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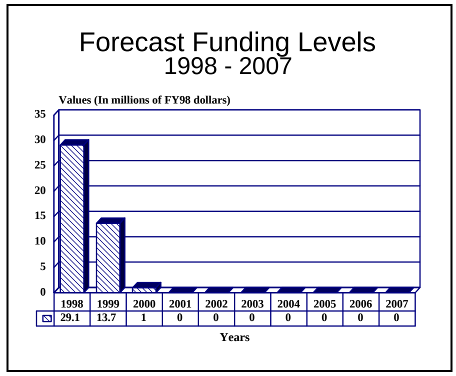
MIMIC/MAFET - Archived 1/98

Outlook

- Follow-on program from MIMIC
- Funding likely to end in 2000
- Main goal to reduce Gallium Arsenide integrated circuits by at least four orders of magnitude
- Commercial prospects for cost-reduced, MIMIC-derived MAFET systems and related applications abound



Orientation

Description. The Microwave and Analog Front End Technology (MAFET) program is a follow-on to the Millimeter Wave Monolithic Integrated Circuits (MIMIC). The goal of MAFET is a directed effort seeking to reduce non-recurring costs for military microwave/millimeter wave sensor systems.

Sponsor

Advanced Research Projects Agency (ARPA)
Washington, DC
USA

Contractors. The MAFET program has not been identified as being under any particular contractor. However, as MAFET is a direct descendent of the MIMIC program it is possible that one or more of the former MIMIC team leaders is currently working on MAFET. These team leaders were as follows:

General Electric Co
Syracuse, New York (NY)
USA

Hughes Electronics Corp)
Aerospace & Defense Sector
P.O. Box 80028
7300 Hughes Terrace
Los Angeles, California (CA) 90080-0028
USA
Tel: +1 310 568 7860
Fax: +1 310 568 6715

ITT Corp
Defense and Electronics Division
1000 Wilson Boulevard
Arlington, Virginia (VA) 22209
USA
Tel: +1 703 276 8300
Fax: +1 703 276 9704

Lockheed Martin Corp
Electronics Information & Missiles Group
5600 Sand Lake Road
Orlando, Florida (FL) 32819
USA
Tel: +1 407 356 2000
Fax: +1 407 356 2010

Raytheon Co
Research Center
131 Spring Street
Lexington, Massachusetts (MA) 02173
USA
Tel: +1 617 863 5300
Fax: +1 617 642 3936

Texas Instruments
Defense and Electronics Group
P.O. Box 660246
Dallas, Texas (TX)

USA
Tel: +1 214 575 6908

TRW Inc
Electronic Systems/Technology Division
One Space Park R6/1525
Redondo Beach, California (CA) 90278-1001
USA
Tel: +1 310 813 7685
Fax: +1 310 813 4690

Status. MAFET is currently in the RDT&E phase.

Total Produced. It is not expected that any equipment will be produced as MAFET's goal is to reduce the cost of the Gallium Arsenide (GaAs) boards developed through the MIMIC program. It is estimated that approximately 2000 GaAs MIMIC modules and brassboards have been delivered.

Application. While MAFET is addressing a number of areas from the MIMIC program the main thrust is to lower the production costs of the MIMIC derived GaAs boards.

Price Range. Per unit costs for MIMIC derived boards remain highly variable. While costs had markedly decreased during MIMIC, from US$20-$50 level at the beginning of the program down to the present US$3-$6 range, the level was still too high to be economically feasible.

The goal of MAFET is to bring down the costs to the level of approximately US$0.80 per square millimeter of GaAs (the usual measure for determining MIMIC costs). Cost figures can be expected to remain highly dynamic in near term years of the forecast period.

Variants/Upgrades

Increased functionality, enhanced reliability and environmental capability, further size miniaturization and continued cost reduction are unending objectives of microcircuit development programs within the electronics industry. MIMIC's successor, the MAFET program begun in 1995, continues to address these objectives.

Program Review

To better understand the goals of the MAFET program the Program Review starts with the original MIMIC program.

Background. In 1985 a study was conducted on ways to reduce the cost of microelectronic components needed for the new generation of precision-guided munitions. This survey, jointly conducted by OSD, ARPA and the three Services, resulted in the initiation of the MIMIC program. The successful developmental program was an eight-year effort completed in 1995 at a cost of approximately US$500 million. With ARPA currently heading the effort, a MIMIC office was formed at the same level as its strategic technology office to manage the program.

Phase 0 — Completed in February 1988, the concept definition phase, identified 50 systems that could benefit from MIMIC technology. Twelve companies (including seven of the Phase 1 participants — Lockheed Martin/ ITT, Raytheon/TI, Hughes/GE, and TRW), working under contracts worth from US$750,000 to US$1 million, participated in this phase.

Phase 1 — Contracts for initial hardware development were awarded in May 1988. Each of the four Phase 1 teams developed experimental brassboard versions of MIMIC chips. All four teams worked under three-year contracts. Phase 1 involved 29 of the 48 companies that participated in the competition. The US Navy Naval Air Command was in charge of the Phase 1 effort. The first MIMIC chips to be finished in the Phase 1 effort were completed and demonstrated by the TRW-led team in early 1989. Phase 1 accomplishments included the setting up of process lines by Raytheon and Texas Instruments. Phase 1 was completed in the late spring of 1991.

Phase 2 — Started in the late spring of 1991, the main thrust of this phase was to continue Phase 1 technology and product development with the goal of demonstrating the readiness and sustained availability of MIMIC design/ fabrication capabilities. Pilot production lines were expanded to include sophisticated system capabilities. During this phase, the possibility of using less familiar materials with enhanced properties was explored. Phase 2 was scheduled to be completed by the end of FY95. Contracts were awarded to the Hughes (US$79.0 million), Raytheon/TI (US$83.5 million), and TRW (US$65.7 million) teams.

Phase 3 — This phase was conducted in parallel with the consecutive Phase 1 and Phase 2 efforts providing the innovative, additional capabilities or tools needed to meet the overall goal of affordable MIMIC technology for DoD systems in the 1990s and beyond. The focus was on providing reliable and inexpensive methods of producing MIMIC chips and modules. Areas of interest include: MIMIC computer-aided design; GaAs material/device process analysis, modeling, and screening; MIMIC wafer, chip, and module automated testing; and additional technological areas encompassed by the MIMIC program. This phase was designed to address the areas of greatest need.

Phase 3 was supported by annual funding of approximately US$25 million through FY93. The first contracts were issued in mid-1989, with areas of emphasis being computer- aided design, development of improved material growth techniques, automated testing techniques, multi-chip packages, and novel processing techniques. In early 1991, Avantek received a 24-month contract totaling nearly US$3 million for research into foundry fabrication techniques. TriQuint, with GE's Electronics Laboratory acting as a subcontractor (chip design), fabricated and tested MIMIC chips under a US$2.65 million contract.

In May 1992, ARPA announced that the following ten contractor teams would receive 1992 contract awards under the technology support phase (Phase 3) of the MIMIC program. An approximate total of US$6.1 million was awarded. The winning team leaders by technology area were:

<u>Materials</u>
· Bandgap Technology Corp, Broomfield, CO

<u>Computer Aided Design and Modeling</u>
· Compact Software Inc, Paterson, NJ
· Motorola Inc, Scottsdale, AZ
· Sonnet Software Inc, Liverpool, NY

<u>Processing and Fabrication</u>
· University of California San Diego, La Jolla, CA
· University of Illinois, Urbana, IL

<u>Testing</u>
· Casade Microtech, Beaverton, OR
· Scientific Atlanta, Atlanta, GA

<u>Packaging</u>

· Ceramic Process Systems, Milford, MA
· Lockheed Martin, Orlando, FL

<u>Phase 1 Teams</u>. The following is a listing by Phase 1 teams, showing each team's area of responsibility.

Hughes Aircraft / General Electric: Hughes and GE were the team leaders for Phase 1. The team worked under a US$50 million contract, with the US Air Force acting as the lead agency. The Aeronautical Systems Division, Wright-Patterson AFB, OH, issued the contract.

This team was specifically concerned with developing brassboards for the Airborne Active Phase Array (ACPA), the Active Tactical Surveillance Radar (ATSR), the Global Positioning System (GPS), and the Advanced Millimeter-Wave Seeker (AMMWS).

The brassboard for the ACPA is an adaptable, active X-band radar array block that incorporates four transmit/receive modules and control circuitry enclosed in a hermetically sealed single housing. Potential applications include the Advanced Tactical Fighter, F-14, F-15, F-16, and F/A-18 aircraft. The ATSR radar array block is similar to the ACPA, but includes added specifications for efficiency, noise figure, output power, phase error, and spurious/harmonious output parameters.

GPS work involved replacement of the existing hybrid technology in the antenna with MIMIC components that resulted in equivalent performance but with lower costs and weight, and smaller size. E-Systems ECI Division was awarded a three-year US$1.2 million contract by Hughes in August 1988 for this effort. The AMMWS technology has application across the whole range of US smart munitions systems, with particular emphasis on the Maverick missile.

This team has apparently been quite successful in sharing technology, with know-how transfers in such areas as automated test algorithms, epitaxial high-power amplifier processes, gate-recess spray-etching, ion-implanted low-noise amplifier processes, and 0.5-μm fine-line lithography being accomplished. In the Phase 2 contract, GE was no longer referred to as a team leader, possibly being just a team member.

ITT/Lockheed Martin: ITT Defense Technology Corp and Lockheed Martin Electronics and Lockheed Martin Space and Missiles Group were the team leaders. ITT focused on microwave applications and Lockheed Martin was concerned with millimeter-wave technology suitable for smart munitions. This team worked under a US$49.3 million contract. The US Army was the lead agency. The Electronics Technology and Devices Laboratory, Fort Monmouth, NJ, issued the contract.

Contract work included brassboards for EW systems including the ALQ-165 Advanced Self-Protection Jammer, the ALQ-136, Sense and Destroy Armor (SADARM), Multiple-Launch Rocket System Terminal Guidance Warhead (MLRS/TGW), SHF SATCOM, AAWWS, and other missile seekers and communications systems. In the ALQ-165, MIMIC technology replaced existing WRAs (weapons replaceable assemblies) and provided the capacity to add future functional capabilities.

The ALQ-136 brassboard provides five SRUs (shop replaceable units) that include four MIMIC modules in the transmitter, receiver and log video units, with the result that functional capacity was increased while reliability improved and costs and maintenance were reduced.

The Army has indicated that it may be able to save as much as US$120 million in the SADARM program alone through the replacement of present hybrid technology with

MIMIC components that increase transmitter power, reduce transceiver size, and lower the noise figure. Enhanced performance, lower costs and smaller size also result from MIMIC insertion in the MLRS/TGW.

The SHF SATCOM manpack uses MIMIC to meet requirements for reliability, cost, weight, and size. As much as US$150 million may be saved in the AAWWS program with replacement of hybrid technology by MIMIC. The space savings in the HELLFIRE missile allows the inclusion of enhanced Built In Test (BIT) and calibration capabilities.

Interestingly, this team did not receive a Phase 2 contract.

Raytheon/Texas Instruments: Raytheon/TI were the leaders of the third joint venture team. The companies worked under a US$68.6 million contract. The US Navy was the lead agency while the Naval Air Systems Command issued the contract. Efforts focused on an EW application called a transmit/receive module that combines both elements into a single subsystem. This team had hoped to reduce the cost of MIMIC chips from US$20 per square millimeter to US$0.80 per square millimeter by 1994.

The primary focus of the work was on developing a wideband, medium-power EW Linear Transmitter Array brassboard using a 1 x 8 linear phased configuration. Eight MIMIC amplifier/phase shifter modules were to be driven by two power dividers. A module would then be assigned to drive each polarization of a dual- polarized antenna element. Stacking the interleaving flange design blocks of the brassboard in different configurations enabled it to meet the requirements of a self-protection and stand-off jammer. The self-protection jammer application of MIMIC was predicted to result in a substantial cost savings, as well as lower weight and smaller size.

TRW: This last team worked under a US$57 million contract. The US Army was the lead agency, with the team supplying chips to the Army's Electronic Technology and Devices Laboratory, which issued the contract. This team developed five brassboards for smart munitions including SADARM, MLRS/TGW, Multi-Optional Fuzed Armament (MOFA), Advanced Air-to-Air Missile (AAAM), and the Integrated EW System (INEWS).

MIMIC work for SADARM focused on the insertion of MIMIC macrocells in the transceiver interconnected by a planar antenna in a Ka-band radar front-end module. Enhanced transmitter efficiency and receiver sensitivity is expected, along with a 50-percent cost reduction. MIMIC work for MLRS/TGW inserted MIMIC modules into the receiver and synthesizer subassemblies. The result is better phase tracking and amplitude, improved frequency accuracy, and reduced cost, weight and size. The MOFA work saw a reduction in the size of the RF section through the installation of a single-chip MIMIC module containing a mixer and duplexer, IF and power amplifier, and a VCO.

The MOFA was a particularly challenging task, since this smart artillery shell project calls for chip costs of less than US$10 each, with a complete fuze to cost less than US$100. TRW is reported to have built a C-band transceiver chip (frequency-modulated, continuous wave radar-on-a-chip) that makes the fuze capable of true ranging (actually estimating range to target and determining where the target is).

The AAAM brassboard contained five modules: one synthesizer/LO module and four monopulse receiver modules. The use of MIMIC technology resulted in substantial weight and volume reductions, with lower costs and higher reliability. Increased acquisition will result. The EW brassboard saw the installation of MIMIC technology in a tuner, synthesizer, and channelized receiver, resulting in faster threat processing, greater system availability, and significant size and weight reductions.

In February 1989, this team delivered the first chips to be completed and demonstrated in the MIMIC program. One was an attenuator chip designed to lower signal strength. The other two were signal amplifiers. According to TRW, these chips were to be used on at least one of the brassboards that the team was working on.

<u>The USAF AAAPT Program</u>. The US Air Force Advanced Aircraft Avionics Packaging Technology program also uses MIMIC. The objective of this program is to expand and enhance the use of modular avionics across the range of virtually all airborne electronic systems, in an effort to achieve a 30-day war-fighting capability for system avionics. MIMIC is used along with VHSIC, wafer-scale integration, phased arrays, opto-electronics, and high density power supplies. The Aeronautical Systems Division is the sponsoring agency.

The program is envisioned as having three phases. Phase 1 is a trade-off design study. Phase 2 uses the PAVE PILLAR modular avionics design concept for integrating racks and single/double wide module form and fit, and core avionics functions. Phase 3 is concerned with the application of the technologies that are expected to be in an advanced state of development by 1995. Objectives include improving thermal management, reducing vibration failure effects, lowering the number of connectors, lessening power requirements, and reducing the electronics packaging weight.

<u>Other Contractors Involved</u>. Perkin-Elmer (Hayward, CA) was reportedly developing an enhanced version of its Aeble-150 direct-write electron beam system for the MIMIC program. This version was to be capable of generating feature sizes of 0.25 micron and below.

A contract awarded in May 1988 was to result in the company receiving approximately US$13 million over the following 30 month period to develop the enhanced Aeble-150, with the Army's Electronic Technology and Device Laboratory having awarded the first increment. Most of the enhancements to the system were concerned with the electronics and computer portions of the system. The original version of the Aeble-150, of which Perkin-Elmer supplied one to Raytheon for the MIMIC program, costs in the neighborhood of US$3 million.

The machine was to be used to not only write the gate level with an E-beam, but also to use the E-beam to develop the drain and source levels of the MIMIC device, whereas previously only the gate level could be written with an E-beam. Contact printers had filled the other roles prior to that time.

Lockheed Corp announced in mid-1988 that it was making a major commitment to MIMIC, with the main focus on making sure that its own systems stayed current with those of the competition. Apparently there had been internal questioning of the sufficiency of Lockheed's investment in the MIMIC area, especially after Lockheed Sanders lost in the MIMIC competition. In 1989 Lockheed Sanders launched its own MIMIC Initiative Program (MIP).

The MIP included four tasks that were scheduled to be completed by early 1991. These included developing the key MIMIC chips needed to support the company's own EW programs; using advanced packaging and automation to increase fabrication yield and improving module assembly techniques; and developing accurate cost and yield models for those chips and modules that are used in DoD programs. In conjunction with the US Navy, Lockheed Sanders embarked on a Navy Potential Contractor Program under which the company's Microelectronics Center would qualify as a producer of Phase I chips.

Lockheed Sanders received two additional MIMIC contracts in 1992. The first contract, awarded in February by the Raytheon/Texas Instrument team for US$8.9 million, was for the development of four key MIMIC technology areas. These were: develop a brassboard electronic combat array for the F-22; improve MIMIC processing and develop advanced fabrication methods; establish a high-volume, low-cost automated production line for MIMIC modules; and demonstrate the selected manufacturing process.

The second contract was awarded in September by ARPA to demonstrate the feasibility of fabricating and manufacturing MIMICS using X-ray lithography, instead of conventional light optics, to illuminate the printing of the circuits.

The major accomplishment achieved under the Phase 2 program throughout 1992 was the transfer of advanced materials, devices, design software, packaging and testing technologies into MIMIC fabrication lines. FY93 saw the delivery of the first multifunction MIMIC meeting required system specifications.

During this time period, assembly of advanced MIMIC modules and system brassboards was started, with development of advanced materials, devices, design software, packaging, and testing technologies continuing. ITT was selected by Hughes Aircraft as a second source for X-Band power computer chips on DARPA's MIMIC Phase II project in May 1993. The award consisted of chip design and processing 200 wafers and data analysis. Options included processing and analyzing up to 400 additional wafer

As the program progressed throughout 1994, work continued on MIMIC Phase 2 contracts including delivery of process demonstration wafers and the completion of MIMIC Phase 2 chip fabrication. Assembly of MIMIC modules and brassboards also continued.

The MIMIC program was successfully completed by the end of FY95. This included final delivery of MIMIC chips, modules, brass-boards, and demonstrations of advanced technology and hardware.

MAFET. In 1995 ARPA initiated a follow-on to the MIMIC program to continue the pursuit of microcircuit cost reduction, enhanced reliability, environmental performance and to continue to increase the functionality, while decreasing the size, of microcircuit chips. The program is designated as Project MT-06, *Microwave and Analog Front End Technology (MAFET)* of DoD Project Element PE 0603739E. MAFET has a continuous time line which extends through 2000 and an approximate budget of US$147.9 million between 1995 and the project’s completion.

The tasks initiated in 1995 consisted of beginning the implementation of a microwave/millimeter wave computer aided design environment that will reduce non-recurring chip/module/system costs by providing improved design, simulation, synthesis and cost analysis capabilities. This task includes enhancement of CAD tools specifically needed for microwave and millimeter wave circuit use (i.e. not digital circuit design tools which are different), tool set integration, effective use of performance and cost databases, needed circuit and module development, and work on the Microwave Hardware Description Language (MHDL).

The program also provides for the development of low-cost advanced millimeter-wave frequency sensors that are needed to provide increased capabilities to smart-weapons. Funded task activity specifically addresses advanced sensor technology development including needed integrated circuit improvements in performance and yield, advanced material development (i.e. indium phosphate), improvement of related passive microwave and millimeter-wave components, development of new interconnection approaches, improved packaging (particularly at millimeter-wave frequencies), and improvements in assembly and test methodologies.

The MAFET program, which is to provide the US Department of Defense with state-of-the-art electronic systems, is the sole DoD effort that focuses on reducing non-recurring costs for military microwave/millimeter wave sensor systems through improved computer technology. This sector's achievements throughout 1995 and 1996 included implementation of computer-aided drafting (CAD) tools to improve the design and simulation of the chips, modules, and system capabilities required in the MAFET program as well as the advancement of sensor technology development programs and associated tests.

FY 1997 developments included quantitative demonstrations of performance improvements and cost savings achieved through the program's activities for selected critical system applications. The development of an all-solid-state X-band source with high power output and low manufacturing cost was also started during 1997.

FY 1998 include the completion of the CAD environment and continued implementation of MHDL. Demonstrations are due to be shown involving advanced manufacturing techniques, fabrication, and packaging. Equipment demonstrations will include: a novel high-power transistor; high-power amplifier; quasi-optical Ka-Band sources; a MEMS-switch area 4-bit true-time-delay phase shifter in X- and Ka-Bands; and thermal management circuits.

Demonstrations in FY 1999 will be mostly continuations and variations of FY 98 programs. FY 99 scheduled accomplishments not in FY98 will include a demonstrated millimeter wave beam steering module, a 100W low cost X-Band electronically steerable source, and full interoperability of the CAD program with vendors.

Funding

US FUNDING

	FY96		FY97		FY98		FY99 (Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (ARPA) PE #0603739E Advanced Tech. Development Project MT-06 MAFET	-	41.7	-	41.2	-	28.0	-	13.2

	FY00 (Req)		FY01 (Req)		FY02 (Req)		FY03 (Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
Project MT-06 MAFET	-	1.0	-	0	-	0	-	0

All US$ are in millions.

Recent Contracts

No known contracts have been let for the MAFET program

Timetable

	1985	Initial study conducted
Feb	1988	Phase 0 completed
Mid	1989	First Phase 3 contracts issued
Nov	1989	Chip architecture defined
May	1990	Pilot lines in place
Sep	1990	Phase 2 RFP issued

Feb	1991	Fabricated prototype modules
May	1991	Phase 1 effort completed
Aug	1991	Phase 2 contracts issued
Mar	1992	Completed transfer of Phase 2 technology to member companies
Jun	1992	Produced first Phase 3 silicon wafers
Oct	1992	Completed installation of Phase 3 fabrication tools and equipment
Sep	1993	Demonstrated fully integrated Phase 3 manufacturing process and transfer to member companies
Jun	1994	Completed fabrication of MIMIC chips
Aug	1994	Scheduled completion date for Phase 2 contracts
	1995	MIMIC program ended; this technology will be the basis for the efforts in the Microwave and Analog Front End Technology (MAFET) program beginning in FY95.
	FY1995	Deliver MIMIC Phase 2 chips, modules, and brassboards. Complete integrated design/fabrication/test capabilities at MIMIC Phase 2 contractors
	FY1997	Demonstrate integrated digital, analog, and optical function modules in system brassboards
	2000	End of the MAFET segment of the Advanced Technology Development program (derived from funding request figures)

Worldwide Distribution

Although MAFET and MIMIC are a **US DoD** program, there is obvious overseas interest in MAFET/MIMIC technology. Defense Technology Security Administration officials have stated that MAFET/MIMIC design and manufacturing technology should not be transferred to foreign countries due to national security and competitiveness concerns. However, they also indicated that sales of US-produced MAFET/MIMIC hardware are acceptable to certain allies. It is significant that the first ground-based radar to incorporate MIMIC chips, prior to the MAFET program, is the multinational COBRA counter-battery radar, produced by the Euro-Art consortium (GE Aerospace, Siemens, Thomson-CSF). In 1991 GE Electronics Laboratory built the first two COBRA solid-state active-array antennas each incorporating several thousand of GE's MIMIC chips.

Forecast Rationale

The MAFET (Microwave and Analog Front End Technology) program is the direct follow-on to the MIMIC (Millimeter Wave Monolithic Integrated Circuits) program initiated in the late 1980s and ended in 1995. The MIMIC program was to provide the US DoD with highly advanced microwave and millimeter wave technology for weapons systems, sensors, etc., based on Gallium Arsenide (GaAs) chips and boards. Major headway had been achieved in this area under the MIMIC program – GaAs integrated circuits are available, chip costs are dropping, and DoD weapons systems are advancing.

The areas requiring the most attention now are: 1) reduce the time and cost of microwave/millimeter-wave developments by breaking the current design-build- test/redesign-rebuild-retest cycle through improved computer aided design techniques, and 2) develop a family of affordable, high-performance sensors that must be available to field an effective defense.

Chip and module costs have remained high in certain sectors, thus impeding the development of cost-effective weapons systems. To combat this situation, the DoD has focused on an advancing technology and infrastructure program to ensure the US a position of dominance in this arena. The new program has been designated MAFET.

MAFET's main goal is to use advanced manufacturing and CAD techniques to reduce costs from approximately US$3-$6 per square millimeter of GaAs to US$0.80. Such a drop in price would make GaAs-derived technology commercially viable.

The program is also to provide improvements in the performance and affordability of microwave and millimeter-wave integrated circuits and modules. This will complement industry investments in related technology, though commercial applications do not have the same requirements imposed on them as military systems.

Key to securing leadership in the microwave/millimeter wave technology market is the ability to transfer these advances to the commercial sector. TRW, a main MIMIC contractor for ARPA, is integrating its gallium-arsenide-integrated circuits into three major markets: military, automotive, and commercial consumer products. With the technology base established under MIMIC, contractors have a larger horizon to capitalize on in the future. MAFET will aid this endeavor for commercially viable, MIMIC-derived integrated circuitry.

Current estimates seem to indicate that the US is approximately five years ahead of the rest of the world in the development of GaAs integrated circuits.

As the chart below shows, funding will likely end around 2000 for the MAFET segment of the Advanced Technology Development program element according to recent request figures from the DoD.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR FUNDING ($ in millions)

			High Confidence Level			Good Confidence Level			Speculative			
Designation	Application	thru 97	98	99	00	01	02	03	04	05	06	07	Total 98-07
MAFET	IC TECHNOLOGY BASE (US DoD)	104.10	29.10	13.70	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.80