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RELIABILITY AND QUALITY EEE PARTS ISSUES

SPACE TRANSPORTATION AVIONICS TECHNOLOGY SYMPOSIUM

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RELIABILITY AND QUALITY EEE PARTS ISSUES

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RELIABILITY AND QUALITY
EEE PARTS ISSUES

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BACKGROUND

The NASA Office of Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) provides a focal point for the overall development and implementation of NASA policies and procedures for safety and program/product assurance. Within the SRM&QA Office is the Reliability, Maintainability and Quality Assurance Division which has the following objectives as part of its charter:

- Formulate, recommend, implement and evaluate NASA RM&QA policies, procedures and standards.
- Establish technology development programs to ensure use of advanced assurance techniques.
- Plan and execute NASA product assurance activities.

Space transportation avionics activities represent a major effort relative to the overall NASA goals and missions. It is important to be aware of significant reliability and quality considerations such as the Electrical, Electronic, and Electromechanical (EEE) Parts program. This program is an important activity that impacts NASA reliability and quality.

EEE PARTS PROGRAM

This program establishes NASA policy and procedures governing the selection, testing, and application of EEE parts. Key program tasks include the following activities:

- Standardize parts through development and maintenance of a NASA Standard Parts List.
- Issue overall policy and requirements documents for control and management of parts.
- Develop and disseminate guidelines for parts application and use.

- Implement an EEE Parts Management Information System (EPIMS) to provide a database of parts usage and experience.

- Research programs directed at state-of-the-art methods of improving parts reliability such as investigations of advanced microelectronic devices and parts radiation effects.

- Develop general requirements relative to electronic packaging processes such as soldering, potting, and printed wiring.

EEE PARTS AND ASSOCIATED TECHNOLOGIES

Recent advances in the state-of-the-art of electronics parts and associated technologies can significantly impact the electronic designs and reliability of NASA space transportation avionics. This paper focuses on significant issues that result from these advances, including:

- *Recent advances in microelectronics technology (as applied to or considered for use in NASA projects).* These devices can provide significant improvements in design, performance, and reliability; and may be the only alternative to a feasible mission. However, there are problems associated with their use that must be considered and resolved.

- *Electronic packaging technology advances (concurrent with, and as a result of, the development of the advanced microelectronic devices).* A major source of electronic failure is packaging; thus, the applicable design/fabrication considerations must be addressed.

- *Availability of parts used in space avionics.* The uniqueness, small quantity, complexity, reliability, and environmental requirements for these parts and the associated design, fabrication, and testing also affect their availability. This should be recognized and considered in project management and control.

- *Standardization and integration of parts activities between projects, centers, and contractors.* The rapidly changing state-of-the-art accentuates the need for these activities. Therefore, applicable procedures are being developed and implemented.

ADVANCED MICROELECTRONICS

The developments in the design, fabrication, and application of advanced microelectronics have radically changed the approach to electronic system and component design. Application Specific Integrated Circuits (ASICs) are now available as mature parts and are being applied in new designs. The ASIC provides the design engineer with a flexibility to design circuits for specific applications to provide optimum performance and reliability. These circuits are all placed on a single device chip using standard cells and associated design practices. However, increasing the reliability of devices (where every device is unique) is challenging designers to improve the reliability of the entire system.

The state-of-the-art for microelectronics has produced new, remarkable advances that are indicative of the devices that will soon find usage in NASA applications. There are devices available that contain an entire computer or 200,000 transistors on a single chip. Other devices use wafer scale integration, which results in a 4-inch chip with 35 million transistors. Such designs can provide the ability to incorporate fault detection or redundancy for improved reliability and 100 percent yields.

There are many other advances in microelectronic technology that are being applied in present designs and will proliferate to provide improvements in performance and reliability. Among the newer developments are devices with higher switching speeds, chips using smaller line geometries, Gallium Arsenide monolithic microwave integrated circuits and logic devices, hybrid circuits using discrete chips, and networks of thick and thin film resistors and capacitors. These developments miniaturize electronic functions from one-fifth to one-tenth of their original size.

The complexity of electronic designs in NASA vehicles has increased rapidly over the past 20 years, as depicted in Figure 1. The number of parts in a typical design of 20 years ago was 20,000; today's typical designs have 80,000 parts. However, the difference in parts count does not depict the true change in complexity. Some of the parts are integrated circuits containing a number of transistors in monolithic form, and the complexity and number of the integrated circuits used have increased during the 20-year period. Thus, using the number of transistors as a measure of complexity shows an increase from 80,000 to 60,000,000. The estimated complexity counts for a typical 1995 vehicle increase even further to 90,000 parts and 800,000,000 transistors. It should be noted that the straight line approximations shown indicate an exponential increase in complexity over time.

Space qualification of today's complex and customized devices is a costly and difficult process using the existing methods. Qualification entails testing a number of devices for all characteristics under various environmental conditions and for long periods of time. It becomes necessary to develop new, more efficient approaches to this process. Some of the methods being developed are as follows:

- *Qualification of a manufacturer's processes for fabricating devices (rather than qualification of each type of finished device).* This would result in a Qualified Manufacturers List (QML) in lieu of the current Qualified Products List (QPL) approach.

- *Fabricating areas of each chip with test patterns that could be tested to verify overall device suitability.* This would replace testing for each electrical characteristic of the device.

- *Qualifying libraries of standard cells and standard design practices that would be used in designing a device with many complex functions.* This would also require that the designer use approved rules in developing a custom device.

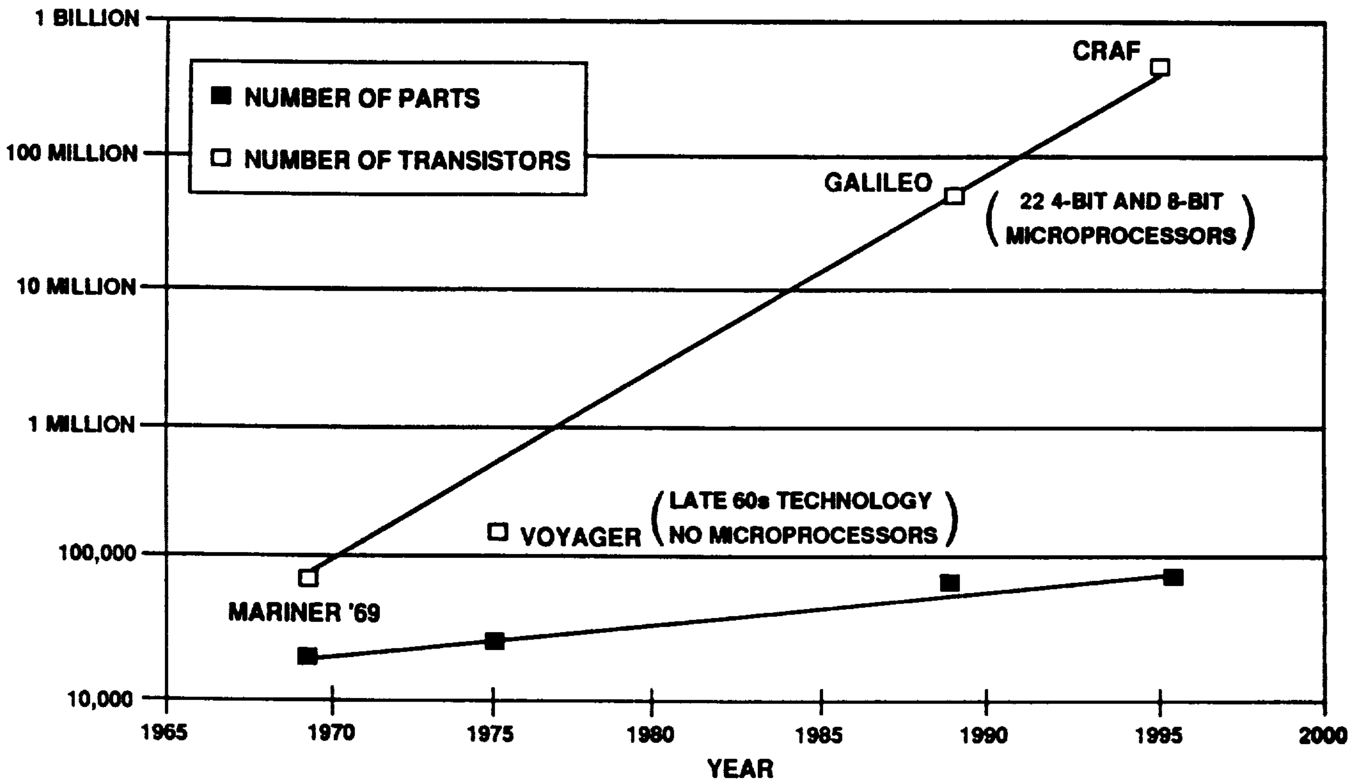

Figure 1. Increase in Space Electronic Complexity

ELECTRONIC PACKAGING

The use of advanced devices (which reduce size and increase performance and reliability) has resulted in radical changes in electronic packaging technology. While the focus is on ensuring the reliability of the devices, not enough attention is given to the circuit packaging methods used. Electronic packaging is a major source of electronic failures.

Surface mount technology is currently one of the strongest trends in electronic packaging. It uses devices as depicted in Figure 2, which have smaller packages and are reflow-soldered directly to the surface of a printed circuit board or substrate. This system allows for greater packaging density of parts, and often reduces the finished size of the end items as well as the number of modules used. Also, it permits packaging advanced microelectronic chips with a large number of inputs and outputs in chip carrier packages that can be leadless.

While surface mount technology has features that should increase reliability, it presents new failure modes that must be overcome. Thermal stresses associated with reflow soldering can produce cracking of packages and/or solder joints. Also, the process does not permit visual inspection of the solder joints. New design, workmanship, and inspection procedures must be developed to ensure adequate spacecraft reliability.

Hybrid microcircuits (see Figure 4) provide a method of packaging many small devices inside of one case to improve size and design flexibility. Chip devices are mounted on a substrate using either solder or conductive epoxy. Wires are then bonded to the chip and to terminals and the package is sealed. Two of the key factors for ensuring reliability of hybrid microcircuits include: (1) assembly performed in a clean area to prevent particle contamination, and (2) adequately controlled chip and wire bonds.

Assembly and packaging problems as depicted in Figure 5 show that these key factors also apply to older technologies. The problems associated with more advanced packaging can be more problematic.

Programs to provide reliable electronic packaging are needed to address these technologies. Efforts are underway to investigate possible process and testing improvements and controls, and update the NASA workmanship requirements documents for electronic packaging processes.

AVAILABILITY OF SPACE PARTS

The high reliability and small quantity requirements applicable to parts procured for space use result in unique problems with regard to their procurement and availability. Normal procurement times for high reliability parts suitable for space usage can be 1 to 3 years, due to special processing and test requirements. Also, space projects do not normally require large quantities of parts. Therefore, procedures should be instituted to: (1) provide for better availability; and (2) obviate use of less reliable parts, which can result in costly failures.

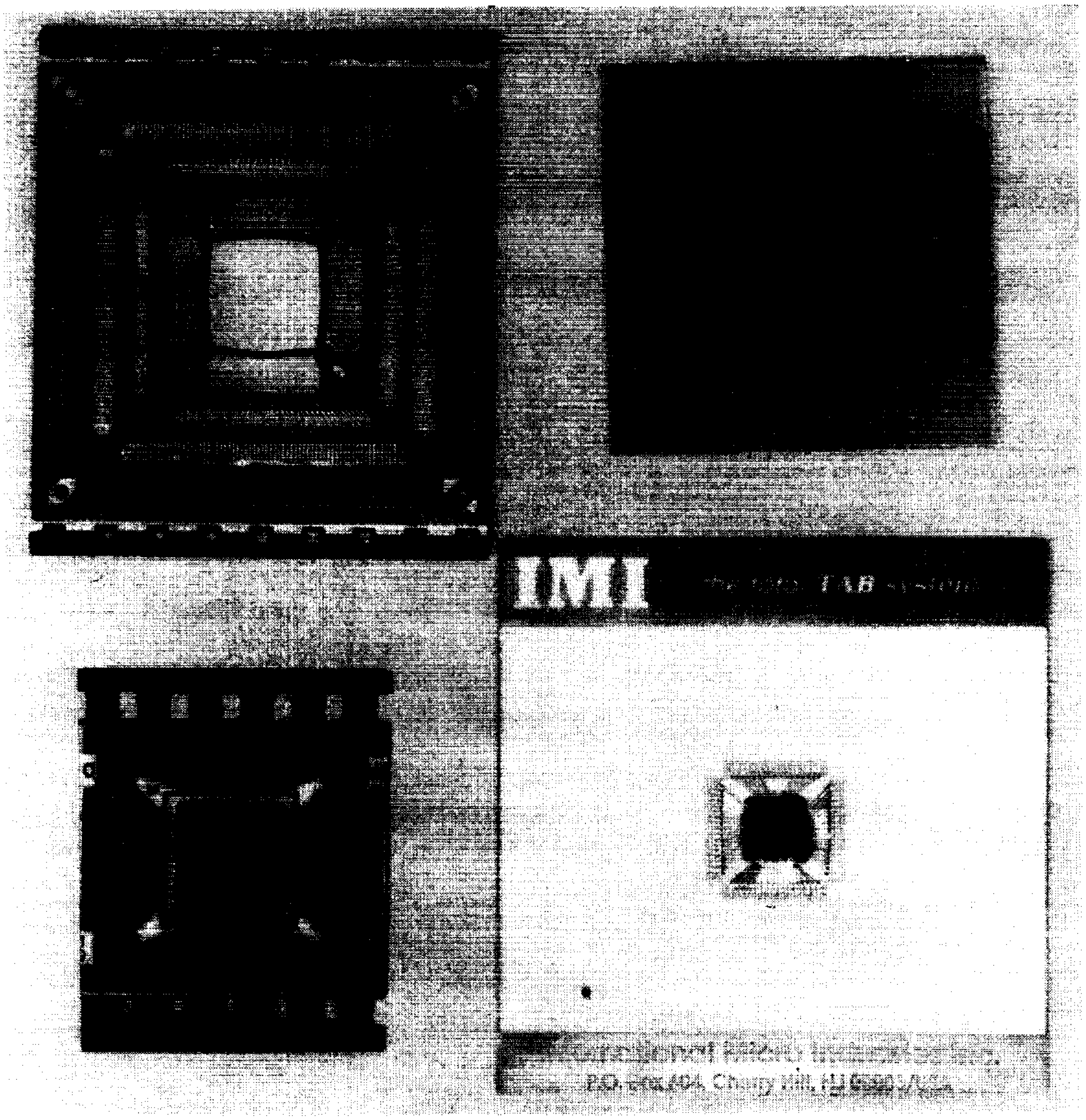

Figure 2. Examples of Surface-Mounted Devices

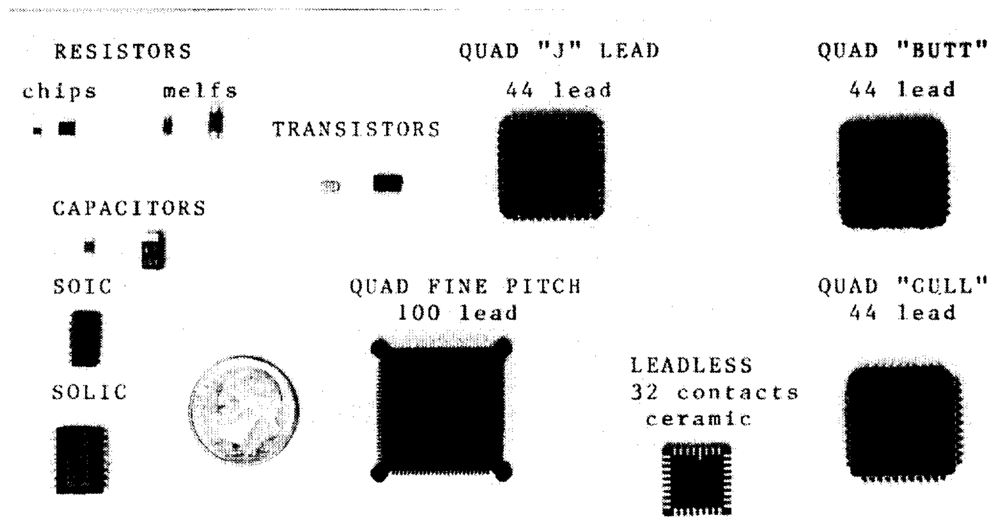

Figure 3. Example of Surface Mounted Devices

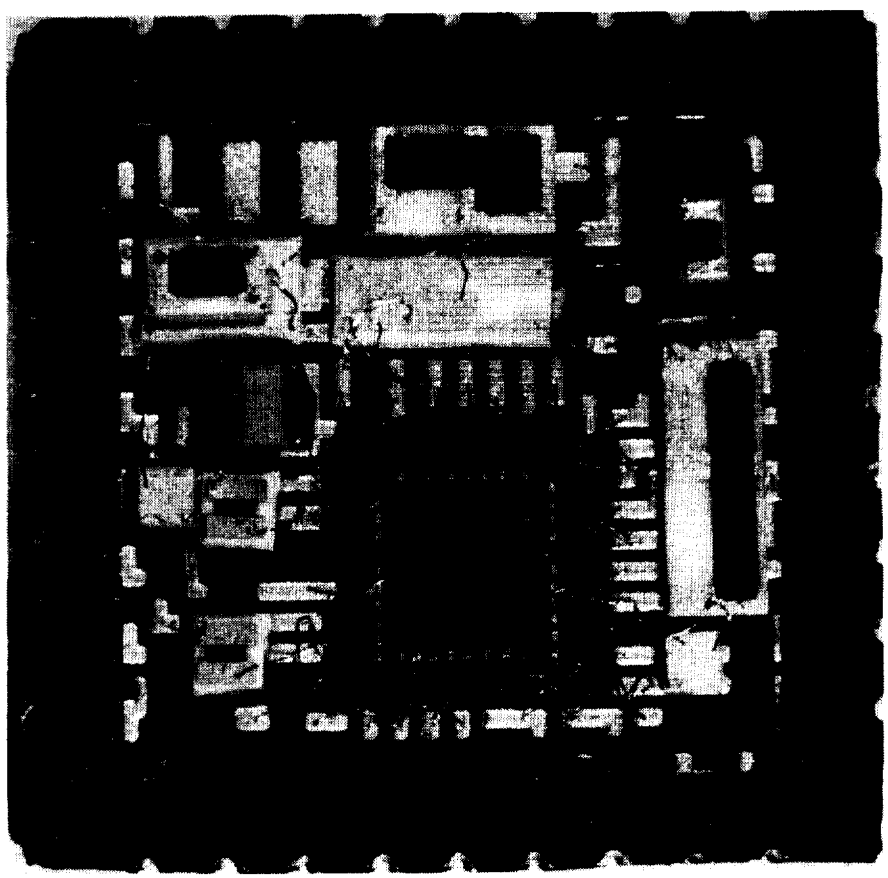

Figure 4. Example of Hybrid Device

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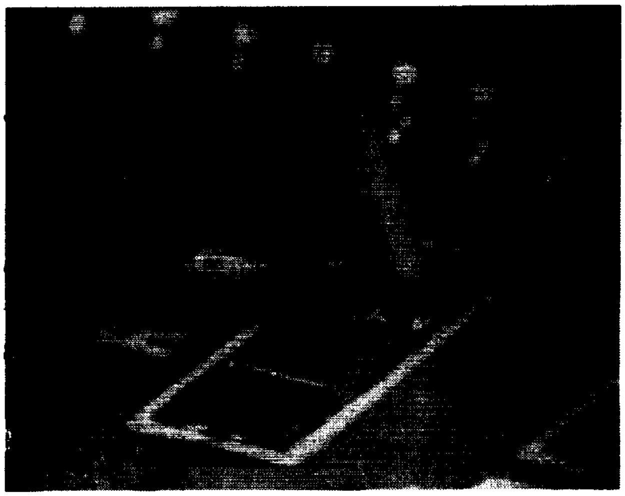
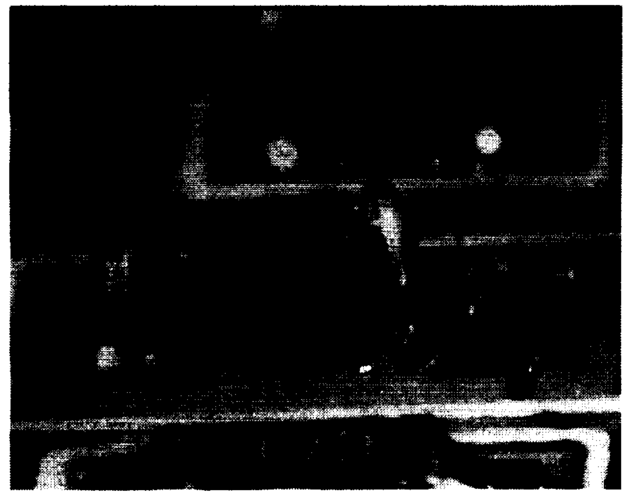
OF POOR QUALITY

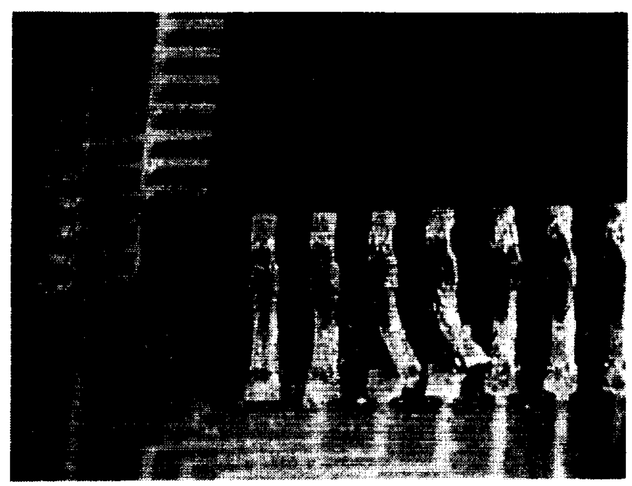


TOMBSTONING



A LIFTED MELF

POOR PLACEMENT OF A CHIP COMPONENT



A SWEEP OF TWO LEADS ON A GULL WING DEVICE

Figure 5. Examples of Assembling and Packaging Problems

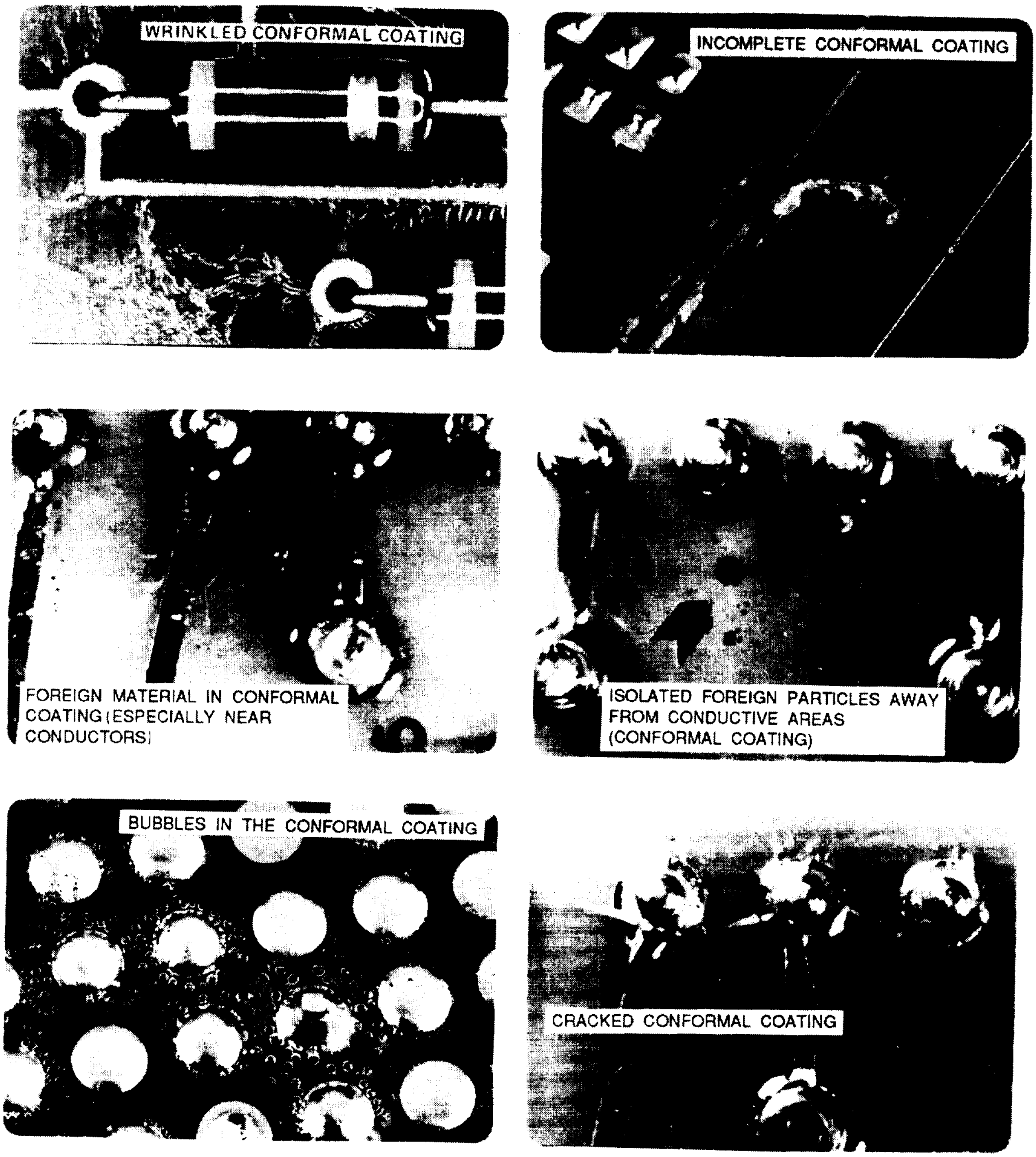


Figure 5. Examples of Assembling and Packaging Problems (Continued)

Standardization of parts can contribute to greater common usage and the ability to stock high reliability space parts. A "JAN S" stocking program was initiated for use by the U.S. Air Force, Space Division, and NASA projects and contractors. However, this program is not being utilized to a large extent and is in danger of being discontinued. It needs additional promotion and usage, and simplified authorization procedures.

The complexity and unique applications of advanced microelectronic devices further increase procurement time. Presently, there are no advanced microelectronic devices on an approved list. This hinders designers from using such parts. Procedures are being developed to overcome this problem.

A highly undesirable practice that results from parts unavailability is the cannibalism of parts from existing projects to meet the needs of new projects. Also, many parts become obsolete and are discontinued due to the development of improved parts. Therefore, the parts availability problem must be considered for new designs as well as for existing projects and the use of old designs on new projects.

INTEGRATION OF PARTS ACTIVITIES

The new developments in parts technology emphasize the need for interchange and dissemination of information between NASA projects, centers, and contractors. This is important to avoid duplication of effort, and also provide a basis for standardization and common usage of advanced devices. Therefore, cost savings, standardization, and earlier detection of problems will significantly improve the success of the project.

The availability of highly reliable parts for space use is affected by the relatively small quantities of parts required for each space project. The space quality parts requirements represent only a minute percentage of the overall market for parts manufacturers. This is compounded by current practices in which there are separate procurements of the same types of parts on each project and even by centers/contractors on the same project. Increased emphasis must be placed on centralized procurement activities.

The NASA Standard Parts Program provides for better standardization of parts through the following documents:

- MIL-STD-975, NASA Standard Parts List
- MIL-HDBK-978, Application of NASA Standard Parts
- NHB 5300.4(1F), Parts Management and Control Requirements for EEE Parts

It is important that these documents be continuously used and updated to promote standardization, improve reliability, and provide a basis for introduction and use of advanced microelectronic devices.

The information data base of EEE parts, EPIMS, is being developed and will be operational in the first quarter of 1990. It will contain NASA EEE parts data from all projects as well as applicable data from the Department of Defense and the Defense

Nuclear Agency. The goal of EPIMS is to disseminate EEE parts data to the design engineer, and consolidate information to form the basis for standardized and centralized procurement practices.

SUMMARY

The recent advances in electronic parts technology provide an important means for improving the performance and reliability of NASA space transportation projects. These upgrades are being incorporated into many electronic design efforts and their usage will increase as even more advances are introduced. However, this creates new challenges as techniques must be refined or adapted and procedures developed or revised to implement the most advanced technology for reliable space systems.

NASA STANDARD PARTS PROGRAM VIDEO PRESENTATION

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL PARTS FOR SPACE SYSTEMS

DANIEL BARNEY, MANAGER EEE PARTS
RELIABILITY, MAINTAINABILITY, AND QUALITY ASSURANCE DIVISION
NOVEMBER 7, 1989

NASA

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL PARTS FOR SPACE SYSTEM

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

- PURPOSE OF VIDEO – NEED FOR HIGH RELIABILITY PARTS
- QUANTITY AND COMPLEXITY
  - 100,000s OF TRANSISTORS ON EACH CHIP
  - MILLIONS OF INTERCONNECTED PARTS
- REQUIREMENTS
  - *ALL* PARTS MUST FUNCTION WHEN TURNED "ON"
  - PARTS MUST REMAIN OPERATIONAL THROUGHOUT MISSION IN HOSTILE ENVIRONMENT
- PARTS PROCUREMENT – CONTRACTOR ON EACH SPACE PROJECT MAKES SMALL BUYS, WHICH CAUSES:
  - HIGH UNIT COST
  - MINIMAL OR NO MARKET INFLUENCE
  - REDUCED RELIABILITY AND STANDARDIZATION

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL PARTS FOR SPACE SYSTEM (CONT.)

- PART FAILURES ARE *VERY* COSTLY AND RESULT IN:
  - LAUNCH ABORT
  - LOSS OF MISSION
  - SAFETY HAZARD

- PART FAILURE COST INCREASES EXPONENTIALLY
  - $100s AT PRINTED CIRCUIT BOARD LEVEL
  - $1,000s AT BOX LEVEL
  - 10,000s AT SUBSYSTEM LEVEL
  - $100,000s AT SYSTEM LEVEL
  - $1,000,000+ ON SPACECRAFT (e.g., Shuttle Crew Repair of Satellite In Space)

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NASA STANDARD PARTS PROGRAM

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

- **FUNCTION – INTEGRATE CENTERS, PROJECTS, AND CONTRACTORS**
  - SET STANDARDS AND ENVIRONMENTAL REQUIREMENTS
  - PREPARE SPECIFICATIONS, PERFORM FAILURE ANALYSIS
- **OBJECTIVES**
  - REDUCE COST
  - INCREASE RELIABILITY
  - STREAMLINE PROCUREMENT
- **KEY DOCUMENTATION**
  - NHB 5300.4(1F), STANDARD SPACE PARTS REQUIREMENTS
  - MIL-STD-975, LIST OF STANDARD SPACE PARTS
  - MIL-HDBK-978, APPLICATION OF STANDARD PARTS
  - MIL-STD-883, STANDARD PARTS TESTING
  - EEE PARTS INFORMATION MANAGEMENT SYSTEM (EPIMS)

A COPY OF THE VIDEO IS AVAILABLE FROM MR. DWAYNE BROWN, NASA CODE Q PUBLIC AFFAIRS OFFICER, (202) 453-8956

EEE PARTS ISSUES

- ADVANCED MICROELECTRONICS
- ELECTRONIC PACKAGING RELIABILITY
- AVAILABILITY OF PARTS
- INTEGRATION OF PARTS ACTIVITIES

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ADVANCED MICROELECTRONICS ISSUES

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

- APPLICATION SPECIFIC INTEGRATED CIRCUITS (ASIC)
- ENTIRE COMPUTER OR 200,000 TRANSISTORS ON A CHIP
- FAULT DETECTION/REDUNDANCY - CHIP WITH 35 MILLION TRANSISTORS
- SPEED, LINE GEOMETRIES, GALLIUM ARSENIDE, 3-DIMENSIONAL, HYBRIDS, DISCRETE NETWORKS

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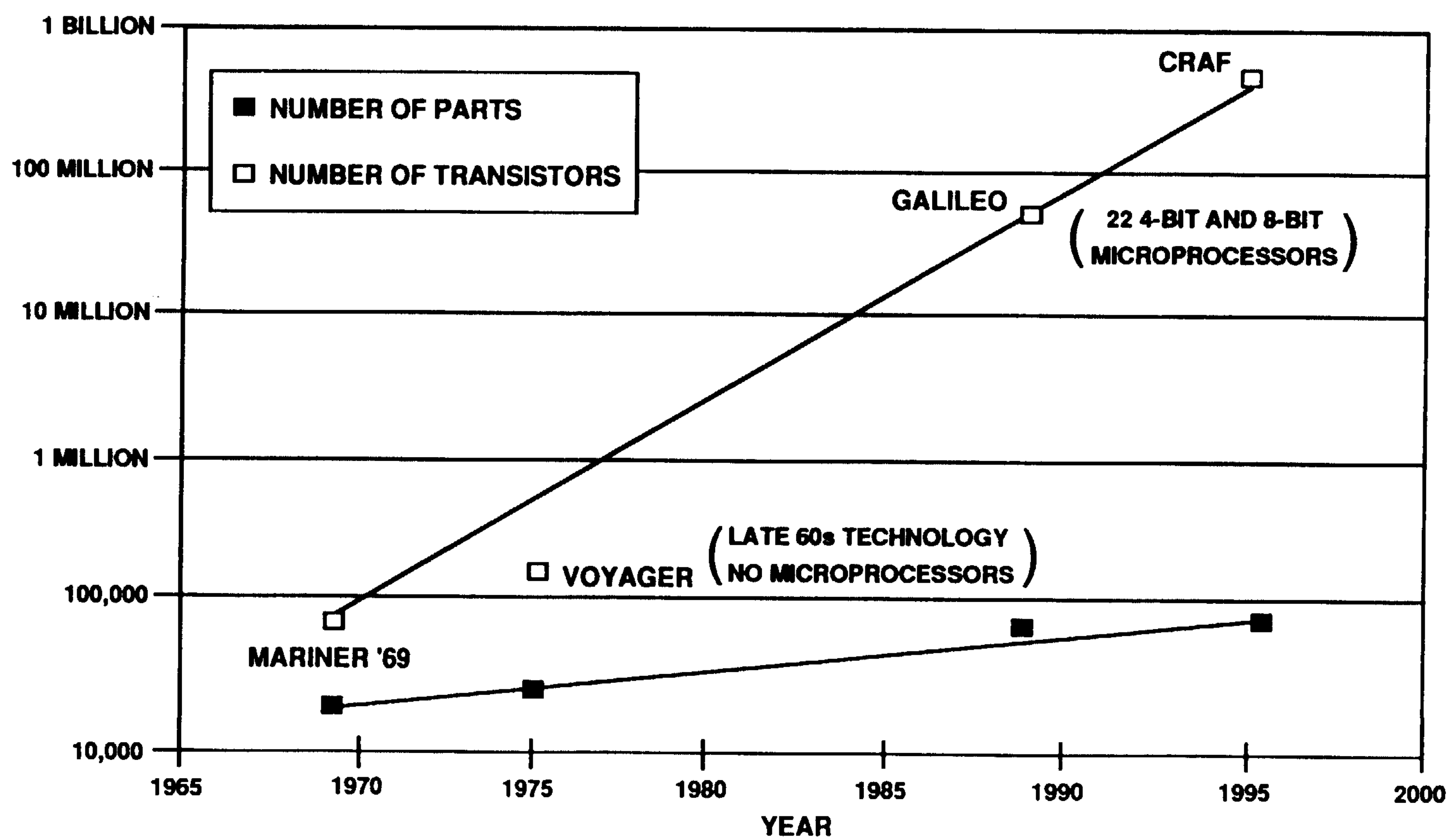
INCREASE IN SPACE ELECTRONIC COMPLEXITY

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE



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SPACE QUALIFICATION OF ADVANCED MICROELECTRONICS

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

APPROACH

- QUALIFIED MANUFACTURERS LIST
  - PROCESS INSTEAD OF FINISHED DEVICE
- TESTING BASED ON INCREASED COMPLEXITY
  - AREAS OF CHIP USED FOR TESTING, SOME DEVICES ARE SO FAST THAT THEY CANNOT BE TESTED
- STANDARDIZATION OF DESIGN
  - DESIGN RULES AND STANDARD CELLS

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ELECTRONIC PACKAGING ISSUES

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

- MAJOR SOURCE OF ELECTRONIC FAILURES
  - SURFACE MOUNT DEVICES
  - HYBRIDS
  - WIRE BONDS
  - SOLDER JOINTS
- INSPECTION IS DIFFICULT
- RELIABILITY IMPROVEMENT PROGRAM IS NEEDED

AVAILABILITY OF SPACE PARTS

- LONG PROCUREMENT TIMES (UP TO 3 YEARS) (BOTH ADVANCED AND APPROVED PARTS)
- NO ADVANCED MICROELECTRONIC PARTS ARE ON AN APPROVED LIST
- STOCKING PROGRAM UNDER-UTILIZED
- CANNIBALISM PRACTICES
- OBSOLESCENT/DISCONTINUED PARTS

SOLUTIONS: INTEGRATION OF PARTS ACTIVITIES

- INTEGRATION AND COORDINATION BETWEEN CENTERS, PROJECTS, AND CONTRACTORS
- NEED FOR CONSOLIDATED PROCUREMENTS
- IMPROVED RELIABILITY THROUGH STANDARDIZATION
  - MIL-STD-975, NASA STANDARD PARTS LIST
  - MIL-HDBK-978, APPLICATION GUIDE
  - NHB 5300.4(1F), EEE PARTS REQUIREMENTS
- USE OF COMMON DATA BASE, EEE PARTS INFORMATION MANAGEMENT SYSTEM (EPIMS)

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SUMMARY

SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

ISSUES:

- SPACE QUALIFICATION OF ADVANCED MICROELECTRONICS
- IMPROVED ELECTRONIC PACKAGING RELIABILITY
- SPACE PARTS AVAILABILITY PROBLEMS

SOLUTION:

- STANDARDIZATION AND INTEGRATION OF PARTS ACTIVITIES

Section 2

PANEL OVERVIEW AND INTRODUCTION PRESENTATIONS

- OPERATIONAL EFFICIENCY
- FLIGHT ELEMENTS
- PAYLOAD ACCOMMODATIONS
- SYSTEMS ENGINEERING AND INTEGRATION (SE&I)