs 9.01 through 9.08.

9.01 Bills and Vouchers

The function that accounts for the majority of MMA time is the classification, coding, and processing of bills and vouchers associated with the daily operations of an MMG. This function expands when the MMG is also a centralized spare parts location and a module repair depot. The MMA personnel must be thoroughly trained in proper time and materials accounting procedures.

All expenses incurred by MMG personnel whether for training, meetings, or expenses incurred because of maintenance, should be submitted to and verified by MMA personnel to assure the use of proper forms and correct classification or accounting codes.

9.02 Travel Arrangements

Employee working advances should be prepared by MMA personnel for the MMG for any type of travel. The MMA personnel should also make reservations for hotels, airlines, car rentals, etc., associated with travel of MMG personnel. Documentation, such as airline and hotel guides, should be kept on file and up to date as a quick reference in case travel is necessary by MMG personnel, especially in emergency situations.

9.03 Time Reports and Payroll Information

Another function that requires timeliness and accuracy is the completion of time reports and payroll information. Since maintenance personnel charge time to multiple account and classification codes, processing time reports requires MMA personnel to be well informed in all aspects of time-reporting procedures and coding. Shift work and overtime worked for evenings, nights, weekends, callouts, holidays, exception reporting, etc., occur frequently and MMA personnel are responsible for verifying the accuracy of individual time sheets and preparing records for payroll processing. The MMA should transmit this information to payroll for proper pay treatment.

Any deviations in time reports, such as time off for illness, accidents, vacations, etc., must also be accurately recorded and personnel files updates periodically by personnel assigned to the MMA function.

9.04 Typing and Dictation

Some consideration should be given to the amount of typing involved with the MMA work group. There are many reports, parts orders, correspondence to vendors, engineering departments, other MMGs, etc., that require a degree of proficiency in this area.

9.05 Answering Telephones and Taking Messages

Although a minor function, this is still an important one. The MMA personnel must know exactly who in the MMG performs what function so phone calls can be directed to the proper person. A qualifications list of all MMG personnel to the MMA would be of assistance. When a message is taken, the MMA personnel should ensure that all information regarding the call is included in the message and that it is delivered to the MMG personnel to be acted on as quickly as possible.

9.06 MMG Mail

This function is also another minor job function that will create problems if procedures are not followed correctly. Mail pickup and delivery should be done as frequently as necessary and distributed to the proper MMG personnel. The mail or correspondence should be sorted and prioritized before it is distributed.

9.07 Publications and Documentation

The MMA personnel should be the only focal point for the arrangement, procurement, and distribution of the various publications. All publications, especially periodicals, should be administered by MMA personnel. In this way, renewal notices and payments for these publications can be tracked and errors or duplicate ordering, etc., can be avoided.

9.08 Filing and Documentation

The MMA personnel encounter large amounts of varied types of information from electronic parts and test equipment suppliers and other vendors. There are also magazines, newspapers, catalogs, and flyers on electronic products which an MMG receives that contains information useful to MMG personnel. The MMA should maintain a filing system for this information. The system must be updated periodically and obsolete documents removed and archived for future reference.

10. MMG FORCE SIZING

This explains the guidelines used to efficiently and effectively size and staff a minicomputer maintenance work force. In an effort to establish an easily applicable methodology these guidelines are defined in an MMG Force Sizing Model. The application of these guidelines to this model, will identify an Equivalent Force that is expected to be sufficient to perform corrective and preventive maintenance for a specified universe of maintained minicomputer systems. The model is sophisticated enough to benefit all BOC/IDC and simple enough to be implemented by every BOC/IDC. It also has the flexibility to be able to grow as MMG planning strategies and management techniques evolve.

10.01 Model Parameters

Three basic parameters were considered in the development of the MMG Force Sizing Model. These are:

- The use of measurable inputs
- The allowance for local adjustments
- Consideration of varying MMG organizational and operational characteristics.

A. Input Only Measurable Quantities

The model involves only parameters that can be measured reliably: Mean Time To Failure (MTTF), Mean Time To Repair (MTTR) and Preventive Maintenance Time (PMT). Definitions of these parameters are given in paragraph 10.2.

B. Allow Local Adjustments

The model allows adjustments to all measurable inputs to reflect the effects of varying local conditions.

C. Consider Organizational/Operational Characteristics

In addition to MTTF, MTTR, and PMT, there are other factors that affect maintenance planning but are independent of individual options. The model is designed to guide administrators in quantifying these MMG characteristics.

10.02 Definition of Terms

Group: A group is an arbitrary collection of computer hardware defined according to local convenience. Normally all the computers occupying an MMOC form a group.

Base: As discussed in paragraph 10.1 (B), the model is flexible enough to allow local adjustments. However, flexibility can cause a model to be unreliable if adjustments cannot be tracked. To avoid this, the model is based on historical data, called the "base." For example, local BOC/IDC data on MTTF, MTTR and PMT can be used.

Period: Every planning activity must have a specified period of time for the plan application. Every implementation of the MMG force-sizing model, therefore, should have an associated time period. This avoids inappropriate use of the model outside the intended period and also helps to properly identify the model application for comparison purposes.

Option: A piece of computer hardware is called an option if it is maintained as a unit. For example, disk-drives, printers, and CPUs are options. Different makes and models, e.g., RM05, RP06 disk-drives, should be identified as different options if they require different amounts of maintenance effort. The differences in ages or usage should not be used to differentiate options, since these differences can be represented by adjustments. For example, if the RP06 disk-drives of a heavily used COSMOS system may break down more often than other RP06s, then all the COSMOS systems or just the COSMOS RP06s which are affected by the heavy work load can be considered as a separate group.

Quantity (QTY): The number of units of an option type, in the group.

Mean Time To Failure (MTTF): The average of time (in days) between failures of individual options of the same type during the planning period. (A planning period is an arbitrary period of time determined by the BOC/IDCs to analyze force sizing requirements.) The MTTF is a random variable for a future planning period. To estimate this random variable, the model uses the average of time intervals between failures obtained from the base: MTTF can be modified by the MTTF coefficient, KF, as described below.

MTTF Coefficient (KF): A dimensionless value to represent the adjustment needed for the group under consideration. (Default value is one.) For example, if the MTTF in the base is 120 days and the estimate for the planning period is 150 days, then KF is 1.25 (150/120).

Mean Time To Repair (MTTR): The average of time (in hours) needed to repair a failed option. Like MTTF this is also a random variable and is estimated using base data.

MTTR Coefficient (KR): Similar to KF, this is a dimensionless quantity and is used to adjust MTTR. For example, if the MTTR in the base is 6 hours for an RP06, and because of lower experience levels in minicomputer maintenance for the group being addressed, the MTTR is 9 hours, then KR is 1.5 (6/9).

Preventive Maintenance Time (PMT): This is the average number of hours spent yearly doing preventive maintenance on the individual options during the planning period. For example, if we expect to spend, on the average, 20 hours of preventive maintenance on one unit of an option during 2Q87, and the planning period was 1 year, then PMT is 80 (=20x4 quarters) hrs/yr.

PMT Coefficient (KP): A dimensionless quantity to adjust PMT. Unlike KF or KR this coefficient does not necessarily have to be close to one. Depending on the base and on the preventive maintenance, it may be as low as zero or as high as two, three and even more. To expect reliable estimates from the model, however, it is desirable that KPs should be close to one. That is, MMG administrators should try to choose a base with a preventive maintenance policy as close to theirs as possible.

Corrective Maintenance Hours (CMH): This is the yearly rate of total corrective maintenance hours spent for all the units of the same option type. CMH is a random variable estimated from base data. If, for example, the plan period is 4 months, then the estimated total corrective maintenance hours during the period is one-third of CMH.

Corrective Maintenance (CM): This is the sum of Corrective Maintenance Hours (CMH) for all units of all options identified in the group.

Preventive Maintenance Hours (PMH): This is the yearly total preventive maintenance hours expected to be spent on all the units of the same option type.

Preventive Maintenance (PM): This is the sum of Preventive Maintenance Hours (PMH) for all units of all options identified in the group.

Total Maintenance Hours (TMH): Total of CMH added to PMH.

Total Maintenance (TM): This is the sum of CM and PM.

Total Maintenance Coefficient (KT): Represents the adjustment needed on the total maintenance effort for a given group due to global conditions. For example, if the TM for a group is 100 hours and it is estimated that inadequate air conditioning will increase the overall maintenance effort by 10%, then KT = 1.0 + .1 or KT = 1.1. Adjusted TM is calculated TM x KT = 110 hours due to global adjustment.

Work-Hours (WH): To have a meaningful planning tool a standard number of yearly working hours is necessary. For the purpose of this model, 47.50 weeks per year or 1900 hours will be used. The number of productive hours for each craftsperson should be calculated by each BOC taking into consideration vacations, training, meetings, sick time, etc.

Equivalent Force (EF): This is the size of maintenance force which is expected to be sufficient to perform the corrective and preventive maintenance activities as planned. If CMH plus PMH equals 4750 hours, then the average work load is expected to require two and one-half maintenance persons (=4750/1900). The experience and absenteeism of maintenance forces may vary greatly and should be considered when establishing Equivalent Force.

10.03 The Model

The model is built in the following steps:

Step 1: Identify the group, the period and the base.

Step 2: Identify the list of options in the group and the number of units of each option type.

Step 3: For each option type, identify MTTF, MTTR and PMT from the base.

Step 4: Adjust if necessary KF, KR and KP (default values are 1.0).

Step 5: For each option type, calculate
CMH = (365/(MTTF x KF)) x (MTTR x KR) x Quantity
PMH = PMT x KP x Quantity
TMH = CMH + PMH.

Step 6: Sum TMHs for all options, to calculate TM. Sum CMHs and PMHs to calculate CM and PM respectively. (TM = CM + PM)

Step 7: Multiply TM by the global adjustment coefficient (KT), if appropriate.

Step 8: To estimate equivalent force, calculate (Adjusted TM)/1900.

10.04 Implementation Guide

The MMG force sizing model does not make planning decisions but rather is a tool to quantify planning alternatives. The previous section gives insight into the model. This illustrates the use of the model with an example and presents implementation guidelines.

A. An Example

Suppose we want to use the model to estimate MMG force requirements for Group XYZ during 3Q87. Suppose also that we want to use Group ABC's 1985 yearly plan assumptions because the plan was successful (i.e., the actual maintenance effort was found to be close to the model results) and Group XYZ's 3Q87 characteristics are similar to Group ABC's 1985 characteristics. Even if the two plan periods are of different lengths we can still use one as the base for another because both use comparable quantities, i.e., yearly rates and dimensionless coefficients.

Assuming that the basic results from the model are given in Figure 7, let us review the work sheet:

We have, in Group XYZ, two RP06 disk-drives, one LA36 printer, etc. The MTTF for an RP06, in ABC-1985, is 300 days. But we expect in Group XYZ more frequent breakdowns because of inadequate air conditioning, thus we assume 240 days, or KF = 0.80. However, we expect, on the average, 10 percent faster repairs due to the greater expertise of our maintenance force, i.e., 13.5 hours instead of 15, or KR = 0.9. The LA36 printer is expected to break down less frequently due to decreased demand for hardcopy outputs, that is MTTF is 1200 days instead of 800, i.e., KF = 1.5. Repairing an LA36 takes about 10 percent longer in this group, i.e., KR = 1.1. We plan to perform 50 percent of preventive maintenance effort that ABC spent in 1985, i.e., KP = 0.5. With the above data established the model can be applied as described in paragraph 8.3, The Model, in steps 1 through 8 as follows:

Step 1: Identify the group, the period and the base.
Group - XYZ
Period - 3Q87
Base - ABC's 1985 data

Step 2: Identify the list of options in the group and the number of units for each output type.
2 RP06s
1 LA36
Etc.

Step 3: For each option type, identify MTTF, MTTR and PMT from the base.

Option	MTTF (Days)	MTTR (Hrs)	PMT (Hrs)
RP06	300	15	6
LA36	800	6	1

Step 4: Adjust if necessary KF, KR and KP (default values are 1.0).

Option	KF	KR	KP
RP06	.8	.9	1.0
LA36	1.5	1.1	.5

Step 5: For each option type, calculate
CMH = (365/(MTTF x KF)) x (MTTR x KR) x Qty
PMH = PMT x KP x Qty
TMH = CMH x PMH

RP06
CMH = (365/(300 x .8)) x (15 x .9) x 2 = 41 HRS/YR
PMH = 6 x 1.0 x 2 = 12 HRS/YR
TMH = 41 + 12 = 63 HRS/YR

LA36
CMH = (365/(800 x 1.5)) x (6 x 1.1) x 1 = 2.0 HRS/YR
PMH = 1 x .5 x 1 = .5 HRS/YR
TMH = 2 + .5 = 2.5 HRS/YR

Step 6: Sum CMHs and PMHs to calculate CM and PM respectively. Sum TMHs, for all options, to calculate TM. (TM = CM + PM)

Sum all CMHs = CM
41 + 2 = 43
Sum all PMHs = PM
12 + .5 = 12.5
Sum all TMHs = TM
63 + 2.5 = 65.5

Step 7: Multiply TM by the global adjustment coefficient (KT), if appropriate. Not appropriate for this example.

Step 8: To estimate equivalent force, calculate adjusted TM/Work Hours (WH).
TM/WH = EF
65.5/(1900 HRS per YR/4 QTRS per YR) = .14
Equivalent Force necessary to maintain group XYZ = .14 persons.

NOTE - If "XYZ-3Q87" plan is used as the base for another plan, the adjusted numbers should be used. For example, MTTF for RP06 is 240 hrs/yr, PM for LA36 is 0.5 hrs/yr, etc.

B. Global Conditions

Some of the factors affecting maintenance activities should not be reflected to option-level parameters but rather be treated globally. Included are such factors as air conditioning performance, vacation scheduling, training, etc. These are identified as global conditions. Suppose that in the previous example, it is estimated that inadequate air conditioning increases the maintenance time by 10 percent. Suppose also that the maintenance force, having higher-than-average service years, have about one more week of vacation time, which increases the maintenance time by 2 percent, ((extra vacation week)/(work weeks - 1) = increase of maintenance time) or (1/(47.5 - 1) = 0.02). In other words, the total maintenance coefficient, KT, is 1.12 = (1 + 0.1 + 0.02). Equivalently, the adjusted TM (= 73.3) is TM x KT (or 65.5 x 1.12). The total yearly maintenance hours for Group XYZ in 3Q87 is calculated:

Standard maintenance time	65.5
A/C adjustment (10%)	6.5
Vacation adjustment (2%)	1.3
	+
Total (hrs/yr)	73.3

NOTE - The equivalent force in this case will be 0.16 (= 73.3/1900/4 QTR per yr) persons. Keeping the option-level factors separate from the global conditions will allow the administrators to use model results to support their proposals, for example, to improve environmental conditions. This will also avoid unfair comparisons of work forces due to conditions other than technical expertise.

C. Travel Time

Travel time is considered productive time, and thus should be included in the option-level model, provided that a travel time accounting procedure is applied consistently. For example, in the previous model, XYZ maintenance policy requires the maintenance crew to fly whenever they travel to a remote location. Assume that the roundtrip travel time is eight hours, and that after the completion of repair lasting, on the average, 13.5 (= 15 x .09) hours on the RP06, the remaining 2.5 (= 16 - 13.5) hours of the second day can always be utilized for preventive maintenance. The total number of hours of productive time spent on an RP06 repair is:

13.5 +	8 x	(13.5/16)	= 20.25
MTTR	TRAVEL TIME	2 WORK DAYS	MTTR

We can represent this in the model in one of two ways:

1) We can adjust KR, 1.35 (= 20.25/15).

2) We can define a travel time adjustment coefficient, KTT, and add this to the model; here KTT is 1.5 (= 20.25/13.5).

In either case the model assumptions have to be clearly stated so that, if desired, they can be appropriately used as a base in other applications of the model.

> **NOTE** - The first alternative is simpler, especially when using a base from the same group.

If we decide to adjust the repair time with travel time, we have to be careful to distribute it consistently. For example, if after an RP06 repair, the maintainer has to return without performing any preventive maintenance, the travel time which should be added to the RP06 corrective maintenance is still 6.75 (8 x 13.5/16) hours; the remaining 1.25 (= 8 - 6.75) hours has to be considered in general travel time expenditures of Group XYZ. Clearly, at some other occasion, such as combining two repairs, the actual travel time spent during an RP06 repair may be less than 6.75 hours, say 4 hours. In this case, 2.75 (= 6.75 - 4) hours has to be deducted from the general travel time. The purpose of this is to keep meaningful statistics to be used as base in the future applications of the model.

Optionally, if option-level accounting of travel time is infeasible, then travel time can be treated as a global variable (paragraph 4.10 B).

D. Adjustment Policies

The model allows local adjustments to reflect the differences in travel time, system usage and vendor support, and treats the conditions affecting all the maintenance activities, such as environmental conditions, globally. MMGs should define policies on how to adjust model parameters and should contain limits for adjustment. Adjustments exceeding defined limits should require written explanation. For example, if Group BCD is utilizing data from Group ABC's 1985 characteristics and BCD is using a KR = 3.0, or 3 times the MTTR for an RP06, they should explain why their MTTR is excessively higher than the MTTR of Group ABC.

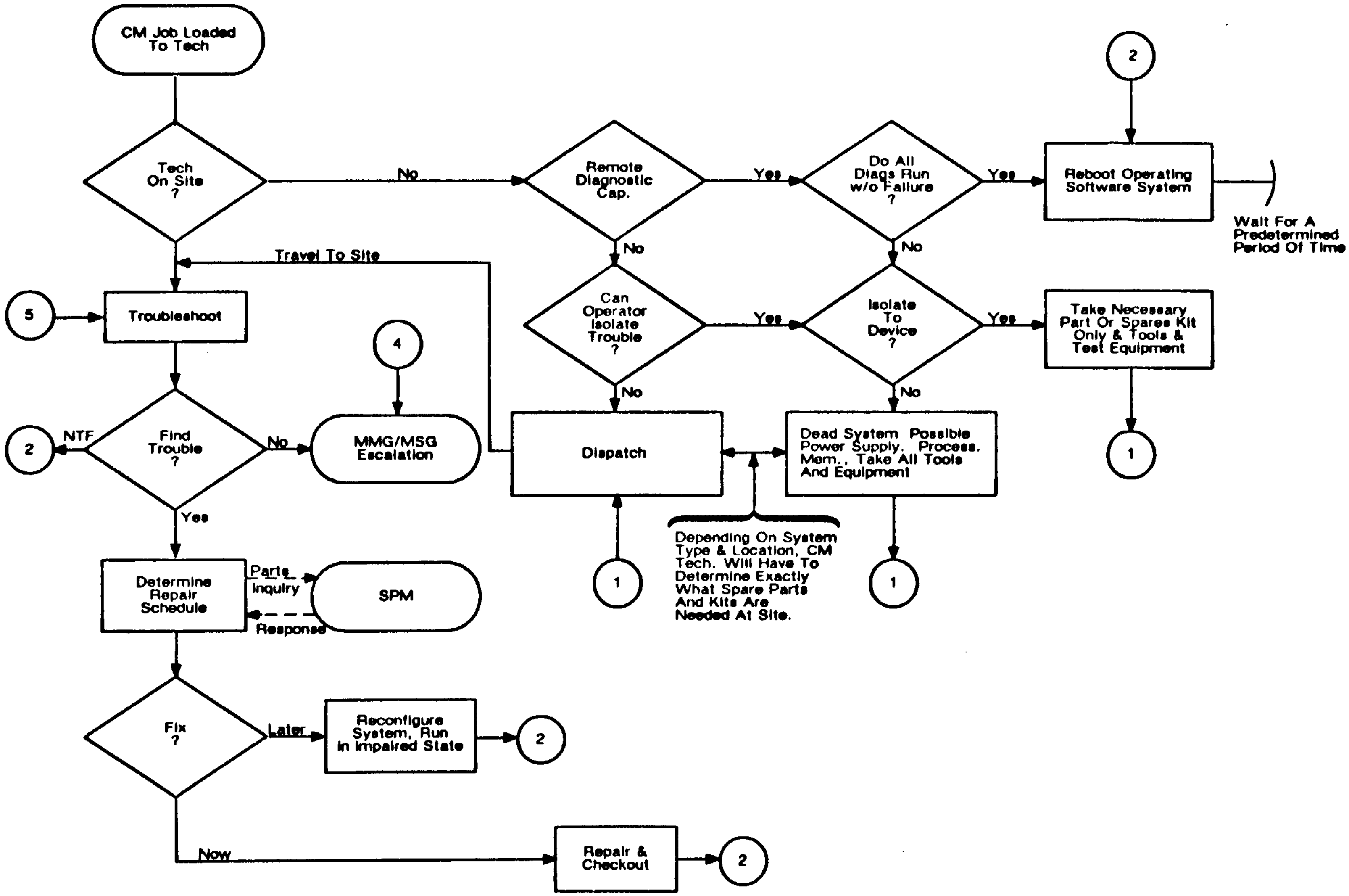

Figure 1. Corrective Maintenance Work Flows (Sheet 1 of 2)

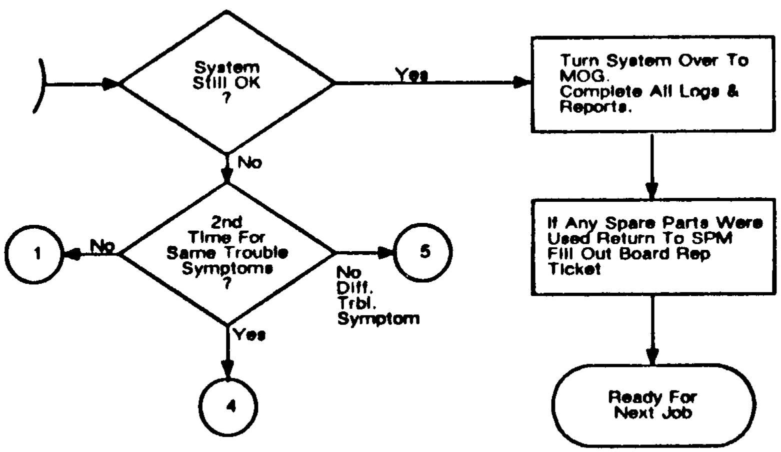

Figure 1. Corrective Maintenance Work Flows (Sheet 2 of 2)

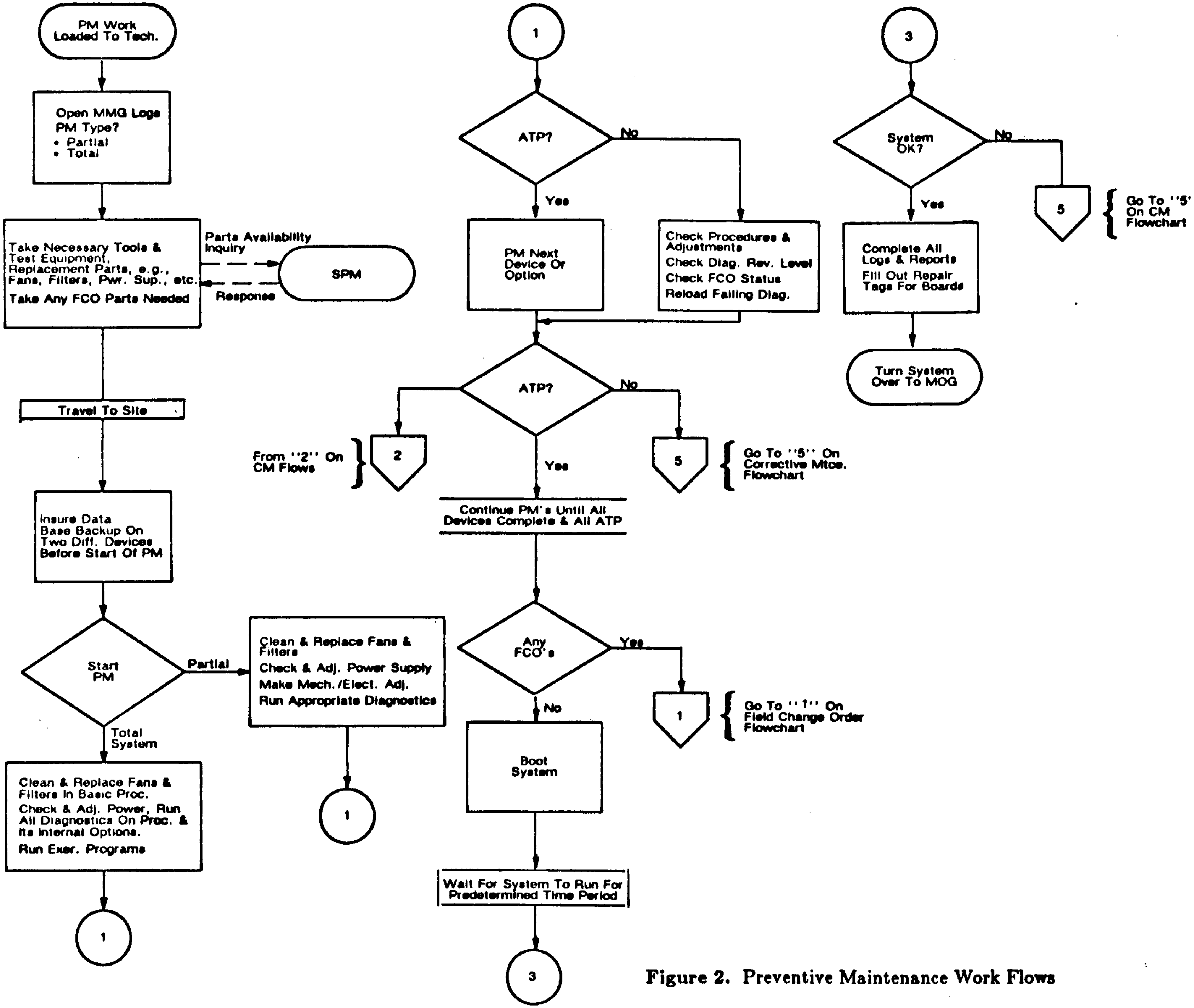

Figure 2. Preventive Maintenance Work Flows

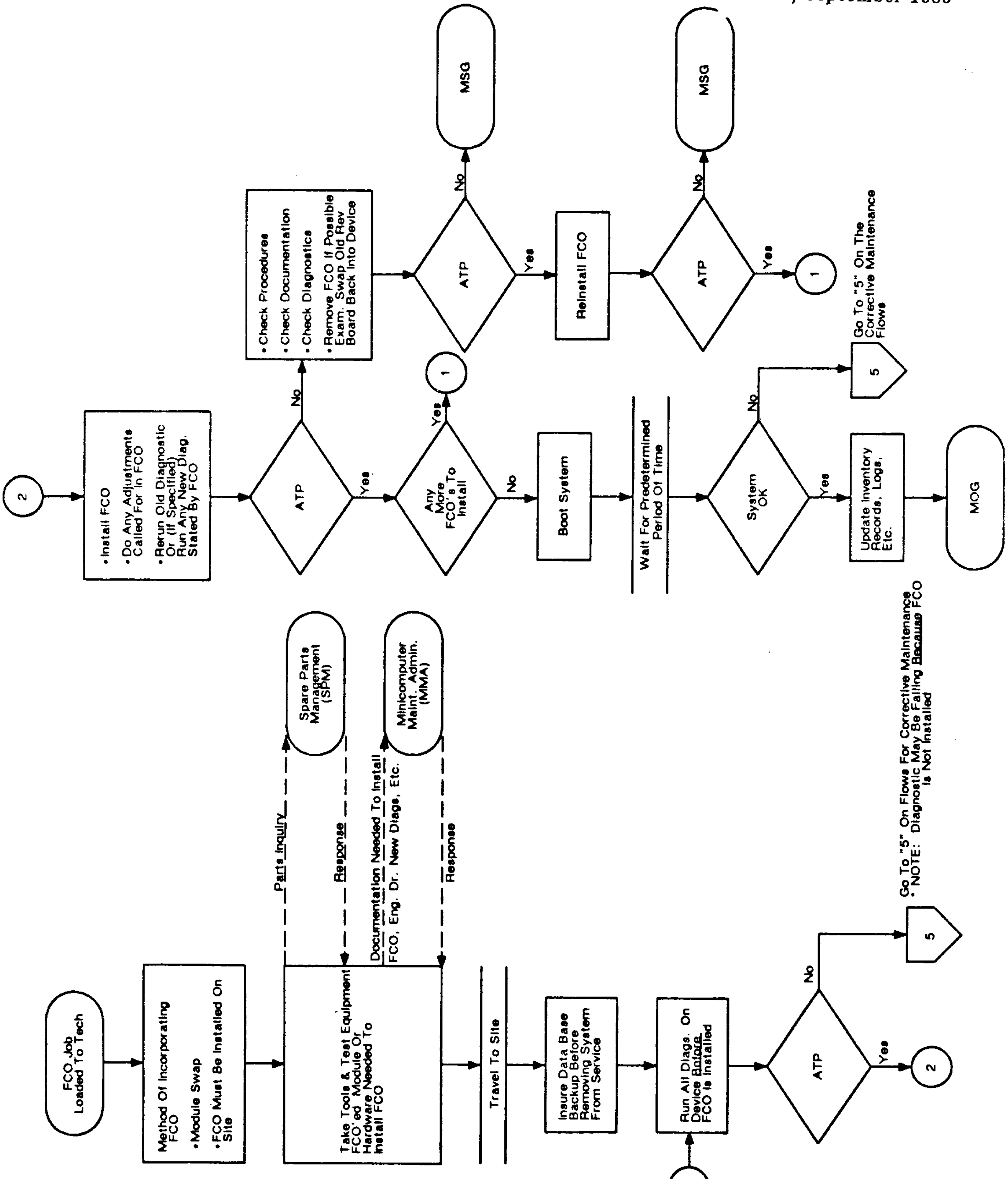

Figure 3. Field Change Order Work Flows

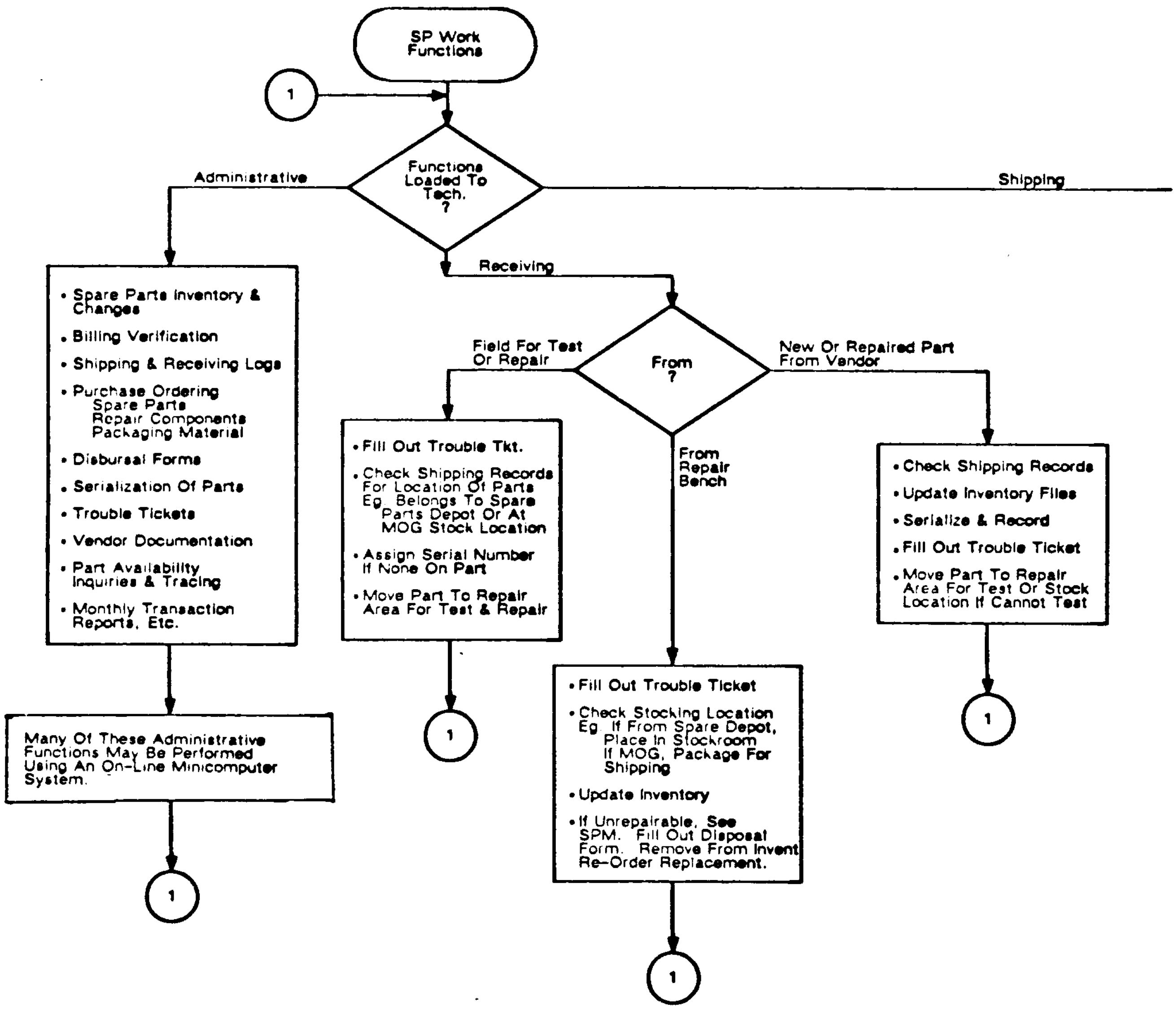

Figure 4. Spare Parts Management Work Flows (Sheet 1 of 2)

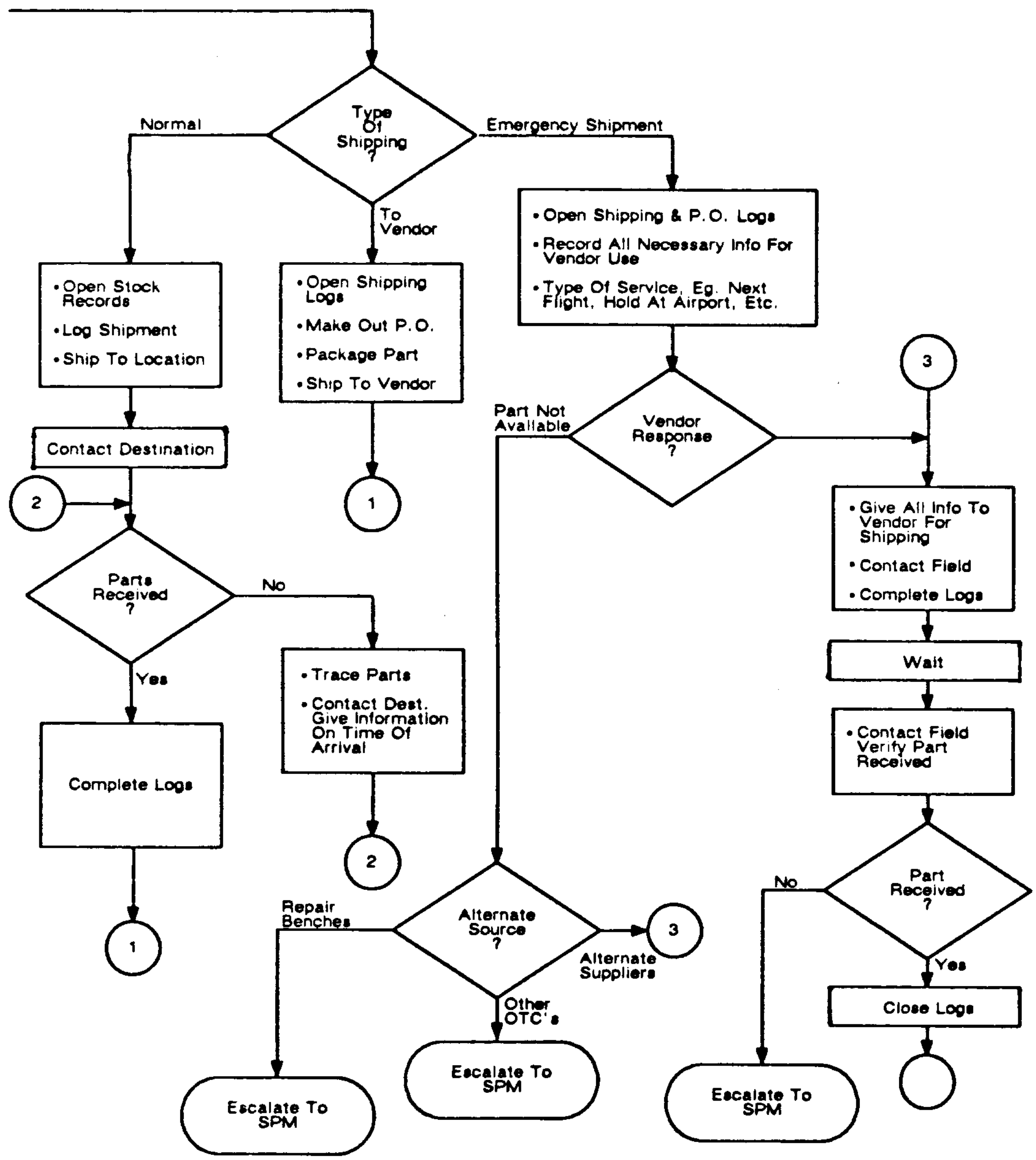

Figure 4. Spare Parts Management Work Flows (Sheet 2 of 2)

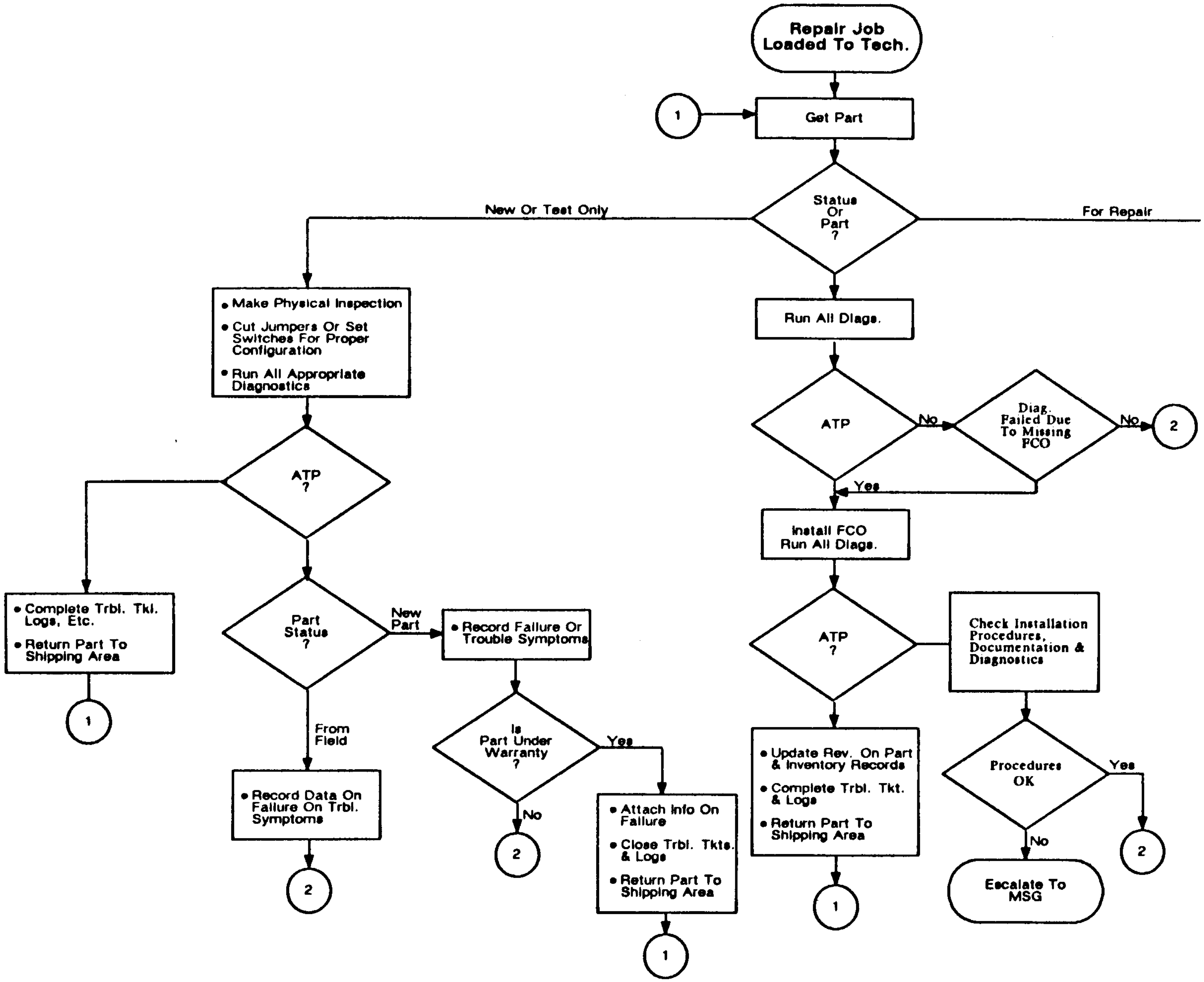

Figure 5. Module Repair Work Flows (Sheet 1 of 2)

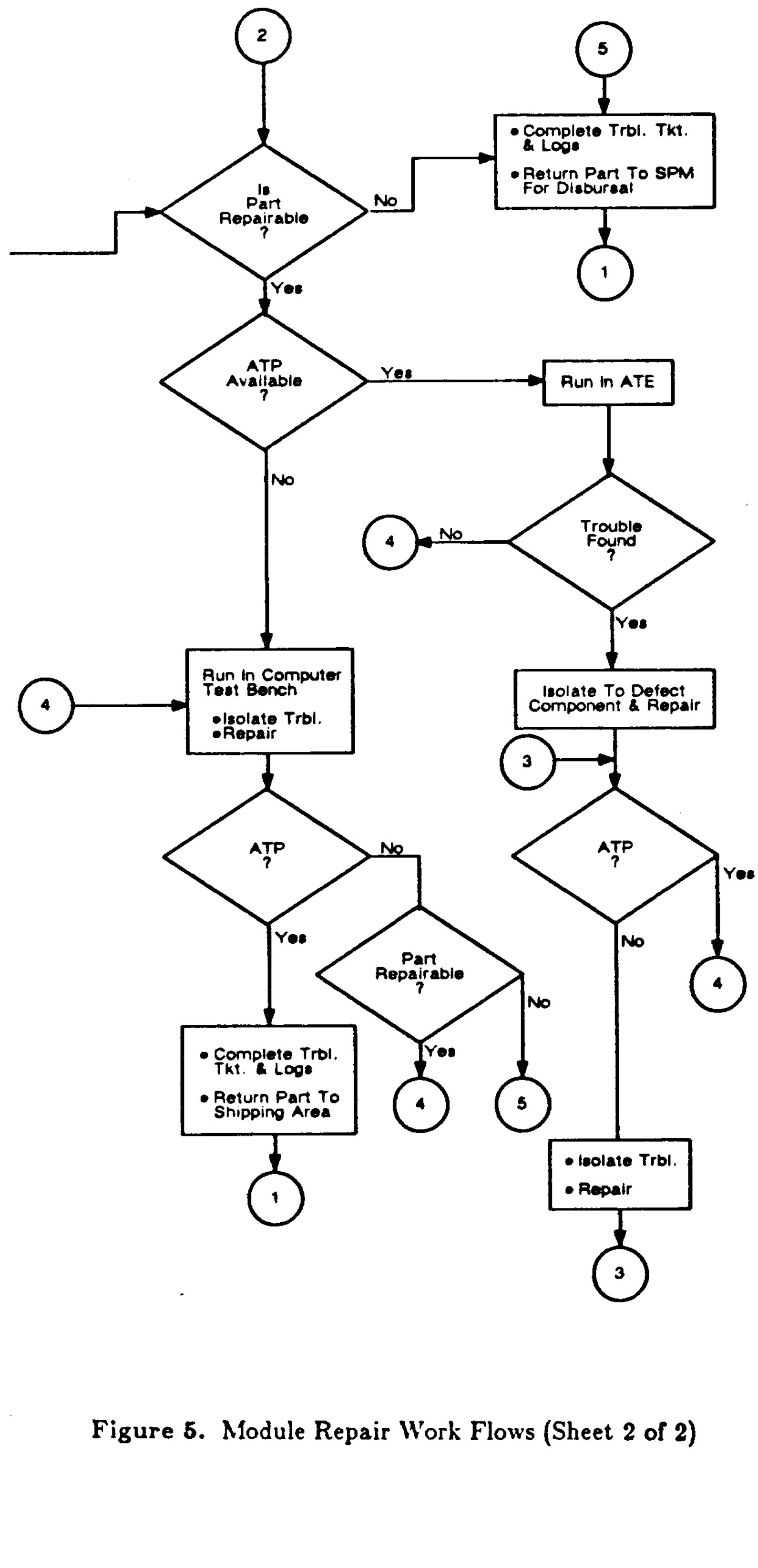

Figure 5. Module Repair Work Flows (Sheet 2 of 2)

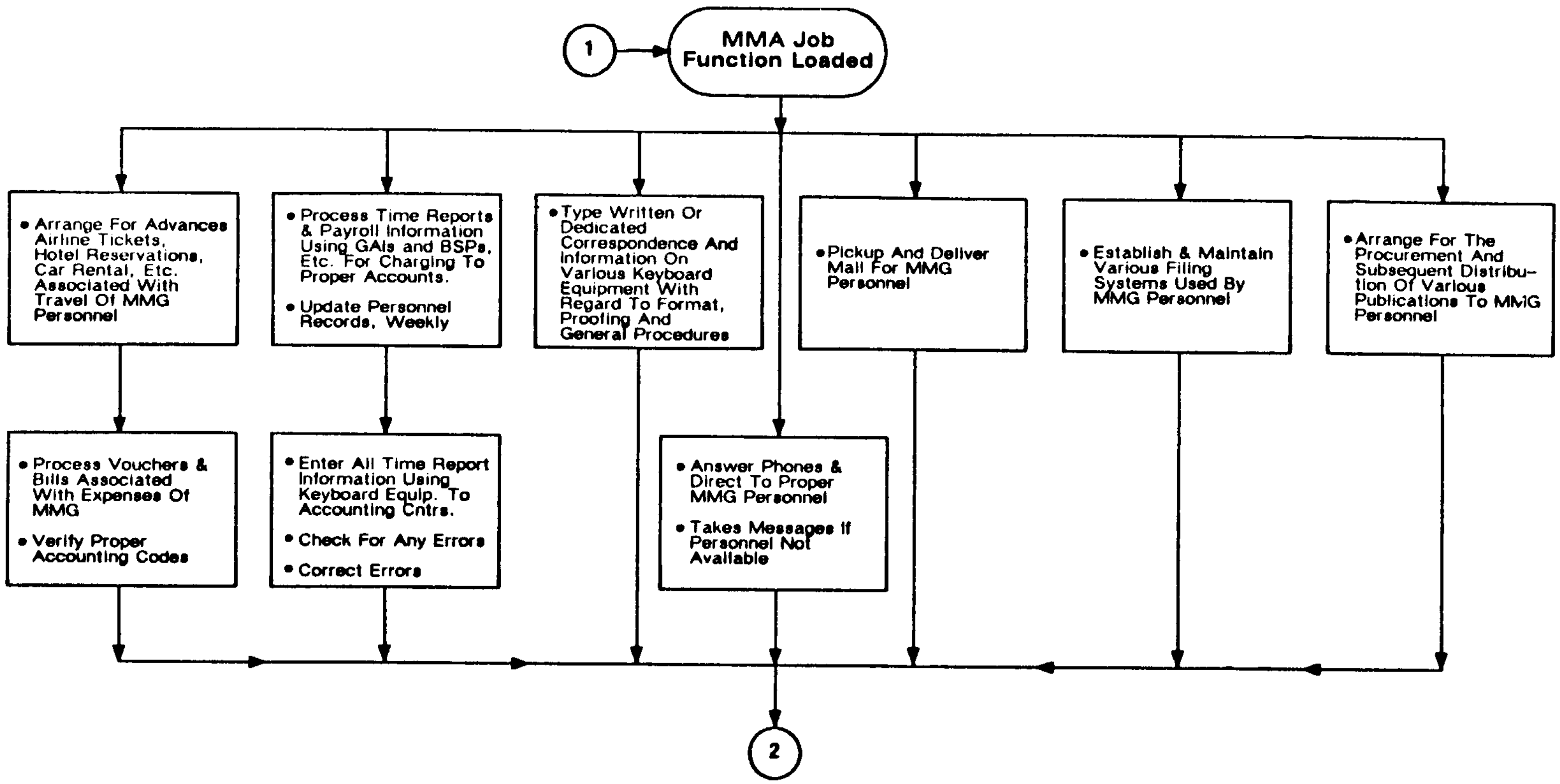

Figure 6. Minicomputer Maintenance Administration Work Flows (Nonmanagement)

(Insert Your Company Logo)

MMG Force Requirements

ISD-121 (6-86)

Base	Group	Period	Date
ABC-1981	XYZ	1/18/82	3Q83

Device		Quantity	MTTF (Days)	KF	MTTR (Hours)	KR	PMT (Hrs./Yr.)	KP	CMH (Hrs./Yr.)	PMH (Hrs./Yr.)	Total (Hrs./Yr.)
1	RP06	2	300	0.8	15	0.9	6	1.0	41	12	63
2	LA36	1	800	1.5	6	1.1	1	0.5	2	0.5	2.5
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
Summary PM/(PM + CM) = 19 Equivalent Force = 0.14 Persons									+ 43	+ 12.5	+ 65.5

Figure 7. MMG Force Sizing Sample Worksheet