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MIMIC--AN OPPORTUNITY THAT MUST NOT BE MISSED

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ABSTRACT

The Microwave and Millimeter Wave Monolithic Integrated Circuits (MIMIC) program, sponsored by the United States Department of Defense (DoD), provides the resources and structure that will make it possible to transition the results of many years of productive research and development in gallium arsenide technology into a manufacturable production process. This will allow the efficient and affordable manufacture of monolithic format, microwave and millimeter wave frequency integrated circuits needed for a wide variety of applications. Profitable production of these circuits will allow a self-sustaining business base to be established and assure the future availability of these circuits. This paper describes the objectives that must be met for this effort to be a success, reviews the progress to date on the program and discusses future planned activities.

INTRODUCTION

A unique and timely opportunity currently exists to transition the hard work and exciting results of the past twenty years of research and development in gallium arsenide technology into production-ready, manufacturing capabilities. The microwave industry will then be able to produce gallium arsenide microwave and millimeter wave monolithic format circuits which meet the operational requirements of many types of microwave systems at an acceptable cost. The manufacture of products of high value and wide utility will create a level of market demand that makes their production profitable and, hence, self-sustaining. It will then be possible to gain the benefits of solid state reliability, small size and low weight, as well as the advanced microwave signal processing achievable with such devices. In short, the objective of the many years of work on solid state microwave technology using gallium arsenide devices will finally have been reached.

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The United States Department of Defense (DoD) has planned and put into operation a program to accomplish these objectives. The program is called MIMIC -- MIcrowave and Millimeter Wave Monolithic Integrated Circuits. It provides industry with the opportunity to establish a solid foundation for designing, fabricating, testing and using MIMICs for military applications and for transitioning the technology into commercial products as well. The success of the program in reaching its objectives depends on how well and how completely the contractors in the program accomplish the following tasks:

1. Establishing robust, controllable processing capabilities that can be used to fabricate the required chips at high yield. This is the first key ingredient of a low cost MIMIC.

2. Developing and installing highly automated, on-wafer testing to characterize and screen MIMIC chips early in the fabrication process in order to weed out from further costly processing those chips and wafers that do not meet specifications. If possible, the wafer probing should be contactless in order to maintain high yield. This is the second key ingredient needed to bring costs down to affordable levels.

3. Developing a comprehensive computer aided design (CAD) system that provides an "open architecture" framework for the common use of a wide variety of software tools from different organizations and allows the designer to choose an optimum mix of software modeling and design packages. This capability is needed to reduce the cost of designing MIMICs. It must provide a short time cycle between the development of a system concept and the preparation of specifications for the hardware and software needed to implement the system. By implication, the CAD system must also be capable of producing highly accurate design information which minimizes the number of re-design cycles needed to achieve the specified hardware performance. This is the third necessary ingredient for a successful MIMIC capability.

4. Invoking modern production discipline to all the design, fabrication, assembly, and test procedures in order to transform them into sustainable, low cost production operations. This is the fourth key ingredient for program success.

If these tasks are to be accomplished efficiently, an unprecedented degree of cooperation must take place between the many companies engaged in the program. The cooperation must extend over all the various technical disciplines which contribute to the design, fabrication, and use of microwave and millimeter wave hardware. The MIMIC program was specifically structured to foster and manage such interactions. Consortia have been formed among the program participants to identify and solve the CAD problems, to establish common CAD interfaces, and to share modelling information. Processing problems that are common to the industry are being isolated, discussed and collectively solved within contractor teams. Additional contract support has been given to the production of advanced gallium arsenide material, the development of contactless testing techniques and equipment, work on multi-chip packages, and university research on more accurate device and circuit models. Collectively, all program activities are aimed at developing the ability to produce almost any circuit needed for applications in the 1 to 100 GHz frequency range. This paper will review the progress to date on the MIMIC program and discuss its blueprint for the future.

BACKGROUND AND PROGRAM STRUCTURE

The MIMIC program is under the direction of the Defense Advanced Research Projects Agency (DARPA). The author is the MIMIC Program Manager and the Deputy MIMIC Program Manager is Elissa Sobolewski. Each Service (Army, Navy and Air Force) has also appointed a MIMIC Program Director and has established a MIMIC Program Office. The Service offices not only manage the normal day-to-day activities of the MIMIC contract programs, but also perform the extremely useful function of serving as a catalyst for the early application of MIMIC products. They are expected to establish contact with system program managers in their Service and brief them on the MIMIC program activities and objectives. Those programs for which MIMIC offers high potential benefits in performance and cost are then further examined for insertion opportunities.

The program is divided into four sections or phases of activity. The first of these (MIMIC Phase 0) was a one year study undertaken by forty-eight companies that grouped themselves into sixteen teams. The study was completed in February, 1988. It determined the technological developments that would be needed for successful design and manufacture of MIMIC products and identified the most promising system candidates for using MIMIC products. Four of these contractor teams were selected to perform the tasks of the first three-year hardware development phase (MIMIC Phase 1). A second three-year hardware development program (MIMIC Phase 2) is scheduled to begin at the conclusion of Phase 1.

The final portion of the program, MIMIC Phase 3, which runs concurrently with Phases 1 and 2, consists of a number of highly focused, independent technology efforts, some of which are mentioned in the introduction above. These efforts have been selected and contracted for on the basis of their expected contributions to those areas of MIMIC which are considered to be most critical to success and, therefore, in need of special emphasis. Additional Phase 3 contracts and areas of emphasis will be selected (funding permitting) later in the MIMIC program.

PRESENT PROGRAM STATUS

On May 20, 1988, four contractor teams consisting of twenty-six individual companies were awarded contracts totaling $225 million to carry out the tasks of the first 3-year hardware portion of the MIMIC program. Fig. 1 shows the prime contractors, their team members and the value of their contract awards.

PRIME	TEAM MEMBERS	CONTRACT AWARD VALUE
HUGHES/GE	E-SYSTEMS, AT&T, M/A COM, HARRIS MICROWAVE, EEsof, CASCADE	50,046,901
ITT/MARTIN MARIETTA	ALPHA, HARRIS GOVERNMENT SYSTEMS, PACIFIC MONOLITHICS, WATKINS-JOHNSON	49,275,471
RAYTHEON/TI	AEROJET, AIRTRON, COMPACT, CONSILIUM, GENERAL DYNAMICS (FT. WORTH), MAGNAVOX, NORDEN, TELEDYNE	68,821,088
TRW	HONEYWELL, HITTITE, GENERAL DYNAMICS	57,466,614

Fig. 1: MIMIC Phase 1 Contractors

Each company possesses expertise in one or more technical areas encompassed by the program. These areas include gallium arsenide material growth and wafer preparation, device and circuit modelling, computer aided manufacturing equipment, packaging, automatic testing equipment, and microwave system development. Collectively, the teams are charged with developing a large number of components which can demonstrate the benefits of applying MIMIC in military systems. These include 79 MIMIC chip types, 23 assemblies of chips into circuit modules, and 16 assemblies of the modules into system demonstration brassboards. These are shown in Figs. 2-5.

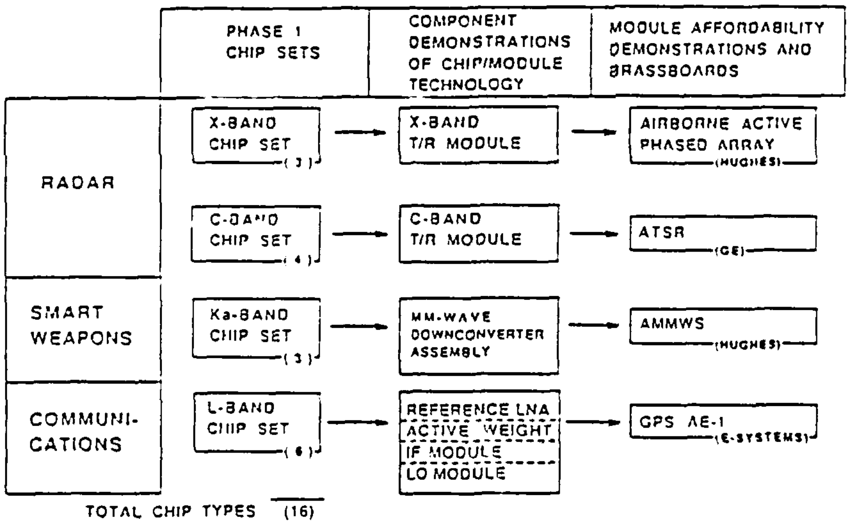

Fig. 2: Hughes Team's Hardware Demonstrations

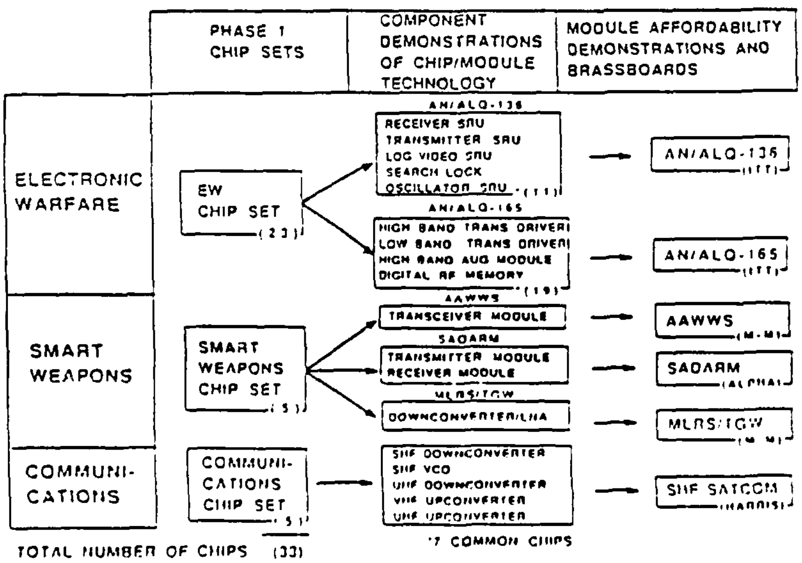

Fig. 3: ITT/Martin Marietta Team's Hardware Demonstrations

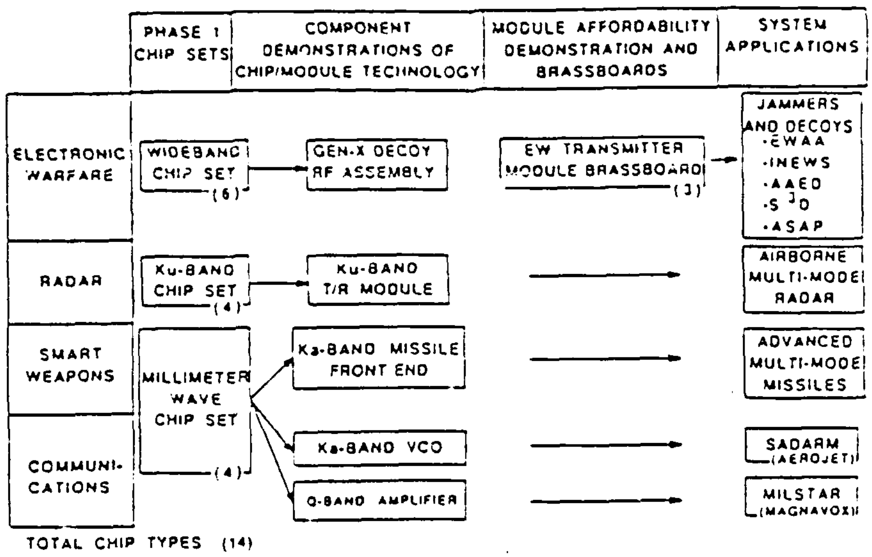

Fig. 4: Raytheon/TI Team's Hardware Demonstrations

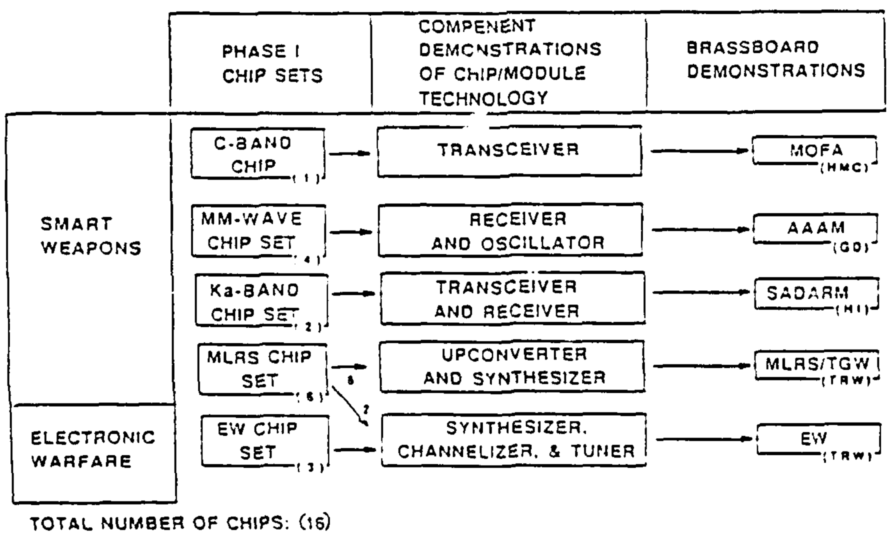

Fig. 5: TRW Team's Hardware Demonstrations

However, the most important responsibility of these teams is to put into place the manufacturing framework and capabilities necessary to produce these and other chips and modules needed for the wide variety of systems that operate in the 1 to 100 GHz range of frequencies. Fig. 6 shows the major activities that are being pursued by the contractor teams during this phase of the program. From the beginning, every contractor participating in the program was made aware of the constant necessity to share information not only with members of the same team, but, to the maximum possible extent, between teams. It is gratifying to see the degree of cooperation extant between the participants of the program. Two sets of major contractors--Raytheon and Texas Instruments, and ITT and Martin-Marietta--have formed formal joint corporate ventures to carry out their program responsibilities more effectively.

BUSINESS PLAN
SYSTEM AREA SELECTION(S)
TECHNOLOGY DEVELOPMENT AND REFINEMENT
- DESIGN
- FABRICATION
- PACKAGING
- ENVIRONMENTAL CONSIDERATIONS

MANUFACTURING
- ADDITIONAL SOURCES OF PRODUCT SUPPLY

DATA BASES
TEST AND EVALUATION
DEMONSTRATION OF PROGRESS

Fig. 6: Summary of Phase 1 Statement of Work

Within each team intense cooperative efforts are evident in the search for solutions to fabrication "roadblocks" and in the institution of multiple, robust manufacturing capabilities. Team members are cooperating to solve some of the most challenging processing problems. For example, AT&T, a member of the Hughes team, has transferred complete and detailed information on their spray etching approach for gate recess fabrication to the other members of their team (Hughes, GE, M/A Com and Harris Microwave). Clearly, this results in a substantial savings of money and time for the program. All of the teams are using the COMETS computer aided manufacturing system, developed by Consilium, to manage the high volume of data flowing from their manufacturing lines. All of the teams have also agreed to fabricate a set of standard test structures on wafers from the same material. These wafers will then be exchanged among all of the teams to compare measurements on the GaAs material, devices and circuits, performed by all program participants. The goal is to achieve consistent measurement results within reasonable bounds of error. In a closely related activity, the U. S. National Institute of Standards and Technology has organized a consortium which will develop additional measurement standards and techniques for use at microwave and millimeter wave frequencies. These are needed to assure the accuracy and repeatability of measurements on materials, devices, and circuits made by the entire microwave community. It will unquestionably be a valuable addition to the activities of the MIMIC program in this area.

In a second area of cooperation, the four MIMIC teams have voluntarily formed a consortium to work collectively toward standardized computer design interfaces, common hardware description languages, and improved device and circuit models. They have been discussing and collectively solving common design problems as they arise. The objective of this cooperative effort is to establish a common framework for most effectively using the software tools being developed both on this program and by independent commercial activity. In addition, because of the involvement of the major microwave software houses such as EEsof and Compact, the software CAD packages being developed will continue to be supported after the conclusion of the MIMIC program.

A large fraction of the cost of a gallium arsenide microwave chip is attributable to the testing that it undergoes in the process of being manufactured - testing at the wafer level, at the separate chip level, and at the fully packaged level. This area has one of the greatest potentials for cost savings. Although on-wafer testing techniques and equipment for use at the lower microwave frequencies have been available for some time and are routinely used, additional work must be done at frequencies above 40 GHz. Several of the MIMIC Phase 3 contracts address these higher frequency needs. One of these efforts will develop the technique for pulsed power testing of MIMIC devices in the frequency range between 50 and 75 GHz. Other efforts are studying the use of electro-optics techniques, by which GaAs material parameters and MIMIC circuit characteristics may be measured without mechanically contacting the chip. The electro-optics approach also offers the possibility of very wide bandwidth measurements.

SUMMARY

The initial activity of the MIMIC contractor teams is very encouraging. Of the 79 planned Phase 1 chip types, 12 have been successfully fabricated and demonstrated within the first six months of the program. The specifications for all 79 chips have been completed and the module and brassboard designs are well underway. All of the teams have current pilot production capabilities which typically can start 100 wafers per week per shift. Each facility is moving toward the use of 4 inch diameter gallium arsenide wafers and installing step and repeat lithographic equipment to pattern all circuit dimensions except the transistor gates. These gates are, in general, patterned by E-beam lithography, although one contractor is using self-aligned gate structures to solve the challenging processing problems associated with gate definition including controlled etching of vertical geometries.

The Phase 3 supporting efforts have been initiated. Twelve contracts have been awarded (see Fig. 7) and the work is now underway. One of the responsibilities of the Service program offices will be to see that these Phase 3 efforts are closely coordinated with the work in Phase 1 which they have been selected to support.

AUTOMATED TESTING TECHNIQUES	COMPUTER AIDED DESIGN
AT&T: OPTICAL DIAGNOSTICS FOR WAFER CHARACTERIZATION	GATEWAY: ADVANCED DEVICE CAD MODELS FOR MIMIC MANUFACTURING
BALL: MIMIC ON-WAFER AUTOMATIC TESTING	NORTH CAROLINA STATE U.: RF PERFORMANCE SENSITIVITY MODEL FOR MIMIC CAD
COMSAT: OPTICAL ON-WAFER MIMIC CHARACTERIZATION	U. OF COLORADO: MODELING & CAD METHODOLOGY FOR MIMIC LAYOUT OPTIMIZATION
M/A COM: AUTOMATED PULSE POWER TESTING OF POWER MIMIC WAFERS	
VARIAN: NON-CONTACT WAFER PROBING	
MATERIALS	**OTHER**
SPIRE: MOCVD PROCESS TECHNOLOGY	ITT: ADVANCED MULTICHIP CERAMIC PACKAGE
VARIAN: MOLECULAR BEAM EPITAXY OPERATIONS	TRW: FOCUSED ION BEAM PROCESSING

Fig. 7: Phase 3 Contracts

APPLICATIONS

Ultimately, the sole basis upon which the success or failure of the MIMIC program will be and should be judged is whether or not the products and capabilities developed are effectively and promptly used to solve both the cost and performance problems of military (and commercial) electronic systems. The program has gotten off to a good start with the commitment of the High Speed Anti-Radiation Missile (HARM) program office to use MIMIC amplifiers in their system. This application will require the production of 1200 MIMICs/month for the next five to six years. Other systems likely to use MIMICs within the next two years include the Global Positioning System (GPS), and the Advanced Medium Range Air-to-Air Missile (AMRAAM). In the longer term, application opportunities exist in more than 50 additional military systems including a multi-national one: the Multi-Launch Rocket System/Terminally Guided Weapon (MLRS/TGW). MIMIC use is also planned for commercial applications such as automobile radar systems, collision avoidance systems and mobile communications.

CONCLUSION

The MIMIC program is off to an outstanding start. Assuming that the level of cooperation and enthusiasm between contractors and contractor teams is maintained, success appears inevitable. Of course, the bottom line determination of success is the number of system "customers", both military and commercial, that sign up for the use of MIMIC products. If we use the experience of silicon digital technology as a guide (with due caution, of course), the availability of high performance, high reliability, low cost gallium arsenide microwave and millimeter wave circuits could create a commercial market that greatly exceeds the military one. The most obvious commercial market would be that of automotive safety systems which, alone, could represent annual chip production in the millions. For the present, however, the focus of the MIMIC program will continue to be on the requirements of military microwave and millimeter wave systems. To this end, every contractor team as well as each MIMIC Program Office is committed to constantly interacting with system program managers to assure that their needs are met and that the insertion opportunities are successfully fulfilled.