NASA TECHNICAL NOTE

NASA TN D-2321

C. 1

NASA TN D-2321

WELDED ELECTRONIC MODULE FABRICATION

by John C. Lyons and David R. Dargo

Goddard Space Flight Center

Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • JUNE 1964

WELDED ELECTRONIC MODULE FABRICATION

By John C. Lyons and David R. Dargo

Goddard Space Flight Center
Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Office of Technical Services, Department of Commerce,
Washington, D.C. 20230 -- Price $0.50

WELDED ELECTRONIC MODULE FABRICATION

by

John C. Lyons and David R. Dargo

Goddard Space Flight Center

SUMMARY

A pilot facility for the fabrication of welded electronic modules has been developed at the Goddard Space Flight Center for the purposes of: (1) providing a quick-reaction group in the research and development phases of module fabrication, and (2) determining in detail the requirements in terms of facilities and trained personnel to insure the production of high quality welded modules. The experience gained in the successful application of the welding technique to modules in Ariel I (the International Ionosphere Satellite, 1962 o1) and Explorer XVIII (the Interplanetary Monitoring Platform, 1963 46A) has provided a firm base for the utilization of this concept in future spacecraft programs.

CONTENTS

WELDED ELECTRONIC MODULE FABRICATION

by
John C. Lyons and David R. Dargo
Goddard Space Flight Center

INTRODUCTION

This report presents a general discussion of the activities of the Goddard Space Flight Center in the area of welded electronic module fabrication during the past 2 years. The experience acquired during progress of the work on the International Ionosphere Satellite, Ariel I (1962 o1) and the Interplanetary Monitoring Platform, Explorer XVIII (1963 46A) forms the basis of the report.

The welding technique offers great advantages over other methods of module fabrication. Since interconnection wire can be welded to component leads immediately adjacent to the component body, greater packing densities are achieved. Since the strength of the weld joint closely approaches the yield strength of the wire itself, mechanical integrity of the module is enhanced. Welded interconnections are not limited to connections on one or two surfaces. Therefore, layout design is simplified and packing density increased by the addition of layers of interconnections as required. The successful operation of the encoders in Ariel I has effectively demonstrated the value of the welding technique in module fabrication. These encoders comprised approximately 2000 components and were about 90 percent welded. A study of the effects of random and single frequency sinusoidal vibration on a test unit encoder for the Explorer XVIII program has been completed. This unit, shown in Figure 1, contains approximately 1300 components and 8000 welded interconnections. It was found to be unaffected, electrically and mechanically, after

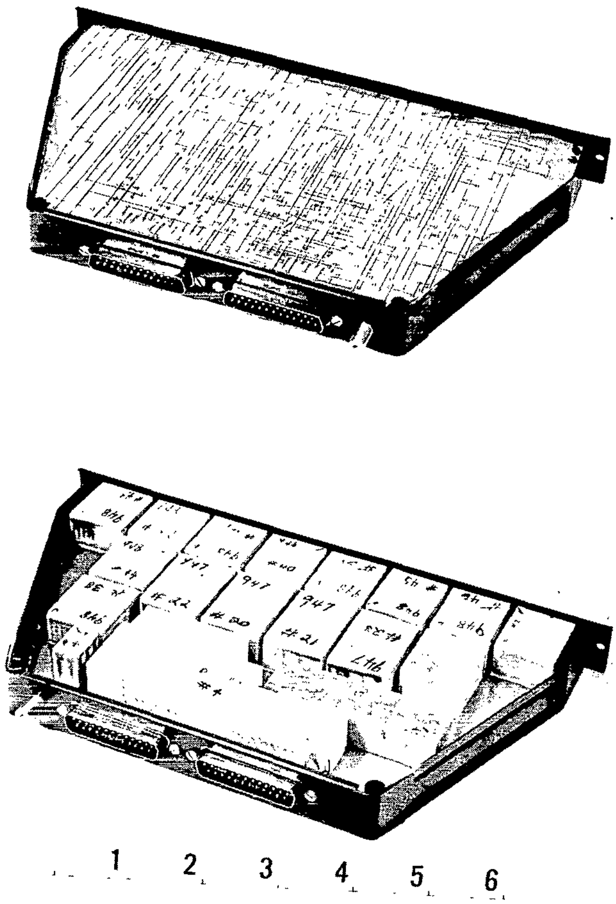


Figure 1—Typical welded electronic package.

being subjected to 27g (rms) random vibration within the frequency spectrum of 20-2000 cps for 4 min. duration along each of 3 mutually perpendicular axes. Sinusoidal vibration sweeps at the rate of 2 octaves per minute at levels of 60g (peak) over the frequency range of 2000-3000 cps, 50g (peak) over the range of 44-3000 cps, and 0.5 in. (double amplitude) over the range of 10-44 cps likewise left no effects upon the unit.

In the interest of greater packing density, the matrix film technique is favored at the Goddard Space Flight Center over the point-to-point technique. Because crossovers are not possible with the point-to-point technique, it does not permit as many connections to be made on a single layer as does the matrix technique. In addition, the point-to-point method requires the fabricator to bend and form the connecting wire as he assembles the unit. This practice produces inconsistent weld characteristics. The matrix film technique simplifies both layout and inspection. Connections can be made on both sides of the film, reducing the number of connecting layers. Individual matrix films may be inspected as they are completed; this permits step-by-step quality control. The problem of bending and forming wire does not occur since all wire runs are straight. This eliminates operator responsibility for their arrangement.

DESIGN CONSIDERATIONS

Practicable package design is a compromise between optimum placement of components and optimum placement of the leadout wires. Since interconnection of the modules is the most important part of package design, lead placement should be given primary consideration. In spacecraft digital circuitry design a characteristic of the circuits is normally ultralow power, and few projects arise where component placement is influenced by power considerations. In general, components should be arranged to provide a minimum number of interconnection wire crossovers. Where a great many interconnecting leads are required, consideration should be given to the fabrication of large modules so that a considerable number of the interconnections will be internal. For example, two 25-transistor modules pose a much simpler interconnection problem than do ten 5-transistor modules.

In general, modules are designed to have a plan area no smaller than 1/2 square in. and no larger than 3 square in. This is a rule-of-thumb based on practical considerations, and should not be construed, therefore, to be an inflexible rule. Although welded module packaging can be applied effectively to sections of a system's circuitry, experience indicates that the best approach to efficient welded module design requires that the package designer be given the entire system circuitry for breakup. The designer should then be permitted freedom to make a functional breakup from the point of view of minimum module interconnections, provided that the breakup does not interfere with electrical performance.

LAYOUT

Layouts were made with tape on mylar at a scale of 8 to 1. Tape is preferred over all the other commonly used materials for indicating wire runs, because it is a clean material that can be quickly applied and readily removed, where modifications are required, and is adequate in every respect. The completed layout is photographically reduced and the resultant film positive becomes the matrix film. Ozalid prints of the layout are used as assembly drawings by the welders, and as checking prints by the inspectors. A typical layout is shown in Figure 2. Note that cut marks are used to identify the leads to be terminated in this layer.

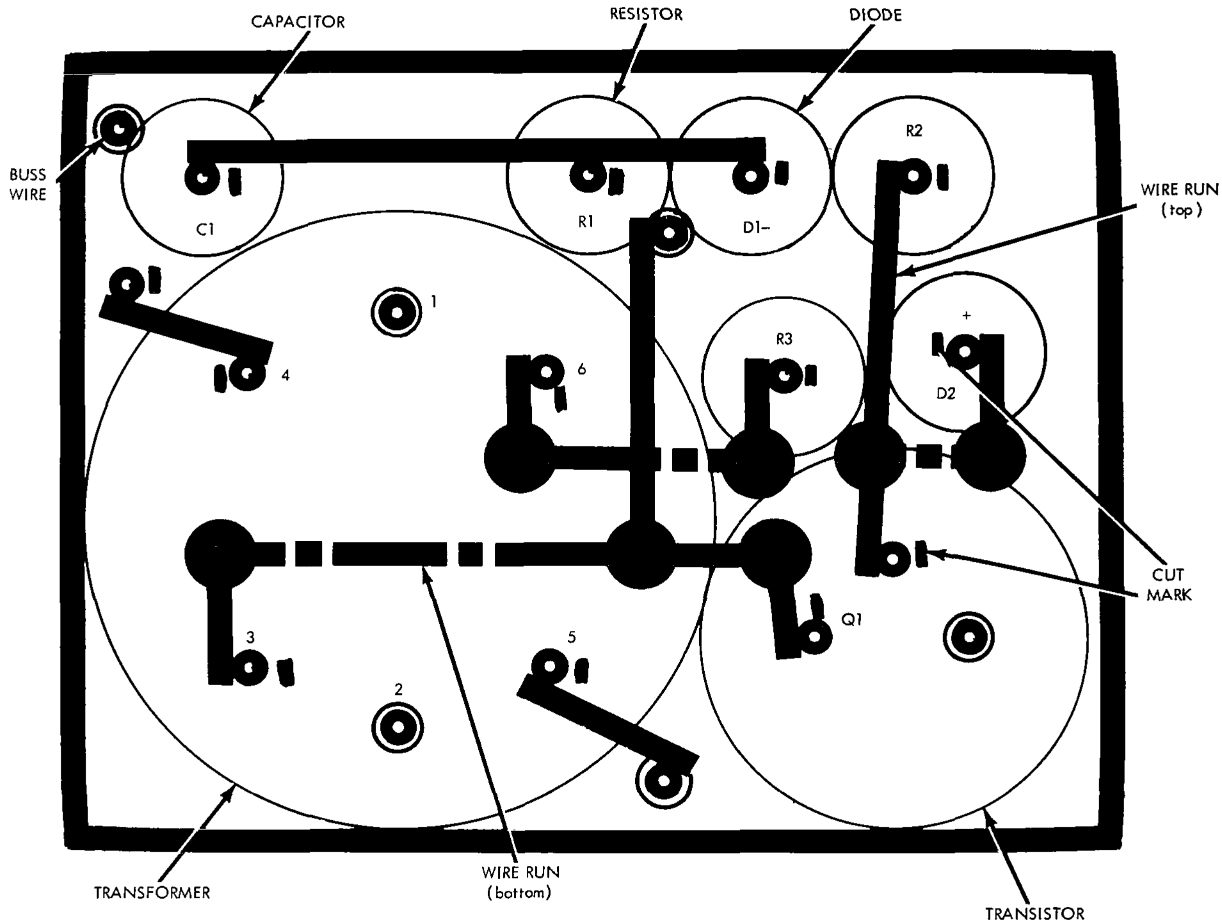


Figure 2—Typical layout for welded modules.

MATERIALS AND EQUIPMENT

It is important that due consideration be given to the choice of materials for component leads, interconnecting wires, and matrix film. Components may be obtained whose leads are either weldable or nonweldable and either magnetic or nonmagnetic. For welded module applications, suppliers should be required to provide components with weldable leads, where possible. Weldable metals which have been found to be satisfactory for component leads and interconnecting wires are nickel, Kovar, Dumet, and Alloy 180. Since the magnetic properties of most commonly used weldable metals would have an undue influence on the magnetometers included in many satellites, a nonmagnetic weldable metal, such as Alloy 180, should be used for component leads and interconnecting wires in these applications. Standard stable-base photographic film is adequate for the matrix film.

The shop equipment necessary for a welded module fabrication facility consists of welding machines, microscopes, punch presses, a pull tester, and assorted hand tools. This equipment is shown in Figure 3. The welding machines comprise two major components, a weld head and a power supply. The weld head is a two-electrode device which passes current through the workpiece to make the weld. The power supply is basically a dc supply employing a large capacitor at its output which is discharged through the primary of a step-down transformer. The secondary of the transformer is a low voltage, high current winding connected to the two electrodes. The microscopes are of the adjustable focus, variable power, binocular type and are used in observing the welding process and inspecting the welds for quality control purposes. The pneumatically operated pull tester is also an essential quality control tool. A close correlation has been established between external appearance of the welds and the pull-test results.

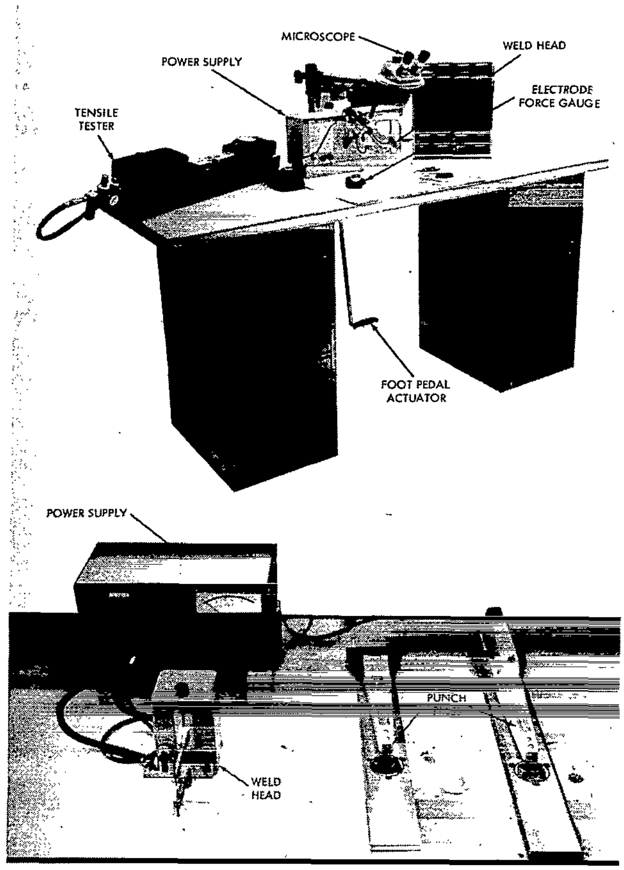


Figure 3—Shop equipment.

ENVIRONMENTAL CONDITIONS

It has been effectively shown that welded electronic modules can be successfully fabricated under ordinary laboratory conditions. Therefore, although the industrial practice of providing special workrooms and regulations for welding operations should be encouraged, it is not mandatory to maintain "white room" conditions.

WELD SCHEDULES

Weld schedules specify the equipment to be used, the material and configuration of the electrodes, the electrode pressure to be applied, and the weld energy in watt-seconds for each combination of materials to be welded. A typical schedule is shown in Figure 4. It might be expected that strict adherence to the schedule would enable the welder to produce consistently acceptable welds. It has been found, however, that because of minor daily variations in the performance of

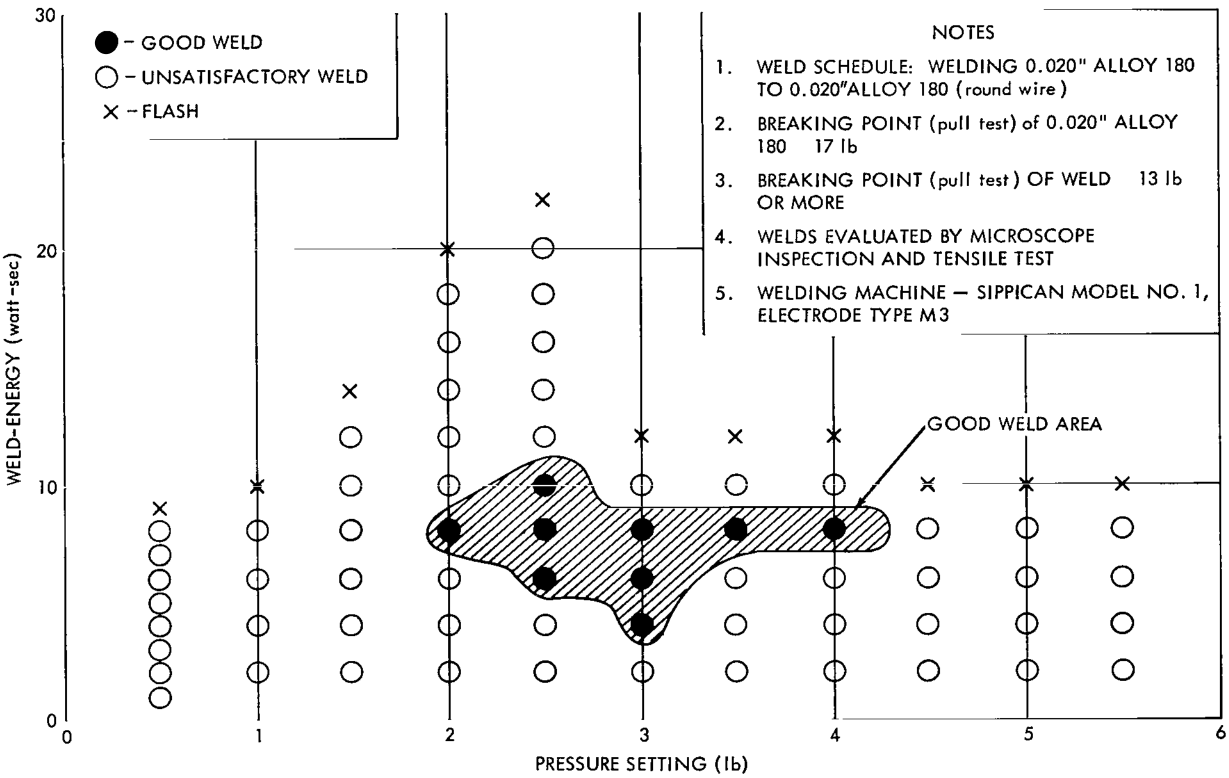


Figure 4—Typical weld schedule.

machines, coupled with the effect of the basic differences between operators, a standard weld schedule does not insure consistently acceptable welds. Therefore, the pressure and energy settings specified in weld schedules should be considered as rough estimates, defining the range in which acceptable welds can be produced. Figure 5 shows this range.

Visual inspection is the most valuable quality control tool. Metallographic analyses and pull tests may be used to determine the quality of welds in establishing the basic schedule. An analysis requires the examination of photomicrographs of the cross-section of welds, by a metallographer, to determine whether the crystalline structure of the joint is satisfactory. Since neither the external appearance nor the pull strength of a weld can be closely correlated with the

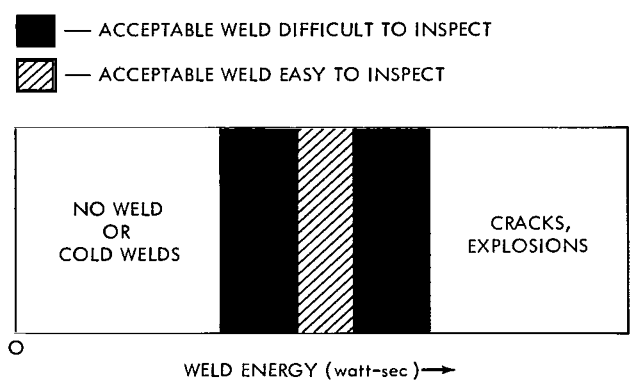


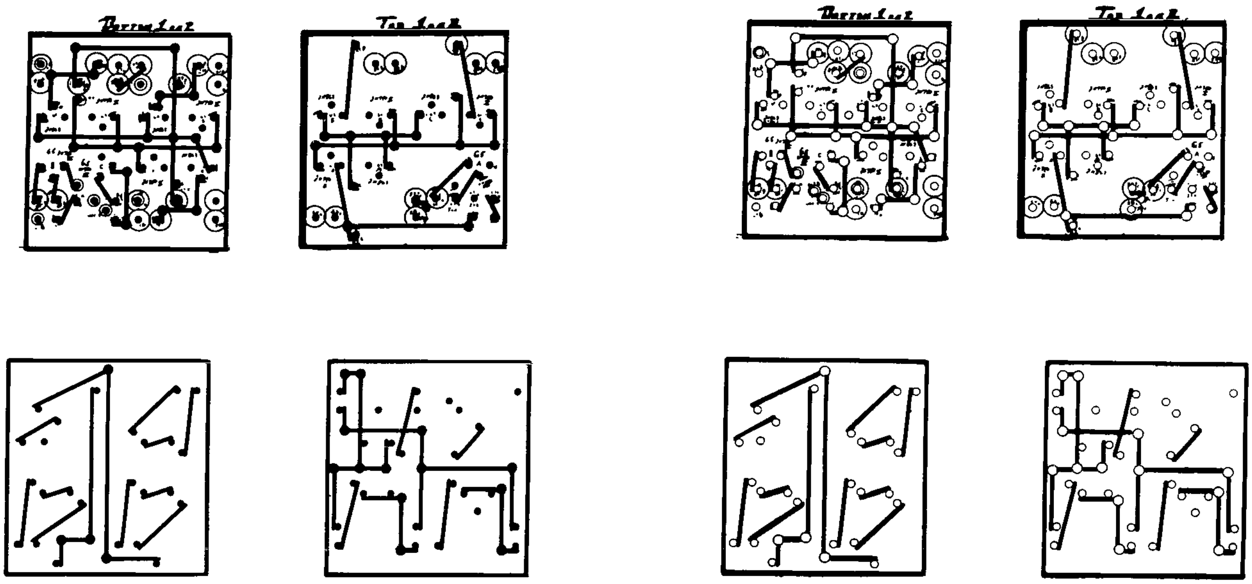
Figure 5—Range of acceptable welds.

results of metallographic analysis, and since welds cannot be sectioned during flight package fabrication, metallographic analysis, although of academic interest, is of little practical value in the workshop. The results of pull tests, flexure tests, etc. may be very closely correlated with external appearance of the welds. For example, the color, deformation, and bead configuration (where applicable) have been found to have a definite relationship to the strength of the weld. Visual criteria have been successfully employed in training personnel to produce acceptable welds.

ASSEMBLY AND INSPECTION

The assembly operation proceeds from the photographic reduction of circuit layouts to the installation of the final layers of the module. The major stages of assembly are illustrated on the following pages: Typical matrix films are shown in Figures 6 and 7. Matrix wires are welded into place (Figure 8); note the parallel arrangement of the wires on each side of the film. Figure 9 shows an operator welding a component lead to the matrix. Transistors are installed in the matrix (Figure 10). Submodules similar to the one depicted in Figure 11 are fabricated and assembled to the matrix (Figure 12). When the bottom layers (Figure 13) are welded into place the module is ready for potting. Figure 14 shows a completely assembled module.

Operators and inspectors should examine welds microscopically, using established visual criteria to determine the quality of welds. One important criterion for inspection is consistency. It is important that all welds in any given package be consistent in appearance.



UNPUNCHED PUNCHED

Figure 6—Matrix films for a module.

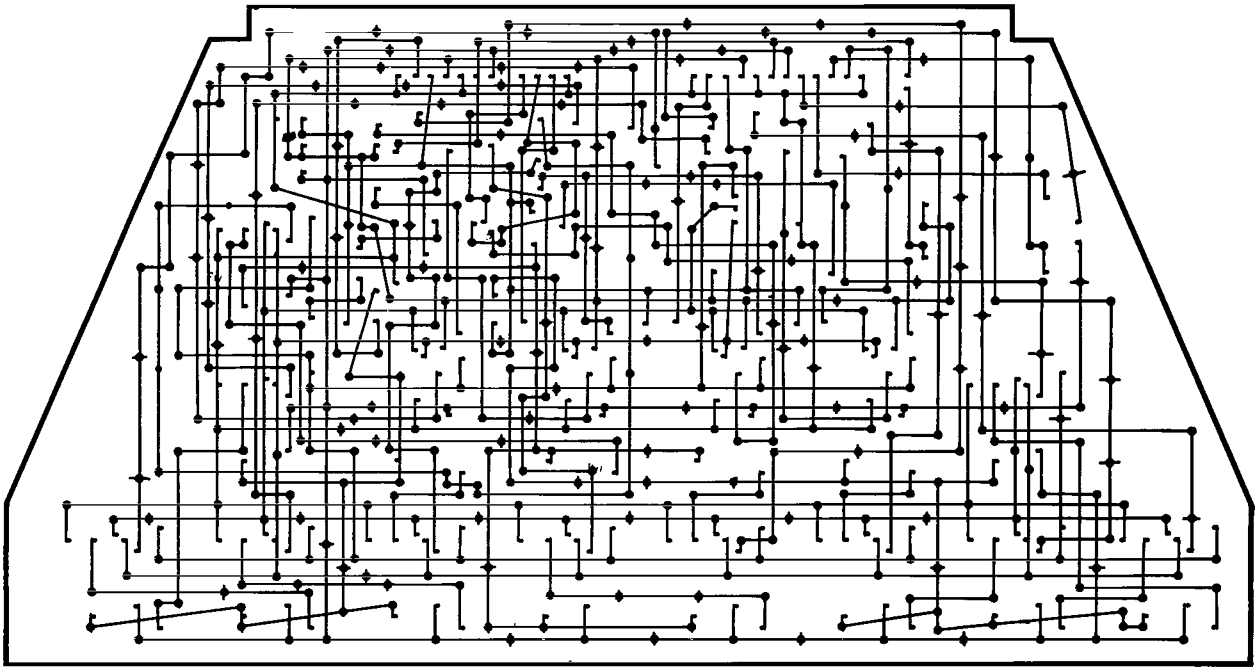


Figure 7—Unpunched matrix film of a package interconnection layer.

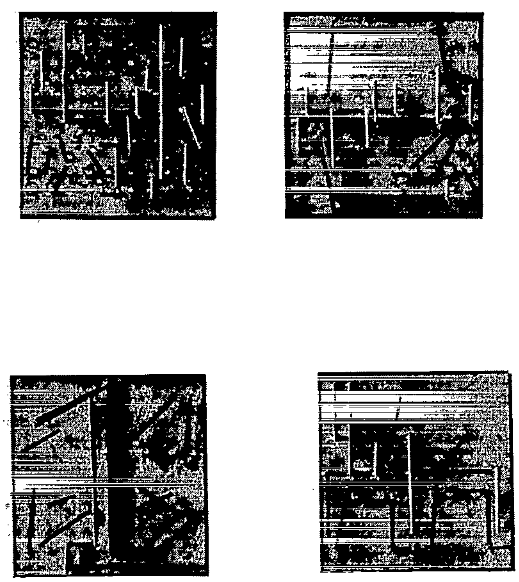


Figure 8—A welded matrix.

Figure 9—The welding operation.

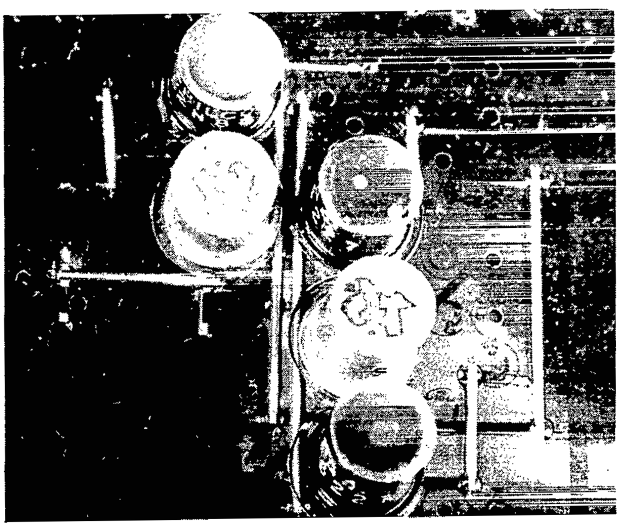


Figure 10—Matrix, transistors installed.

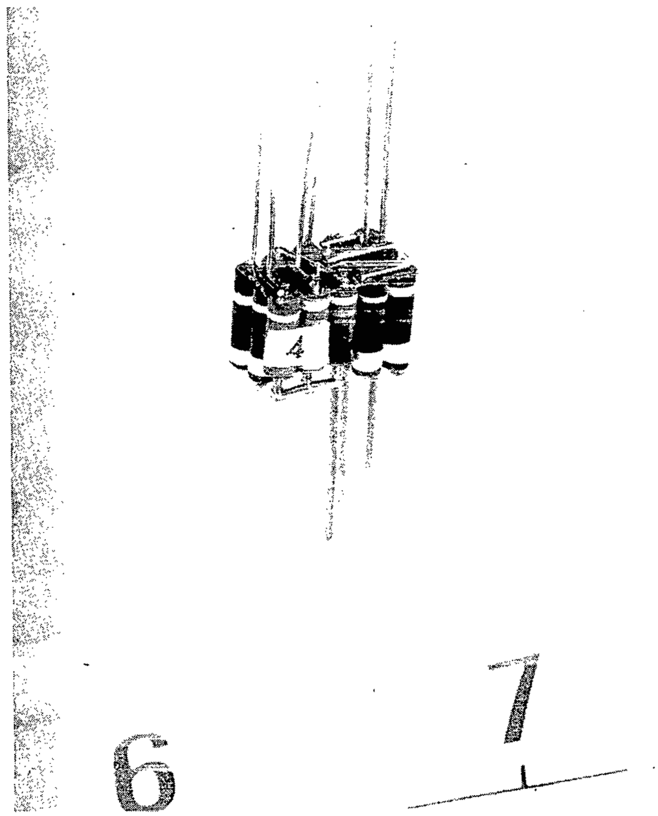


Figure 11—A typical submodule.

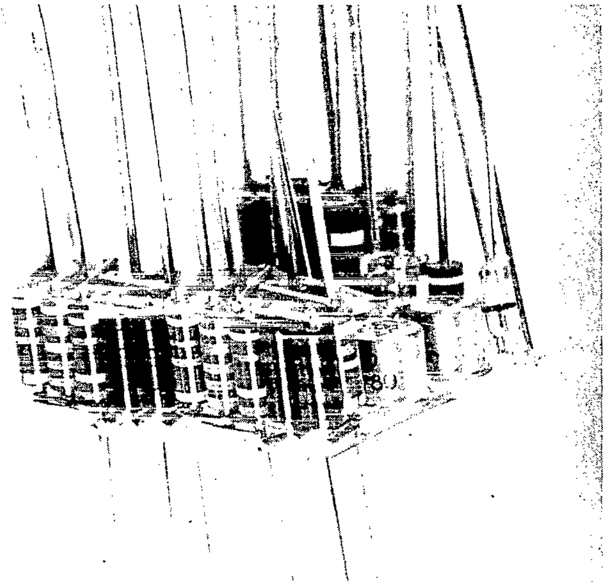


Figure 12—Submodule-transistor assembly.

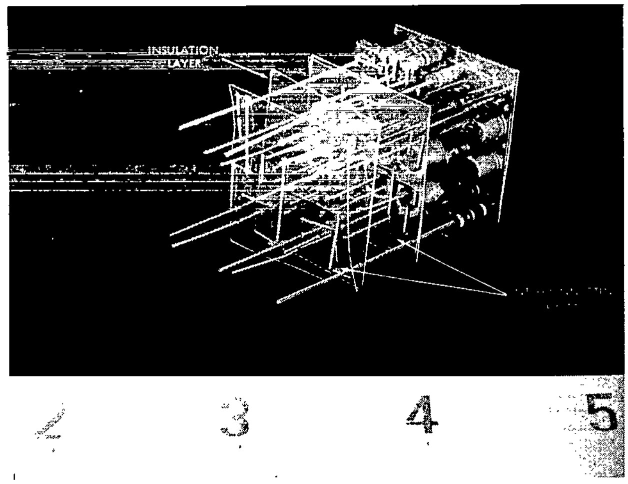


Figure 13—Bottom layers.

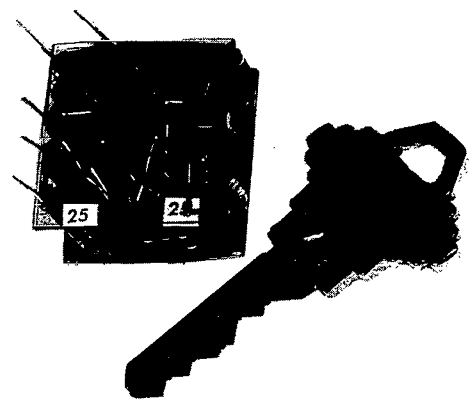


Figure 14—Welded electronic module (ready for potting).

REPAIR

Prior to potting, welded modules are completely repairable. Any component that fails can be replaced in a manner that maintains the quality of the unit and assures its acceptability for flight. In most cases potted units can also be repaired. Faulty potted units must be judged on an individual basis in determining the feasibility of accomplishing necessary repairs. The quality of all reworked potted units should be thoroughly evaluated to insure that the repair processes have in no way impaired the reliability of the unit.

CONCLUDING REMARKS

The research and development phases of the welded electronic module fabrication program have been concluded in most respects. However, all work in this field will be monitored for developments which appear to advance the state of the art. An up-to-date facility and capability in welded electronic module fabrication will be maintained at the Goddard Space Flight Center.

(Manuscript received December 10, 1963)

2171 PT

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Technical information generated in connection with a NASA contract or grant and released under NASA auspices.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

TECHNICAL REPRINTS: Information derived from NASA activities and initially published in the form of journal articles.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities but not necessarily reporting the results of individual NASA-programmed scientific efforts. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546