

The Future of Component Level Miniature and Microminiature Electronic Repair

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Abstract — When discussing component level electronics maintenance, most people think of diagnostics - find the fault and your problem is solved. However, there is another side of electronics repair that has been neglected. After diagnosis, it has become increasingly difficult to physically repair the electronics. Such mundane operations as soldering, desoldering and component replacement have become complicated by extreme micro-miniaturization, the use of lead-free solders, new thermally challenging pc boards and intricate component packages (e.g. BGA's) that are difficult to install. As a result, many DoD Depot/Intermediate facilities have lost the organic capability to repair modern electronics, opting to hire outside contractors to perform the more difficult repairs. This paper will review the history and current status of NAVSEA's 2M (Miniature/Microminiature) Electronics Repair Program, which provides the tools and techniques required for certified Navy, Marine Corps, Air Force (under the AFREP Program) and Coast Guard electronic repair technicians to perform highly reliable, high quality repairs on complex circuit card assemblies. Current capabilities of key electronics repair Depots will also be examined, including Tobyhanna Army Depot, Robins AFB, FRC Southeast, MCLB Albany and others. Finally, we will analyze future technologies that may impact DoD's ability to maintain an organic repair capability.

Keywords — 2M/MTR; 2M Repair; Miniature/Microminiature Electronics Repair; Lead-Free Soldering; BGA Rework; Rework and Repair; AFREP; Air Force Repair Enhancement Program; AMRIP

I. BACKGROUND HISTORY

The Miniature/Microminiature and Module Test and Repair (2M/MTR) Program has a long and rich history. Although managed by NAVSEA for the past three decades, the origins of 2M can be traced to NAVAIR's Avionics Module Repair Improvement Program (AMRIP) instituted during the late 1960's. AMRIP was the brainchild of a visionary/maverick NAVAIR engineer named Ephraim "Raim" Regelson, who was struggling with severe reliability and maintainability issues created by the AN/AWG-10 Fire Control System on the F-4. An electronics technician himself during World War II who witnessed battlefield repair issues firsthand, he formed the germ of an idea. Regelson recognized that manufacturing and testing techniques had developed to a much higher technological state than electronic component repair procedures. Rather than fixing *one* troublesome weapon

system, why not seek a more generic approach and develop the tools, techniques and training to repair *any* electronic module, anywhere? Regelson assembled a team of seasoned technicians at the Naval Weapons Center (as it was then known) at China Lake in Ridgecrest CA. He then enlisted the help of PACE Incorporated (now known as PACE Worldwide), well known experts in the nondestructive rework and repair of complex circuit card assemblies.

In 1968, PACE was awarded a contract to provide the specialized equipment, tools, techniques and training required by NAVAIR technicians to perform reliable component level repairs in the field. PACE performed the initial certification training onboard Aircraft Carriers in 1968, and fielded an early version of the PRC-350 Bench Top Repair Center (see Fig. 1), an integrated kit with all the necessary tools needed to handle the most delicate or difficult electronic repairs. An exhaustive Training/Technical Manual was produced by PACE in 1969, whose specialized techniques and procedures were incorporated into later DoD manuals, and are still in use today.



Fig. 1. PACE PRC-350 Bench Top Repair Center was an early Miniature/Microminiature electronic repair system adopted by NAVAIR's Avionics Module Repair Improvement Program (AMRIP)

Regelson's AMRIP Program reaped immediate benefits. If a shipboard system went down and a spare circuit board was unavailable, it might take weeks or months to repair. By providing an AMRIP work center, a ship enhanced readiness and operational availability by eliminating the need to wait on new or depot repaired cards, with the added payback of saving significant operating dollars. The age of 2M had begun. ^[1]

II. CURRENT STATUS OF 2M/MTR

Under the skillful management of NAVSEA 04 since the early 1980's, the 2M/MTR Program has significantly expanded. It is now a joint-service program with active participation from the Navy, Marine Corps, Coast Guard and Air Force, and has been adopted for use by many of our foreign military allies. According to Mr. Rich McConnell, NAVSEA 2M/MTR Program Manager, "It's the best kept secret in the Department of Defense."^[2]

Cost savings are immense. From April 1996 to December 2014, Navy maritime commands outfitted with 2M/MTR capabilities reported 189,844 repairs completed, which resulted in 12,329 CASREPS averted/corrected and \$689M in OPTAR cost avoidance as shown in Table I below.^[3]

TABLE I. 2M PROGRAM COST AVOIDANCE METRICS



Note the above chart does not include any cost avoidance data from 2M repairs completed by Naval Aviation, Marine Corp (Ground), the Air Force 2M Program called AFREP (Air Force Repair Enhancement Program) or other 2M/MTR shops. The cost savings become more apparent if you consider that the 2M Program receives only \$5 million per year in funding.

Other Program benefits include the following:

- Improves readiness
- Avoids potential maintenance costs associated with reliance on depots
- Increases equipment sustainability
- Reduces life cycle costs

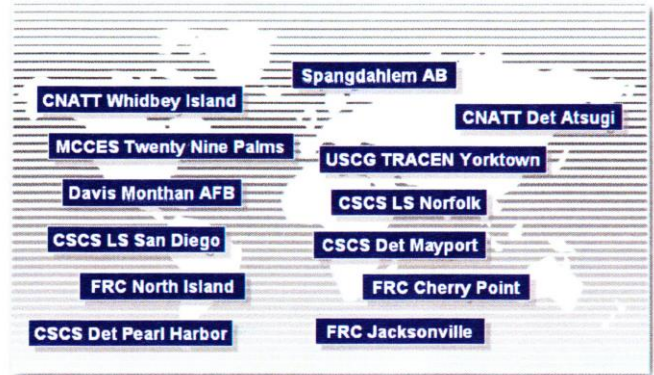
During a recent 2M/MTR briefing by members of NUWC DET Norfolk, Capt. Harold Goldman introduced the speakers by summarizing "Computers are everywhere and with the board and circuits, there's an art to repairing these things. It's a dying skill. This program has been instrumental in keeping the fleet going and keeping this skill alive. It prevents us from having to buy new computers. It's about saving money."^[4]

III. 2M/MTR TRAINING SITES

All 2M/MTR technicians are highly capable individuals who have satisfactorily completed a stringent training regimen to become certified. It is not easy – not everyone completes the

training. 2M Repair is divided into two distinct capability levels: *Miniature Electronic Repair* is a 4 week training school. If the student has excellent hands-on skills, an additional 2 week session in *Microminiature Electronic Repair* may be offered. Table II. shows locations of official 2M Training Sites.

TABLE II. 2M TRAINING SITES



A. Miniature Electronic Repair

Miniature Electronic Repair covers the repair of single and double sided circuit boards focusing on discrete and multi-lead, through-hole devices and includes (see Fig. 2 below):

- Removal and replacement of pcb components
- Removal/re-application of conformal coatings
- Hi-reliability soldering of various connectors and terminals
- Removal and replacement of damaged conductors and printed circuit board laminate
- Electrostatic Discharge (ESD) familiarization and handling procedures



Fig. 2. During the Miniature Electronic Repair Class, students can expect to work extensively under 20x microscopes.

B. Microminiature Electronic Repair

Microminiature Repair is more technically demanding and is considered an advanced capability when compared to Miniature Repair. Therefore, Miniature training is a prerequisite for Microminiature training. Microminiature Training involves (also see Fig. 3):

- Surface Mount Technology (SMT) repair

- Multilayer conductor and laminate repair
- Flex-print repair
- High-density component packaging
- Edge-connector repair



Fig. 3. A Marine Corp 2M Microminiature Repair technician in Afghanistan performs an intricate multilayer excavation. The technical skill required to successfully accomplish this task can only be obtained through 2M training.

C. Recertification

To ensure that a technician is maintaining the required qualification level, periodic evaluations by 2M Inspectors are conducted every 18 months. By inspecting and evaluating the technician's work, certification teams ensure that the minimum standards for the technician's level of qualification are met. If the standards are met, the technician is recertified; if not, the certification is withheld pending retraining and requalification.

IV. 2M REPAIR EQUIPMENT AND TOOLS

In addition to the requirements for special skills and training, 2M also requires special tools. 2M repair stations are equipped with a power supply, specialized desoldering and soldering handpieces, hand tools, specialty pliers, dental picks, pc board holders and in some cases a microscope. A central component of 2M's "Mini" and "Micro" Repair Kits is the PRC 2000, manufactured by PACE Worldwide (see Fig. 4).



Fig. 4. Renowned for their reliability, sustainability and longevity, over 2500 PRC 2000's have been fielded in support of 2M/MTR since 1994.

First introduced in 1990, over ten thousand of these workhorse stations have been manufactured (approximately 2500 for the 2M Program), many of which are still in use after 20+ years. Renowned for their reliability, sustainability and longevity, PACE continues to support the PRC 2000 series with upgrades and enhancements. System capabilities of the PRC 2000 include:

- ESD-safe repair of any electronic module or CCA including multilayer and flexible printed circuits
- Easy and safe removal of surface mount/thru-hole components from circuit card assemblies
- High reliability soldering via conductive, convective, resistance and lap reflow techniques
- Clog-free desoldering using continuous vacuum Solder Extraction
- Conformal coating removal, including epoxy, urethane, silicone, acrylic and parylene coatings
- Precision drilling, grinding, abrading, routing, brushing and cutting, for conformal coating removal/pcb repair
- Drilling Test Probe/Brake Probe capability for multilayer pc board excavation
- Substrate repair, including burns and delamination
- Damage-free thermal wire stripping for removal of all types of insulation, including Teflon
- Self-contained solder paste and flux dispensing
- Built-in vacuum for vacuum/component handling wand

Utilized exclusively for Marine Corp 2M requirements, PACE's MBT 350 (see Fig. 5) is much smaller/compact than the PRC 2000, rugged enough for field deployment, yet capable of handling the highest level 2M repairs.



Fig. 5. MBT 350 is a central component of USMC's TK-8641 Tool Kit

In 2006, the MBT 350 was designated the primary electronics repair system in the USMC field deployable TK-8641 Portable Microminiature Solder Tool Kit. Over 500 have been supplied.

V. CIVILIAN DEPOT CAPABILITIES IN 2M/MTR REPAIR

During the mid-2000's, PACE Worldwide performed an informal survey to determine which civilian Military Depots had the heaviest concentration of electronics maintenance personnel. Such questions as the following were asked:

- How many electronics/electrical engineers were employed onsite?
- How many electronics technicians or electronics mechanics were presently employed?
- Was there a soldering certification course, and if so, how many were certified or trained per year? Was recertification a requirement?
- How many electronics maintenance contractors were supported by the Depot?
- Was the Depot an active participant or supporter of 2M/MTR?
- Were upper management, supervisors, or technical engineers aware of the latest trends in commercial industry, such as impending lead-free solder mandate, or the proliferation of new Area Array components, such as BGA's or QFN's?

As a result of the survey, the following chart (see Table III below) was produced, representing the Depots with the highest level of electronics maintenance activity:

TABLE III. MAJOR ELECTRONIC MAINTENANCE DEPOTS

Major Civilian Depot Maintenance Sites with Electronics Maintenance Capability

Navy
 FRC SE Jacksonville
 FRC East Cherry Point
 FRC SW North Island
 SPAWAR, San Diego
 Norfolk Naval Shipyard
 Puget Sound Shipyard

Marine Corps
 MC Logistics Base, GA

Federal Gov't
 FAA Tech Center, OK



Army
 Tobyhanna Army Depot
 Corpus Christi Army Depot
 Letterkenny Army Depot

Air Force
 Robins AFB, GA
 Tinker AFB, OK
 Hill AFB, UT

Coast Guard
 USCG Elizabeth City

Note that the survey was very informal and could not be considered a scientific study in any manner.^[5] However, several interesting conclusions could be drawn:

1. NAVAIR Fleet Readiness Center Depots were the only active 2M participants, teaching standard courses in Miniature and Microminiature Electronics Repair on a regular basis. The 2M classes were only taught to a small minority of key Electronics Mechanics, while most the Electronics Workers received a standard basic soldering course appropriate to what they might be repairing. (On the shop floors of non-FRC Depots, then was practically no awareness of the 2M/MTR Program.)

2. Structured soldering/electronics repair courses were available at most Depots, but most of the Depots did not require recertification. In many cases, an Electronics Worker might have been initially trained at the start of his/her career, but never re-trained for decades. One of the worst nightmares for a solder/rework Trainer is an assembly/repair tech with little to no training – the tech has picked up bad habits which are next to impossible to break. At many civilian Depots where the median age of the workforce is 57 years old, this becomes a huge issue.
3. Soldering Instructors at the largest Depots (Tobyhanna, Robins AFB, Hill AFB, Tinker AFB and the FRC's) were excellent, dedicated teachers, but were frustrated with the assembly line/production-oriented approach in the Shops. In some cases, the instructor was forced to provide a passing grade to an employee that was clearly unsuited for the job.
4. Most of the Depot personnel, including Solder Trainers, were unaware of issues that might occur as a result of upcoming RoHS rule changes that mandated the use of lead-free solder throughout industry.
5. While Engineering personnel were aware of ball grid array (BGA) technology and were looking at ways to generate an in-shop capability to repair CCA's that utilized them, there was no workload generated that would justify an organic BGA rework capability. So most BGA assemblies were farmed out to contractors for repair. In several cases, (at Tobyhanna Army Depot, Robins AFB and Hill AFB), expensive BGA Rework systems were procured yet never used because the desired workload did not ever materialize.

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