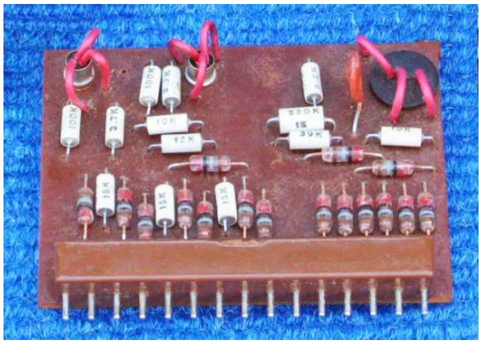
# Semiconductor Technology Progression at Univac/Sperry/Unisys/LMCO in Minnesota

## Introduction


Early computers used vacuum tubes to perform logic functions. The photo is of a File Computer main chassis logic card. Size, power, heat, and reliability were major problems needing solutions. Fortunately, in 1947 the transistor was invented. That was followed in 1958 by the invention of the monolithic integrated circuit. It took several years of development before these devices would be used in computers. As with any new technology, it had to be tested to ensure a commitment to the new technology was the best path to take. The following sections describe the use of and progression of semiconductors at Univac Defense Systems Division (DSD) and ensuing companies.

## Early Semiconductors

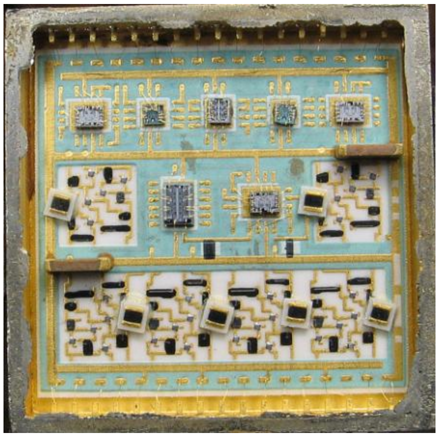


ERA/Univac began using transistors in the Transtec and Athena computers about 1956. The Transtec was mostly a test bed for the technology. The Athena computers were land-based for missile support and are discussed to some extent in other articles on the VIP web site. The photo shows a 15-pin Transtec card. Note in the photo that the transistors (with red insulated leads) are installed upside down. This card performs a simple logic function, probably equivalent to what is considered one gate. It measures 2.0 inch by 2.5 inches. The very first semiconductors were based on a germanium substrate. Germanium has some advantages but it was replaced by silicon-based devices early in the 1960s. Silicon remains the predominant substrate to this day.

## Hybrids

The first attempts to put multiple semiconductor die in one package appear to be in the days of the ADD and Nike-X computers (early 1960s). Packages were 10-lead hermetic cans. The photo at right is one of the early hybrids used in the Nike program. It included discrete transistor and diode die (the black rectangles). Note that although the package is round (0.6 inch diameter), the external pins (gold posts) are on a square pattern. These hybrids were provided as customer furnished material and were made by Western Electric.

Sperry in St. Paul established its own hybrid manufacturing facility. Hundreds of designs were completed, mostly as line drivers. The photo at left is one of several similar devices. Note that it contains multiple integrated circuit die, not just transistors and diodes. It is an inch square.

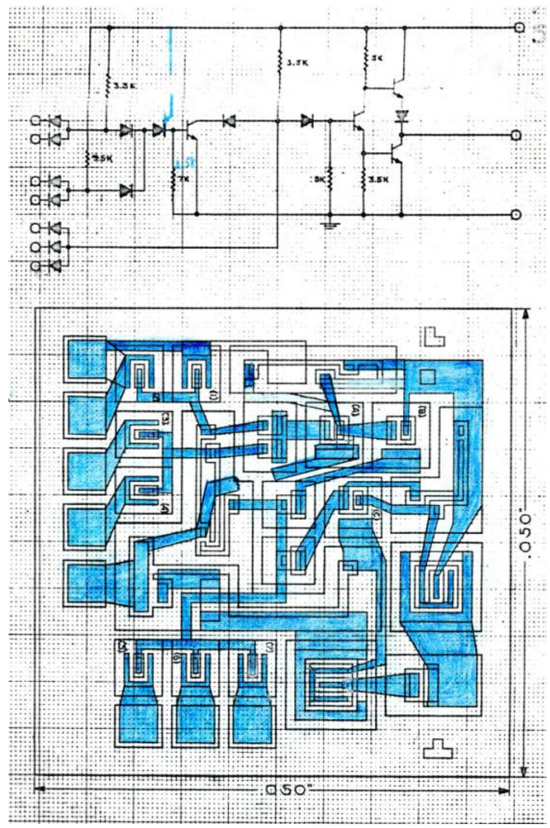


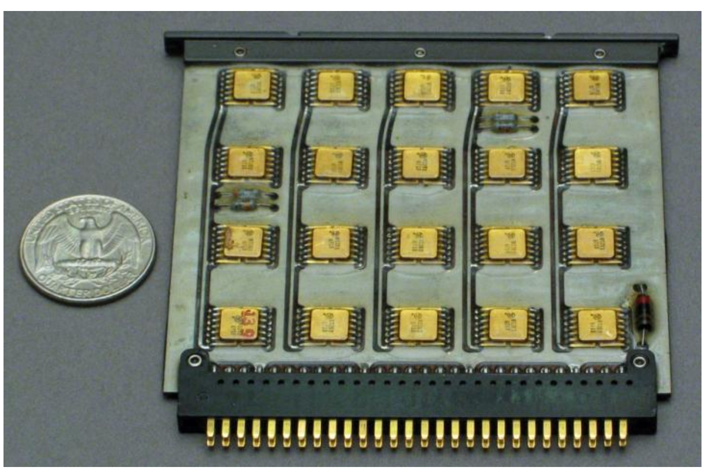
This group also made several fiber optic transmitter and receiver hybrids. This has evolved into a very good line of business and is now a separate Lockheed Martin organization, still based in Eagan.

Over the years, over 350 hybrid types and variants were documented for DSD.

## Custom

A series of custom integrated circuits [monolithic silicon die with multiple elements] was developed for the MMRBM, BGRV, MBRV, and 1824 programs about 1960. These were all missile-based applications so the advantages of size, weight, and power of monolithic circuits could be utilized. The diagram at right shows the logic diagram and physical layout diagram of one of the very first monolithic integrated circuits developed by Univac DSD in 1963. This is an And-Or logic gate and was fabricated by Westinghouse Semiconductor. Note that the die size is 1/20th of an inch square and contains 7 resistors, 13 diodes, and 4 transistors diffused into one silicon substrate. This was followed by the development of the 7901000 series of monolithic circuits that is discussed fully in a separate article on the VIP web page 15 [IT Legacy, Documents – Nov '08 or http://vipclubmn.org/Articles/The_Univac_7901000RevC.pdf.] The photo below shows a card fully populated with 7901000 series circuits.



{Editor's Note: This 56-pin Printed Circuit (PC) card type measures ~3.5"x3.5". The mechanical design originated with the CP-901 processor development for the Navy's AN/ASQ-114 airborne system aboard the P-3C aircraft. Integrated Circuit (IC) component cooling was from the IC case to aluminum layer to a metal T-bar at the card's top. A metal to air heat exchanger was clamped over the rows of the T-bars in chassis. This card style was subsequently used in the shipboard AN/UYK-7 computer, RD-358 magnetic tape unit, and several other equipment developments in the '70s.}

## Logic Families

Early designs used Resistor-Transistor Logic (RTL) mostly using discrete semiconductors. This was followed by Diode-Transistor Logic (DTL), again mostly using discrete semiconductors but was also the first monolithic integrated circuit technology used as discussed in the previous section. In the late 1960s, the first commercial logic family to be used was the 54/74xx family of bipolar Transistor-Transistor Logic (TTL) devices. This was followed by the 54/74Hxx family, the 54/74Sxxx family, the 54/74LSxxx family, and the 54/74Fxxx family that took us into the late 1970s to 1980s. Some AS and ALS devices were also used. Limited applications made use of Emitter Coupled Logic (ECL) families.

Then came the development of high-speed CMOS processes. This led to later use of families such as 54/74ACxxx, 54/74ACTxxx, and 54/74FCTxxx.

Each of these logic families has its own set of characteristics. As the technology advanced, each logic family offered faster speeds and/or lower power. Although the smaller geometries of newer technologies would allow more gates per package, most logic families kept the same functional building blocks [AND gates, OR gates, Inverters, Flip-Flops, Registers, Shift Registers, Encoder/Decoders, Adders, Counters, etc.]. Larger packages with higher pin counts allowed the release of more complex functions [arithmetic logic units or multipliers come to mind]. Smaller geometries meant each die for the same functionality was smaller and therefore was lower cost. The computers designed by DSD were not your typical personal computers that have a complex processor chip at its core surrounded by graphics and some input/output capability. The DSD computers were ruggedized mainframes or specialized computers with lots of input/output channels. Thus, the architecture was unique and this required a unique blend of semiconductor functions. When processors were used, they tended to be of the bit-slice 2900 series or 6800/68000 series. The UYK-44 program used a NSC800 processor. The 8080, 80186, and 80386/80387 Intel processors, Zilog Z80, Signetics 8X305, and a few others found limited usage. The latest processors are embedded within programmable logic arrays discussed in a later section.

Today, almost all designs are based on some form of CMOS logic.

## Memory Components

Computers in the 1950s and 1960s used magnetic drum, core, mated film, plated wire, or bubble technologies. All these are based on electromagnetic physics and have the advantage of being non-volatile [data remains if power is removed]. Some of these had a destructive read process so the data had to be written back after a read was performed [typical of core memory designs.] In addition, they are relatively immune to upset from radiation. We were very good at packing a lot of these bits in a limited space.

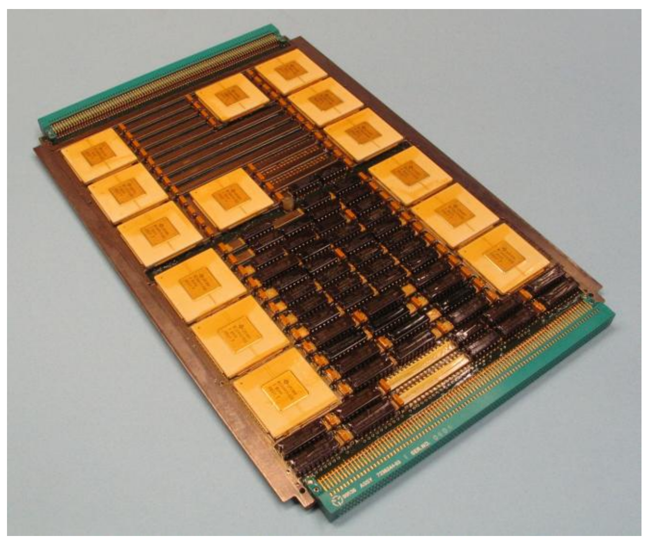
The first semiconductor memory device used was a bipolar 16-bit memory cell developed by/for Univac in the mid 1960s. {Editor's Note: First use was for the CP-890 control memory.} This was followed by a 64-bit bipolar memory. These found use as scratchpad memories since the density was much to low to make them useful as main memory or mass memory devices. They are also volatile and are sensitive to radiation. Higher density devices were used as they were designed and released by commercial suppliers (Static Random Access Memory (SRAM), Dynamic Random Access Memory (DRAM), etc.). One disadvantage of DRAM is that it needs to have its data refreshed several times a second thus adding to the operational overhead. The UYK-43 computer used a 64K bit DRAM.

The first semiconductor read-only memories were mask programmed at the semiconductor manufacturer. The first user-programmable device was a 512 bit bipolar PROM. It was programmed by electrically blowing a fuse for each bit. Since fuses were not always fabricated equally, some blown fuses were marginal and could “grow back”. We implemented a high temperature burn-in for all programmed devices after programming. After burn-in, the program was re-verified. We continued the use of these bipolar devices up to the 64K bit density as used on the UYK-43 and UYK-44 programs. These PROMs were one-time programmable. They were replaced by use of larger reprogrammable CMOS EPROM (erased by use of ultraviolet light) and EEPROM devices which have no fuses but rely on small electrical charges stored on floating gates. Today, Flash EEPROM devices are commonly used.

## ASICs (Application Specific Integrated Circuits)

Gate arrays are an array of standard gate cells on one die which are programmed during die fabrication by use of a custom mask for the metal interconnect layer. The first gate array was a 112 gate I/O device implemented on a Fairchild gate array for the UYK-20/ATC programs in the early 1970s. This was followed by a 132 gate dual I/O device implemented on an IMI gate array for the same programs.

In order to be competitive and optimize performance, Sperry Univac developed a series of gate arrays. These were developed by the new Sperry Univac Semiconductor Operations in St. Paul. The first Schottky bipolar ST-101 series [about 1300 gate capacity] were used in the UYK-43 computer (initially about 20 functions) in the late 1970s. The photo shows a UYK-43 Breakpoint card (14 inches by 8 inches) using fourteen ST-101 ASIC devices. Each ASIC has 139 pins on the bottom. This card has a 279-pin connector on each end. The UYK-44 program used ASICs based on the C2G02 and C2G20 CMOS series (about 1300 gate) about the same time.



Sperry Semiconductor in Eagan continued making these devices until 1987, when the facility was shut down. A search was made for an alternate semiconductor fabrication factory to make the bipolar ST-101 devices. Raytheon Semiconductor was chosen for this until they too discontinued the Schottky bipolar process. At that time all devices were converted to a compatible CMOS gate array process from LSI Logic. This was an expensive conversion (over $100K per function). Later enhancements to the UYK-43 computer lead to the use of gate arrays with as many as 80,000 gates. Semiconductor processes advance at a fast rate and semiconductor suppliers didn’t like to waste fabrication space and equipment by making obsolete, low volume devices. It soon became apparent that LSI would be forcing us to upgrade to the latest process every couple of years. Neither we nor our customers could afford to do this. As a result, we made last time lifetime buys.

Over the years, about 125 individual custom ASIC designs were released for production. Most of these had to be tweaked or modified from 1 to 4 times before they met system application requirements. Most designs used gate arrays, but some were also macro-cell arrays and a couple designs were full custom devices. The largest design was a 354K gate, 60K RAM gate array in a 596 BGA package developed in the early 2000s for the Scalable Coherent Interface (SCI) project.

See also the story of the development of the custom SNERT (Serial NATO Encoder/Receiver Transmitter) on the VIP web site. [http://vipclubmn.org/documents.html#Articles, Sept. '08.]

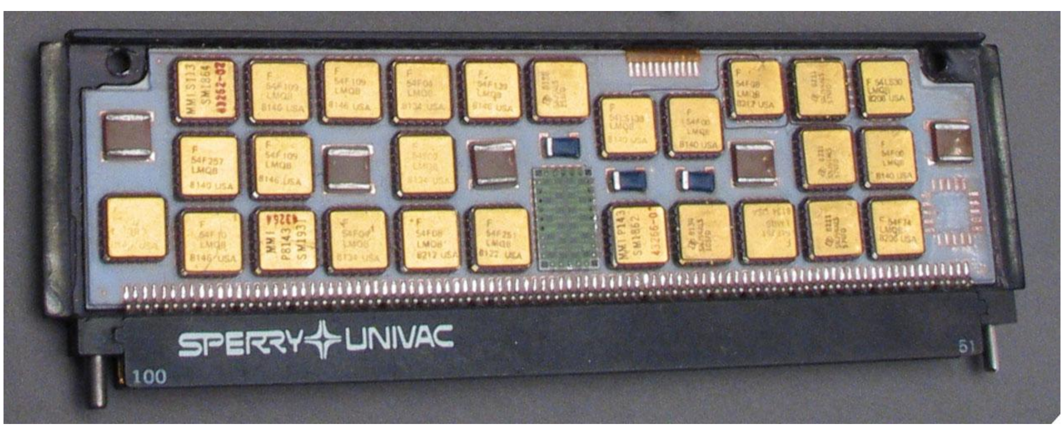
## Programmable Logic

Since most of the defense programs are long term, Unisys could not tolerate having to update gate array designs every 2 years, nor could we make lifetime buys without accurate forecasts of need and funding.

Shortly after the development of bipolar fusible link PROMs, Monolithic Memories developed a series of similarly programmed logic elements they named PALs (Programmable Array Logic). Unisys designs made use of these devices as they increased in complexity. Complexity increased to the point where companies like Atmel, Xilinx, and Altera had developed devices large enough to compete with gate arrays. More complex devices were not merely gate arrays but were macro-cell arrays which contained cells of specific functions like processors or memory. Some used RAM-based connections and needed to be reloaded every time power was applied. Others were EPROM or EEPROM (now commonly referred to as Flash) based. Use of mask programmed gate arrays was discontinued and new programs use user-programmable devices, some with embedded processor cells.

## Packaging

The early devices for the 1824 computer and the 7901000 series were in hermetic flat packs with 10 to 14 leads. Some of the 7901000 series were also placed in hermetic Dual-In-Line packages (DIP) for the Air Traffic Control (ATC) program. The UYK-20 and UYK-43 programs used hermetic DIP packages. The UYK-44 program was the first to use a Leadless Chip Carrier (LCC) surface mounted package on a ceramic substrate card. The ceramic card below is 5.8 inches long. It is double sided and has a similar substrate on the backside. The ceramic substrate appears blue in the photo due to an overcoat of protective epoxy material.

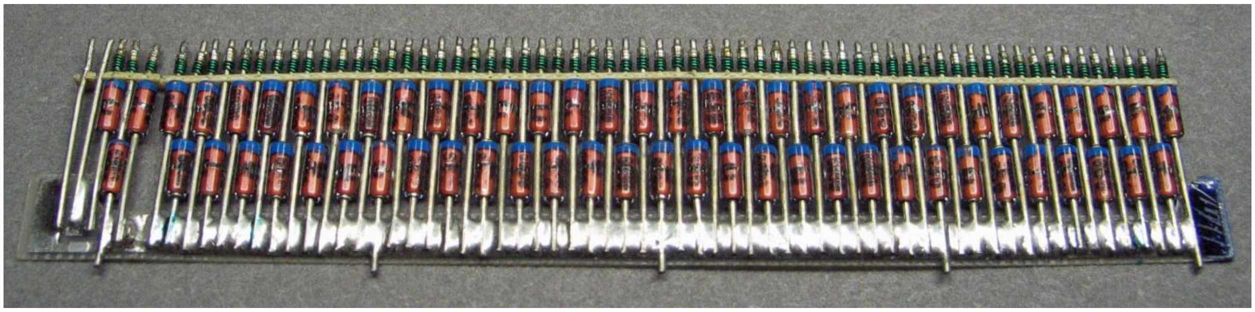


Leadless chip carrier package pin counts ranged up to 84 pins. The UYK-43 gate arrays were housed in 139 pin Pin-Grid-Array (PGA) packages and were soldered in thru-holes on an organic printed circuit board. In the 1990s, a new Ball-Grid-Array (BGA) package began to be used. Pin counts increased to over 500. BGA packaged devices can be found in many consumer devices today.

Sperry did its share of packaging development. One notable development was the Ceramic Computer. Another was the multichip hybrid where multiple integrated circuits were bonded into a single package, either with single or multiple cavities.

## Continued Use of Discrete Semiconductors

Although logic devices and gate arrays were used heavily in the processor functions of the computers, discrete diodes and transistors still found their way into memory and power sections. It was well into the 1990s before semiconductor memories became the technology of choice. Environmental and functional considerations often dictated the use of other technologies for memories: core, mated film, plated wire, and bubble to name a few. The Minuteman plated wire memory chassis (mid 1970s) used hundreds of diodes and field effect transistors in memory selection and driver circuits. The photo shows a 'diode stick' using 65 discrete glass diodes as was used in a Mated Film Memory in the 1970s. Wires at the top went to individual rows or columns of the memory array.



## Specifications

In order to get the early computers to run reliably over a wide temperature range and to optimize performance, electrical characteristics of diodes and transistors needed to be tightly controlled. Univac prepared detailed procurement specifications defining electrical, mechanical, and quality requirements. Usually, the supplier's standard discrete products did not quite meet our needs. Devices needed to be specially selected for various characteristics to meet our application. This continued with the use of the first integrated circuits. However, by about 1970, the integrated circuit suppliers had standardized on families of devices which were designed for common digital and linear applications. At that point, although Univac still generated procurement specifications, they were usually a mirror image of the supplier's standard product data sheet. Standardization also meant that there were often multiple sources for devices. Those applications needing diodes and transistors still required devices with special characteristics.

Prior to 1962, both commercial and military functions were part of the same division. But, applications for commercial/business and military computers are quite different. In 1962, Univac separated into DPD and DSD divisions. Some early specifications and parts continued to be used by both DPD and DSD. But after 1962, each division created and maintained its own documentation. From about 1960 to about 1995, over 2000 diode types and variants, over 800 transistor types and variants, and over 5000 integrated circuit types and variants were documented and maintained by DSD.

## Qualification of Components

Starting in the late 1950s, ERA/Univac created a test lab for the purpose of testing and evaluating the new semiconductor devices. One lab was used for electrical test (see photo at left). Another lab was created for environmental testing, not only of components but for computers and subassemblies as well. Environmental capabilities included temperature, temperature shock and cycling, vibration, mechanical shock, centrifuge, humidity, salt spray, altitude, etc. Early testing was aimed at characterizing the new semiconductor technology. Data was used to determine if semiconductors were going to be useful in the design of computers.

Once it became clear that semiconductors were the way to go, samples of candidate products from multiple suppliers were subjected to a full array of electrical and environmental tests. Acceptable quality levels were established and only those meeting the criteria were allowed as sources for Univac equipment.

At first, discrete semiconductors were tested individually, by hand, at workstations configured for the parameter being tested. Refer to the previous photo of the early ERA/Univac test lab. As complexity of circuits increased and the quantity of circuits used increased, there was the need to automate the electrical testing. A team of DSD engineers designed and built several programmable automatic testers which could measure both static and dynamic parameters and log the resulting data. One of the early automated test systems is shown in the photo. This system used an actual military style computer and tape drives.

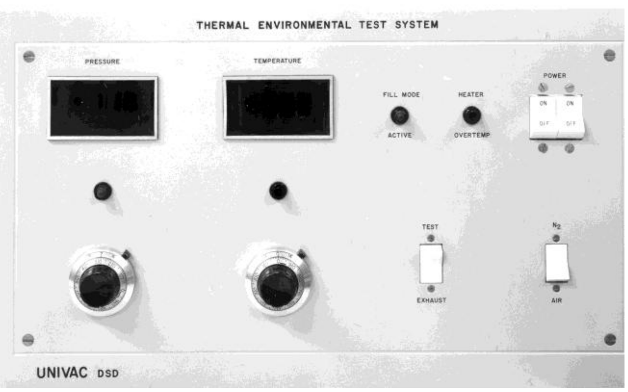
Initially, when there were fewer products, all were tested. However, as more and more products were developed, it became necessary to group them into families based on technology, form factor, or assembly location. Initially, wafer fabrication and packaging were done only in the US. Nevertheless, by the 1970s, suppliers had begun moving the packaging and even wafer fabrication to overseas facilities, either owned by them or subcontracted. By the 1980's, it had become too expensive to qualify all the variables and the supplier's quality levels had improved to the point where it was deemed unnecessary to qualify devices. It was assumed parts would meet the supplier's own data sheet. The electrical component test lab was shut down.

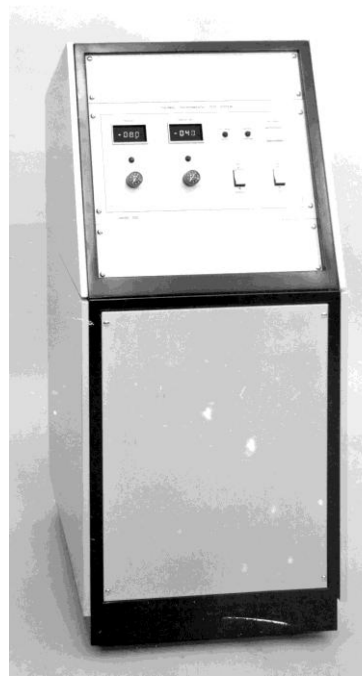
Univac DSD in St. Paul was represented at the Electronic Industries Association (EIA) G-12 subcommittee of Defense contractors. Our qualification processes and results were shared at periodic meetings. We were, in this regard, a major contributor to the standardization of testing procedures used by the semiconductor industry.

## Testing

During evaluation of new technologies and qualification of parts to be potentially used, devices are tested both electrically and environmentally. If failures are found, the supplier needed to be contacted to obtain corrective action. This meant that our data had to be without fault. Great care had to be taken with our test setups and fixtures to make sure they were as per the specification, Electrical fixtures had to meet specified impedances and line lengths had to be minimized. Electrical test equipment had to be calibrated with procedures traceable to the National Bureau of Standards. Devices were often tested at temperature extremes (-55°C to +125°C). Making sure the device under test was at exactly the specified temperature was important. One of the techniques used was to soak the device in a chamber at the desired temperature then quickly move it and insert it in the socket. As soon as the device was removed from the chamber, it began to drift toward room temperature. This was especially a problem if the test was long.

Another way was to put the test socket in the chamber too. However, self-heating and temperature effects on the measuring sensors were a problem. However, Univac had a better solution. We designed and built our own thermal test system. See the main cabinet at right and close-up of the control panel at left. It utilized a column of high velocity air that came up through a hole in the bottom of the test socket and impinged on the bottom of the package of the device being tested. This air column was cooled using liquid nitrogen or heated with heating elements. The case temperature of the device under test could be held at temperature for a long time. The main problem we had with this system was the formation of frost on the socket and test device at low temperatures. This system was such a success that we even sold a few to some of our suppliers (e.g. Motorola).



## Receiving Inspection

The reliability of Univac computers relies heavily on the semiconductor devices since they form such a large part of the composition of each chassis. Early semiconductors had their reliability issues and it was necessary to carefully inspect incoming lots of material. Even though the qualification process showed that the supplier was 'capable' of producing reliable product; they did not always do so on a repetitive basis. The Receiving and Inspection Department had its own set of testers and utilized statistical sampling methods and 100% inspection where necessary, to ensure that we used only quality devices in our equipments.

## Failure Analysis

From the early 1950s to the mid 1990s, Univac/Sperry/Unisys had a state of the art laboratory for analyzing failures. The photo shows the lab as it existed in the Sheppard Road facility (Plant 1) in 1971.

This lab supported activities of Engineering and Quality Assurance. Care were taken to document all failures, whether occurring in qualification tests of components, card test, system checkout, system qualification, or the field. Field failed subassemblies were returned to Univac by the customer. Analysis was done to determine the root cause of failure.

It is not easy to make a reliable semiconductor. Semiconductor manufacturers were in a learning mode even until the 1980s. There are numerous possible failure modes that can cause immediate or latent failures in semiconductors. The list includes:

- Die diffusion defects caused by mask flaws or contamination
- Aluminum metallization defects caused by mask flaws or improper deposition
- Loose die due to failure to stay attached to the package base
- Lifted bonds (1 mil gold or aluminum wires attach the die to package leads)
- Cracked die
- Corrosion due to contamination
- Loose conductive gold, aluminum, or solder eutectic particles
- Tool damage including scratches
- Lack of hermeticity in the package seal [usually a glass or solder seal failure]
- 'Purple Plague', a form of brittle gold/aluminum alloy first characterized by George Raymond of Univac and presented to the industry in the 1960s. It leads to lifted bonds.
- Electrostatic discharge damage (usually a user-caused problem)

DSD had extensive experience with all of these.

Early analysis tools included electronic test equipment, microscopes, x-ray, de-construction, cross section, and chemical analysis methods. The lab had its own dedicated photo processing capability (macro and micro). Later, the lab was equipped with an electron microscope and had access to in-house chemical spectroscopy analysis. Outside labs were also used as necessary. When the specific cause of failure was defined, photos were taken to document the failure.

The photos were shown to the supplier along with a request for corrective action. It was not uncommon for a supplier, upon hearing about some deficiency in his product uncovered by our testing, to say something to the effect "No one else has ever complained about that." They typically would go on to blame some error in our testing. However, once confronted with our detailed analysis with photos, they would admit they had an issue.

The supplier was given the choice of correcting whatever process was errant, or not be allowed to supply that particular component to Univac.

After DSD stopped qualifying each device and shut down the test labs, we also severely reduced incoming inspection functions and closed the failure analysis lab in the 1990s.

## Vendor Surveillance

Persons in the Univac Vendor Surveillance department traveled to or were stationed at many of the semiconductor supplier's fabrication and packaging facilities. Their main purpose was source inspection (verification that the supplier had, in fact, tested the components as required). If everything checked out, the supplier was allowed to ship the product. In some cases, vendor surveillance was required to witness the testing. In the course of viewing the actual fabrication of the devices, they often pointed out actions which could be detrimental to the quality of the product and they could recommend improved processes. They also assisted in the failure analysis corrective process. The practice of inspecting the manufacturing process at the source was also instrumental in reducing the need for incoming inspection.

## Military versus Commercial

Prior to 1990, almost all semiconductors we used were packaged in hermetic packages, had temperature ranges of -55°C to +125°C, and were individually burned-in prior to use. Each device was fully electrically tested to specified requirements. Mr. Perry of the DoD (Department of Defense) released a memo in 1994 directing that all future defense equipment be designed using commercially available off-the-shelf (COTS) devices. This was based on publicity about the custom $1000 toilet seats required by military specifications. However, there were many interpretations about what was meant my “COTS”. Some said that this meant that users could not apply any special requirement above what was defined by the suppliers own data sheets for devices offered to anyone. Others said it meant use of plastic packaged devices with temperature ranges of 0°C to 70°C or, at most, industrial -40 to +85°C with no additional environmental screening. At this point, many semiconductor suppliers began discontinuing devices with military ratings. This forced LM to offer a lower cost UYK-43 using equivalent plastic, 0°C to 70°C, electrically sampled devices. Fortunately, the design of the computer and the relatively benign environment [environmentally controlled room on a ship] allowed this to work. This becomes more of a challenge for avionics applications.

Most semiconductor devices used in designs today are plastic encapsulated commercial or industrial temperature devices.

## Radiation Hardened Devices

Use of radiation-hardened devices was limited to only a couple applications. The CP-183 program used a CMOS/SOS gate array and RAM as part of the radiation burst detection and recovery circuit. RCA and Harris supplied those parts.

The VIP web site also mentions the development of a custom radiation hard CMOS RISC processor as part of a government CIA contract. [http://vipclubmn.org/cpothers.html#RISC]

## Sperry Semiconductor Operations and Semiconductor Control Facility (SCF)

Sperry Semiconductor Operations made Schottky TTL, ECL, and CMOS devices. Devices used by the defense side of Unisys were mostly confined to the Schottky TTL and CMOS process. Only a few ECL devices were used by the defense side of UNISYS. The commercial side was a big user of bipolar Schottky and ECL devices. The commercial division also used other unique packages. An article by B. N. Svendsen titled “Semiconductors at Univac” is located on the VIP Club web site [http://vipclubmn.org/documents.html#Articles (July '13)] and goes into more detail on this subject. It includes other statements relating to DSD activities as well.

## Linear devices

This paper addresses mainly the digital devices. We used numerous linear devices as well. Functions included voltage regulators, amplifiers, transmitters, receivers, operational amplifiers, timers, etc. Applications include power supplies, input/output drivers and receivers, and memory drivers and sensors. Many of the hybrid devices we designed were a combination of digital and linear devices.

## Market Share

In the 1950s and 1960s, the military emphasis was on small size, lightweight, and low power, especially in missile applications. Computers using vacuum tubes could not meet these needs. Semiconductors offered an alternative. The volumes needed by military contractors induced most semiconductor manufacturers to give military contractors what they needed. The best examples of this at Univac were the specially tested devices used in the Minuteman program as discussed in a separate article on the VIP web site. In the 1980s and 1990s, the commercial market overtook the military market. Manufacturers no longer looked at the military market for high volumes and they began discontinuing military grade devices. The Perry memo in 1994 only served to accelerate the decline. Fortunately, due to the emphasis on quality and reliability in military semiconductors in the 1960s and into the 1980s, the quality and reliability of commercial semiconductors had improved significantly and it was possible to build reliable military gear using commercial plastic encapsulated devices. LM was forced to follow this trend.

## Life after 1995

The Q-70 program introduced the era where LM no longer designed its own custom cards for new systems. Except for the JSF program and the Q-70 Radar Scan Converter, new developments used non-proprietary elements [VME format card racks and cards, servers, hard drives, CDROM drives, LCD displays, keyboards, etc]. LM Eagan was in the business of designing cabinets which could use these commercial grade elements and protect them from the military environment. This continued until the Eagan facility was closed in December 2012. An example of this technology can be seen in the Valiant Workstation on exhibit at the Lawshe Museum of the Dakota County Historical Society in South St. Paul, MN. [http://www.dakotahistory.org]

## Closing Statement

The progression of semiconductor usage as defined herein was not unique to Univac/UNISYS/Lockheed Martin. After the initial acceptance, our usage was always at the forefront of what the technology allowed and what was offered by the semiconductor industry. There are cases where the commercial industry did not offer what we needed or we thought we could do it better. The photos emphasize those areas where we may have been somewhat unique. What is probably most significant is the role played by Univac in defining our needs and providing constant pressure to implement ways to improve reliability. In addition, since Univac was competing with other defense contractors, we also had to be aware of what was coming two to five years into the future. A respectful relationship with our suppliers was always important. The 1950s to 1990s was an interesting time to be involved. We now take semiconductors almost for granted. Integrated circuits now contain millions of transistors on single die, sometimes approaching an inch square. According to Moore's law, the number of transistors on integrated circuits doubles approximately every two years. Who knows what the future brings?

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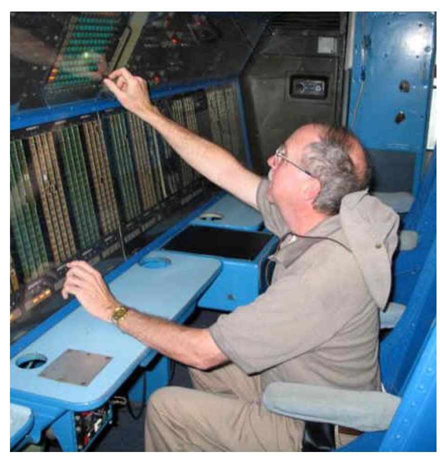
## About the Author:

After receiving his BEE degree, Larry Bolton joined Univac DSD in June of 1965. He started as a Component Engineer assigned to the specification, testing, and qualification of passive electrical components. Shortly after starting, he was assigned to a short-term job as assistant in the effort to improve reliability of the first monolithic integrated circuits. After this assignment, he returned to the passive component group. For period of 5 years, he was on special assignment as a dedicated component engineer for the high reliability Minuteman program. In 1975, Larry returned to the central Component and Material Engineering group starting with semiconductors. He advanced within this group having progressive responsibility over time for most digital integrated circuits and memories. He was the group coordinator for components used on the UYK-43 program. When Lockheed Martin began using existing board, interface, and storage technologies in the 1990s, he assisted in the use of VME boards, media drives, racks, backplanes, etc. During his 41-year tenure, he had been the St. Paul DSD representative to the Sperry Semiconductor Coordinating Committee and JEDEC/EIA G-12 Committee. After the company had been renamed several times, Mr. Bolton retired from Lockheed Martin in August 2006. Larry has been a VIP Club member since then as well as an active participant on the IT Legacy Committee.



{Editor's Note: Larry is shown at the right in an AF museum mockup of the Sperry-Unisys ABCCC system. A cut-away model plane of the ABCCC is at the Lawshe Museum. }

### Editor

Editor of this paper is Lowell A. Benson, BEE 1966 - U of MN. Mr. Benson was a UNIVAC 1960 to UNISYS 1994 employee. Lowell has been co-chair of the IT Legacy Committee since 2005, currently serving the VIP Club as webmaster and President.