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MASKMAKING FACILITIES AT THE MARSHALL SPACE FLIGHT CENTER

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16. ABSTRACT

This report describes the research and development maskmaking facilities at the Astrionics Laboratory of the Marshall Space Flight Center. Information is provided on the level of cleanliness and the environmental control within the various work areas. The available equipment and its function in the maskmaking process are detailed. Sufficient information is provided so that a competent clean-room builder could duplicate the facility capabilities.

EDITOR'S NOTE

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INTRODUCTION

The Marshall Space Flight Center (MSFC) mask and pattern capabilities have been developed basically as a research and development facility. Located in the MSFC Astrionics Laboratory, it represents a sizable investment in both time and finances. The result is a highly capable operation contributing to MSFC and other NASA center programs in microelectronic, hybrid, microwave, and optical systems. The integration of these maskmaking capabilities with the computer-aided design and the microcircuit production facility makes it possible to create and make microelectronic or hybrid circuits from conceptual design through hardware, followed by testing in the Astrionics Laboratory. In addition, the capability exists of producing the design and all patterns through the final masks so that a vendor (RCA) can then produce the devices.

The facility is composed of a regulated clean area (four workrooms, entrance area, and hall) and the associated equipment required to produce quality masks and patterns. Figure 1 shows the layout of the clean area.

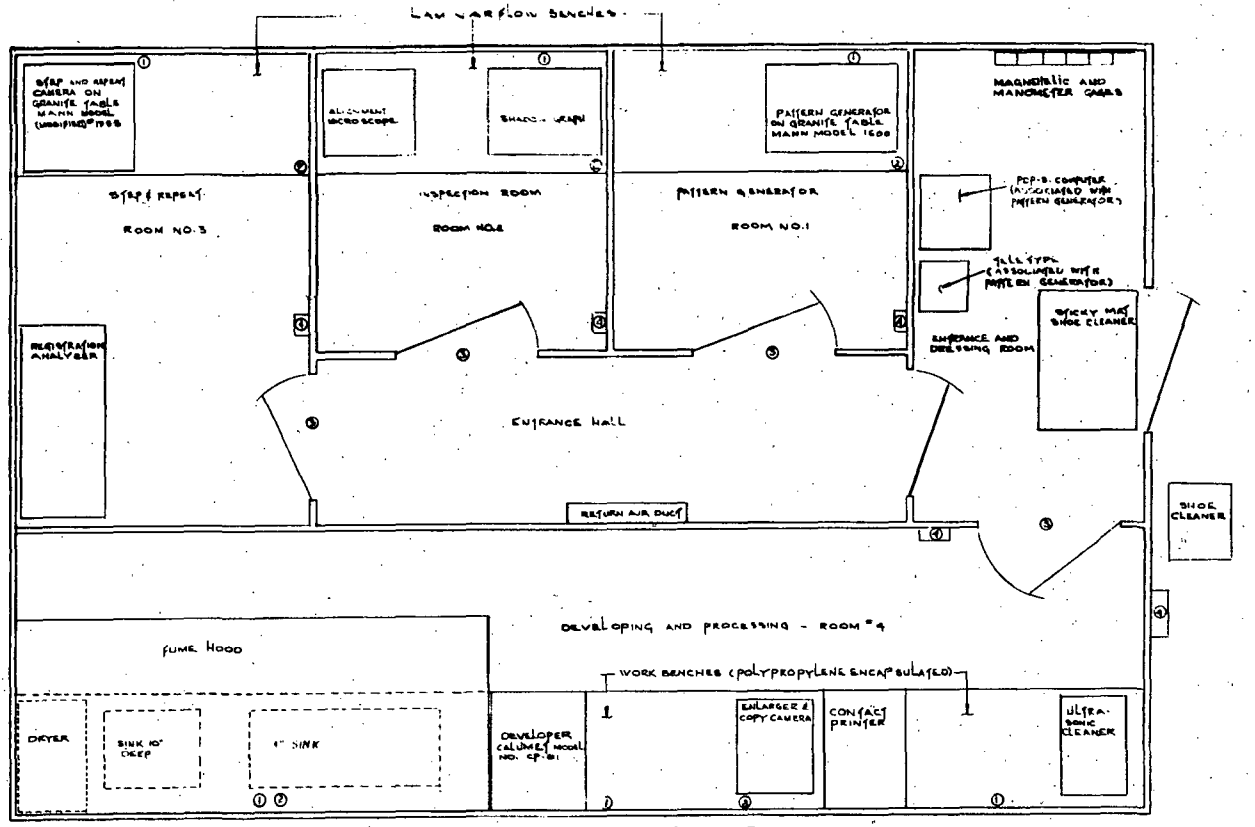
Basic Capabilities

The mask and pattern facility is capable of the following:

1. Creating fine or complex lines, shapes, and circle patterns with precision and excellent line edge quality.

2. Providing a rapid turnaround time from program input to completed masks.

3. Providing a rapid and easy method of creating data and arranging and formatting these data for use on the Mann (1600 and 2600 series) or the Gerber (1000 and 2000 series) pattern generator.



Mask and Pattern Clean Room

NOTES:

1. A positive pressure differential of 0.05 in. of H_2O is maintained between the 10K and 30K clean areas, the 30K, and general laboratory ambient.
2. Rooms Nos. 1, 2, 3, and 4 have individual white and red light control.
3. Rooms Nos. 1, 2, and 3 are maintained at a cleanliness level of 10K or better.
4. Room No. 4 is maintained at a cleanliness of 30K or better.
5. Temperature is controlled to 68 ± 2^{0} F.
6. Humidity is controlled to 50 ± 5 percent.
7. The work areas under the flow benches are maintained at class 100 or better (Fed. Std. 209A)
8. Doors have automatic closers.
9. Both sinks are supplied with potable water and a high-purity deionized water.
10. The mask and pattern clean room is made from portable walls and ceiling sections located within Room C-136 of Building 4487 of the Astrionics Laboratory.

LEGEND

1 red safe light (kodak 1A filter)
2 dry nitrogen
3 warning light (above door, darkroom in use)
4 internal communications

Figure 1. Facilities layout.

4. Providing the capability of shifting and repeating a pattern (computerized step and repeat).

This facility has created masks or patterns for the following areas:

1. Monolithic masks for research and development microelectronic circuits.

2. Hybrid (electronic circuits) screening masks at final product size.

3. Microwave conductor patterns.

4. Optical grids and line patterns.

5. Holography patterns.

Basic Limitations

The quality of these patterns and lines is limited by the following factors:

1. The mechanical precision and the positional increments of the X and Y stages on the Pattern Generator (PG) and the Step and Repeat Camera (S&R).

2. The transmitting optics of the two machines of item 1.

3. The emulsion of the photographic glass plate.

The basic or major limiting factor is the resolution of the optics (650 line pairs per millimeter). Additional facts regarding equipment accuracies and capabilities are given in a NASA Technical Memorandum.[1]

CHARACTERISTICS OF THE CLEAN AREA

Cleanliness

For the consistent production of quality masks, the environment in which the high-resolution glass plates are handled must be well controlled.

1. Donald E. Routh, Mask and Pattern Characteristics, NASA TM X-64688, August 1972.

In many cases foreign particles of 1 μm in size on the masks will degrade or cause catastrophic failure in a dense or complex circuit. In order to maintain a high degree of efficiency, particles of 1 μm or larger should be removed from the environment. The entire process of maskmaking is achieved within the MSFC clean environment. The input is in the form of a nine-track magnetic tape and the output is that of the final plate or film, suitably packaged and sealed and ready for user application.

Flow Benches. The work areas under the flow benches are maintained at class 100 (FED-STD-209A) or better. Thus the equipment and photographic glass plates are subjected to a very low particle count while in the flow-bench work area.

Workrooms. Room Nos. 1, 2, and 3 are maintained at class 10000 or better. This then provides the flow benches with a relatively clean environment in which the lower class of cleanliness across the work area can be achieved.

Developing Room. This room is maintained at class 30000 or better. At this level the photographic glass and film patterns are enlarged and processed (using filtered deionized water to dilute the chemicals) to produce the output for the device builders.

Temperature

The temperature is maintained at 293.15±1°K (68±2°F). This is the temperature recommended for the developer and chemicals used in processing high-resolution photographic glass plates.

A high degree of temperature stability is required. The cameras and other delicate equipment must be maintained with small temperature variations in order that thermal expansion of metals and components will not cause dimensional changes of the patterns being exposed. Dimensional stability is very important in microelectronics as several levels of masks must overlay very accurately with respect to each other. Long-term temperature stability is required because masks of the same set may or may not be made on the same day.

The unexposed glass plates are stored in this temperature-controlled environment and the masks are then carried through all the required steps

to make the final geometry-controlling patterns without the undesirable temperature variations.

Humidity

The humidity is controlled to 50±5 percent. Two primary considerations must be taken into account in determining the desired humidity. If the humidity is too high, it will adversely affect the metal parts of the delicate equipment and gradually lead to degradation of pattern accuracy; it also adversely affects the emulsion of any stored high-resolution photographic glass plates. If the humidity is too low, static electrical charges begin to accumulate, attracting any available dust particles and creating undesirable working conditions.

Darkroom Capability

Each of the working areas has individual white and red filtered (Kodak safelight filter No. 1A) light control. When the undeveloped photographic glass plates are handled, the red filtered light must be used (as a working light) to eliminate fog and prepattern exposure. The red filter is used because the silver halide emulsion is the most sensitive in the blue and green light spectrums, with the response falling off sharply toward the red wavelengths.

EQUIPMENT LIST AND FUNCTIONS

The following is a list of the equipment used by the MSFC Astrionics Laboratory in the maskmaking process. The primary functions of the equipment are also given.

1. Mask and Pattern Exposing Systems

   a. Pattern Generator System
      Model No. 1600
      David W. Mann Company
      174 Middlesex Turnpike
      Burlington Middlesex, Massachusetts 01803

The Pattern Generator System responds to magnetic or paper tape data commands so that accurately sized and positioned rectangles are exposed onto a photographic glass plate. The complex patterns and masks are created (in a building-block manner) by a series of exposures, rectangle by rectangle.

b. Step and Repeat Camera System
Model No. 1795 (modified)
David W. Mann Company
174 Middlesex Turnpike
Burlington Middlesex, Massachusetts 01803

The function of the Step and Repeat Camera System is to accept patterns on high-resolution photographic glass plates and accurately aligned to a metal frame, to reduce that pattern image by a factor of 10, and then to step and repeat the image in a precise X, Y array. The X, Y array of images (after development processing) is the output of this system.

2. Processing Equipment

a. Developing Machine
Model No. CP-811
Calumet Manufacturing Company
1590 Touhy Avenue
Elk Grove Village, Illinois 60007

The Developing Machine is a multistep processor with temperature control and nitrogen burst agitation used to develop and process film and larger glass.

b. Contact Printer
Designed and built inhouse
Technology Division, Astrionics Laboratory
(S&E-ASTR-RD)

The Contact Printer is used to create negative mirror-image duplicates of patterns and masks on photographic glass plates. The printer is capable of working with glass sizes up to 10.16 by 12.70 cm (4 by 5 in.) and resolving a 1-μm line.

c. Enlarger and Copy Camera
Model PRO-LAB No. D-6
Omega Company
29 Knapp
Stamford, Connecticut

The Enlarger and Copy Camera is used to enlarge and transfer patterns from photographic glass plates to film. It is also used to make copies of patterns going from film to film.

d. Dryer (Glass Plates)
Model No. 5000
Blue M Electric Company
Blue Island, Illinois

This dryer is a small oven used to remove water from the emulsion of the photographic glass plates. During the various processing steps the emulsion swells by absorbing water, becomes tacky, and is easily damaged. Removal of the water is essential before using the mask for geometry control.

e. Dryer (Film)
Model No. AM 14
Laboratory Supplies Company
29 Jefry Lane
Hicksville, New York 11801

This dryer is a free-standing infrared heat lamp used for drying film for the same reasons as stated in the previous item.

3. Inspection Equipment

a. Shadow Graph
Model No. 6C
Nippon Kogaku
Tokyo, Japan

The Shadow Graph is used to inspect larger patterns for defects and flaws (normally produced on the pattern generator). It provides 10X, 50X, and 100X magnification and projects the pattern onto a 30-cm (12-in.) diameter faceplate for easy viewing and checking. Micrometer dials and a cross on the faceplate may be used to check line width, length, and/or overall pattern dimensions.

b. Inspection Microscope
Model N
Olympus Corporation of America
Two Nevada Drive Lake Success
New Hyde Park, New York 11040

The Inspection Microscope is used to check the small and/or fine lines and patterns (usually from the step and repeat camera) for defects and flaws. Magnification of up to 400X with back lighting is available for inspection purposes.

c. Registration Analyzer
Model No. RA302
The Jade Corporation
3003 Philmont Avenue
Huntingdon Valley, Pennsylvania 19006

The Registration Analyzer is an optical system used to make dimensional comparisons between the various levels of microminiature masks. The production of microelectronic circuits requires four or more levels of geometry-controlling masks to register with each other to a high degree of accuracy.

4. Support Equipment

a. Alignment Machine
Model No. 1685A
David W. Mann Company
174 Middlesex Turnpike
Burlington Middlesex, Massachusetts 01803

The Alignment Machine is used as direct support for the Step and Repeat Camera System. The mask to be stepped and repeated (10X master) must be very accurately mounted on a special mounting frame. The function of this machine is to position the 10X master on the mounting frame before it is glued into position.

b. Laminar Flow Benches
Day Enterprise, Inc.
1002-4 Community Street, NE
Huntsville, Alabama 35801

The Laminar Flow Benches are used to create an ultraclean environment (class 100) across a work area. Within this work area is located the delicate and accurate equipment required in maskmaking.

c. Work Benches
Plastic Laboratory Products
423 Nelo Street
Santa Clara, California

The Work Benches are special clean-room benches (polypropylene encapsulated). Their purpose is to provide a clean surface for general processing work, storage, and handling of equipment and masks.

d. Ultra-Sonic Cleaner
Model No. G-80-80-1
Ultrasonic Instrument International, Ltd.
165 Marine Street
Farmingdale, New York 11735

The Ultra-Sonic Cleaner is used for cleaning the photographic glass plates either before or after exposure.

e. Granite Tables
Model No. 975-029
Curtin Scientific Company Division
Foremost-McKesson, Inc.
1210 S. 20th Street
Birmingham, Alabama 35205

The Granite Tables are used as stable mounting platforms for the delicate and accurate photographic equipment.

APPROVAL

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By Donald E. Routh

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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Chief, Technology Division

F. B. MOORE
Director, Astrionics Laboratory

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