Vitro
CORPORATION

FINAL CONTRACT SUMMARY REPORT

for

Contract No. NASW-4311

ENGINEERING, TECHNICAL, AND MANAGEMENT SUPPORT SERVICES FOR NASA HEADQUARTERS OFFICE OF SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE (CODE Q)

February 10, 1994

FINAL CONTRACT SUMMARY REPORT

This report summarizes by task the engineering, technical, and management support services provided by Vitro Corporation to NASA Headquarters Office of Safety, Reliability, Maintainability, and Quality Assurance (now called Office of Safety and Mission Assurance (OSMA)) (Code Q) under Contract Number NASW-4311 from the period February 22, 1988 through February 10, 1994.

Each task summary includes significant Vitro accomplishments, conclusions, and recommendations for future efforts in each of the following divisions within OSMA:

Code	Division Name	Task Order
QW	Engineering and Quality Management	1000, 4000
QS	Safety and Risk Management	2000
QT	Payloads and Aeronautics	3000
QV	Software Independent Verification and Validation	5000
QB	Quality and Productivity Programs Improvement Office	5000
QM	Resources Management	6000, 7000, 8000
QP	Space Flight Safety and Mission Assurance	9000
DSQ	SSF Program Office Level II Safety and Produce Assurance Office	10000

FINAL CONTRACT SUMMARY REPORT

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1000 SERIES TASK ORDER
QUALITY MANAGEMENT

I. BACKGROUND FOR THE OVERALL TASK

OSMA is the responsible NASA organization for developing and maintaining leadership for safety, reliability, maintainability, and quality assurance disciplines to assure safety and mission assurance. This task provides the support necessary in the quality assurance functions including technical support for the disciplines of mechanical, electrical, chemical, industrial, systems, aerospace, data systems, and quality engineering, and the ancillary requirements for effective quality management. This includes functional management reviews, audits, preparation and dissemination of policy, procedures, handbooks, and guidelines for the effective organization, development, and operation of quality assurance programs. These efforts were conducted under Task 1000. The NASA Survey/Audit Program Support was initiated under 4300, shifted to 1700, and then to 1000.

This task began in 1988, supporting the Reliability, Maintainability and Quality Assurance Division. Later this became the Quality Assurance Division, and is currently (February 1994) the Engineering and Quality Division. The specific programs under this task include the following efforts:

- ***Quality Assurance***: NASA Handbooks (NHBs) and Management Instructions (NMIs) and Department of Defense (DoD) and International Quality System Standards.

- ***Nondestructive Evaluation (NDE).***

- ***Metrology and Calibration.***

- ***Materials and Processes.***

- ***NASA Mechanical Parts Program Support***: Mechanical Parts Control Program, Fastener Integrity Program, Fastener Quality Act, Mechanical Information Management System (MEPIMS), Government-Industry Information Exchange Program (GIDEP), NASA Alert Reporting System (NARS), Supplier Quality Research and Technology Operation Plan (RTOP), Contractor Metrics Process Action Team (CMPAT), NASA Continual Improvement Implementation Plan (CIIP), Assuring Dual Sources for Critical Suppliers, Metric Capabilities of USA Machine Shops Survey, Cooperation on Quality Problems with NASA Office of Inspector General (OIG), Small Supplier Quality Assurance Assistance (SSQAA) Program, Interagency Working Group for Problem Parts and Suppliers, International Coordination Meetings.

- *NASA Survey/Audit Program Support*: Task Initiation, Implementation, Survey Activity, FMR Transition.

The survey subtask evolved through design, implementation, and execution of Field Installation on-site surveys by Headquarters, coordination and analysis of corrective action reports, and tracking and closure reports for individual surveys. This evolved into a process where the Field Installations would conduct local surveys and contractor audits and provide data provided to Headquarters for oversight information. With the Field Installation agreement to conduct self-surveys, the large Headquarters survey group activity would be reduced to conducting only small, focused, spot check reviews. The recent development of the NASA "Functional Management" approach to Field Installation self-assessments for Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) functional elements will establish accountability at each Installation functional manager level. Headquarters will retain oversight responsibility and provide Agency level assurance for SRM&QA to the Administrator. The task order support function also supports the internal Headquarters Functional Management Task Team and related subtask team activity due to Code Q participation and subtask coordination functions. The subtask team activity involved revision of the NMI 1240.3 on Functional Management and development of self-assessment evaluation instruments to assess the overall effectiveness of the new Functional Management initiative throughout the Agency.

II. SUMMARY OF THE TASK ACTIVITY

Vitro assembled an interdisciplinary team with the necessary training, experience, and specific expertise to provide innovative, progressive, proactive support to the NASA SRM&QA efforts in the task areas. Working closely with their NASA counterparts, Vitro team members developed, organized and recommended implementation methodologies, new and revised policies, procedures, assessments, technical documentation, reviews, and new and restructured working groups to maintain and improve the Agency SRM&QA program. Specific details are contained in the task summation that follow.

QUALITY ASSURANCE

NASA Handbooks (NHBs) and Management Instructions (NMIs)

The NASA Management Instruction (NMI) 1270.2A, "NASA Quality Policy," was issued on October 11, 1991. The revision/rewrite, NMI 1270.2B, was issued on December 22, 1992. These documents delineated policies and responsibilities for assuring that NASA procures, designs, produces/manufactures, maintains, and operates products and services that conform to requirements and result in mission success. All Code QR and QW programs contain tasks directed towards implementing this NASA Quality Policy.

Technical procedures, standards, policy, and concepts differ from NASA programs to programs and from NASA Field Installation to Installation. Vitro continuously assessed

the documentation to identify cross-program generic elements, program-unique procedures, and quality elements which could be enhanced/improved. From these assessments, recommendations were developed to provide standardized NASA Agencywide plans, instructions, and procedures. Vitro has assisted NASA Headquarters Code QR/QW in the formulation, generation, coordination, and maintenance of the draft NASA publications, as directed.

The effort to provide a compendium of commonly used safety, reliability, maintainability, and quality assurance definitions to ensure standardized assurance communications among NASA Field Installations, Headquarters, and contractors culminated with the delivery and publication of the NASA Handbook, NHB 5300.4(1G), "NASA Assurance Terms and Definitions," in May 1993. This document was the result of extensive research into NASA and Department of Defense (DOD) sources/usage of terms, and coordination within the Agency.

As a result of the review of existing NASA Handbooks and the direction to continuously improve the NASA procurement procedures and the effective use of resources, an effort was initiated to enhance the NASA Handbook, NHB 5300.4(2B-1), "Quality Assurance Provisions for Delegated Government Agencies." The requirement to standardize management of Government Quality Assurance functions to provide the minimum oversight and effective use of resources established the precedence for developing the revision of the Handbook. NHB 5300.4(2B-2), "Management of Government Quality Assurance Functions for NASA Contracts," which emphasizes active participation by NASA and other Agency quality assurance personnel in all phases of contract operations, was delivered and issued in April 1993 after coordination with the NASA Field Installations and industry. Training was coordinated, conducted, and completed in May 1993.

The effort to enhance the NASA Handbook, NHB 5300.4(1B), "Quality Program Provisions for Aeronautical and Space System Contractors," was initiated early in the contract; however, after extensive coordination with the Headquarters, Installations, other Agencies and industry, the final draft rewrite, NHB 5300.4(1B-1), "Quality Program Provisions for Aeronautical and Space Systems," was delivered to Code QR and placed in a deferred status pending NASA adoption of the American National Standards Institute/American Society for Quality Control (ANSI/ASQC) Standards for quality systems as augmented by NASA. Vitro maintains the draft document and makes distribution when directed. Action was initiated on the associated Handbook, "Guide for Corrective Action and Disposition System," but was discontinued at the direction of NASA Headquarters.

In support of the effort to provide program guidance and methodology for structuring and administering test programs to ensure successful operation of NASA Aeronautical and space systems, Vitro generated and delivered the draft NASA Handbook, NHB 5300.4(XH), "Test Verification Guidelines for Aeronautical and Space Systems." The Handbook is being maintained/updated by Vitro while the NASA-wide coordination cycle is underway.

Vitro has assisted in the coordination, review, and statusing of the NASA Workmanship Standards' Handbooks, e.g., NHB 5300.4(3G-1), "Requirements for Interconnecting Cables, Harnesses, and Wiring," and NHB 5300.4(3A-3), "Requirements for Soldered Electrical Connections."

Vitro assisted in the preparation/generation and delivery of the NASA Management Instructions (NMIs); NMI 1270.2A and NMI 1270.2B, "NASA Quality Policy," NMI 5320.X, "Protection and Handling of Electrostatic Discharge Sensitive Items" (Draft), and NMI 5320.XX, "Configuration Management and Engineering Practices" (Draft). A draft "Configuration Management Plan/Approach" and schedule were developed and delivered to Code QR.

Department of Defense (DOD) and International Quality System Standards

Vitro assisted in the preparation for NASA participation in the Office of the Assistant Secretary of Defense (Production & Logistics) International Organization for Standardization, ISO 9000 Working Group. Recommendations were submitted to NASA Headquarters for consideration and inclusion in the joint DOD/NASA-HDBK-9000 and Data Item Document (DID) to supplement ANSI/ASQC Q91 & Q92 requirements and their use in contracts. Vitro generated and delivered the Appendices A1 and A2 for the Handbook reflecting NASA unique requirements.

Vitro also assisted the Headquarters in the preparation of recommendations/comments for the NASA ISO 9000 Working Group which was developing "Augmentation" comments for ISO 9001, "Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing."

Vitro participated in and assisted in arranging for meetings and discussions, relative to the ISO 9000 series of quality standards, with other Government agencies (e.g., the General Services Administration (GSA), the US Postal Service, and representatives of industry, the Aeronautical Industries Association (AIA), and National Security Industrial Association (NSIA).

General

Vitro assisted NASA Headquarters, Code QR/QW, in the review and tracking of the effort on developing "Critical Skills and Certification" training for NASA Quality Engineers, Reliability Engineers, and Quality Assurance Specialists.

Vitro has participated in and has provided technical and administrative support in planning, coordinating, and conducting SR&QA related working group meetings, e.g., NASA/AIA/NSIA Liaison Group, the NDE Working Group, Met/Cal Working Group, and symposia, e.g., the annual IEEE Reliability and Maintainability Symposia.

Vitro has supported the review and comment cycle for NASA draft documentation submitted by NASA Field Installations, e.g., the "Mission Design Process Guide," the

SAF/AQXM "New Look" paper, and the draft NMI "Problem/Failure Controls for NASA Payloads." Comments and recommendations were submitted to Code QR/QW.

Vitro's technical support for the NDE, Metrology and Calibration, and Materials and Processes program areas included in the preparation of procedures and policies, evaluation of Center and contractor programs, and technical support for technical meetings. These activities are described in the following paragraphs.

NONDESTRUCTIVE EVALUATION

Vitro also participated in the restructuring of the NASA NDE program through the new NDE Working Group. Technical direction was provided in redirecting the large LaRC NDE program to be more responsive to NASA program needs. A Code Q committee of Center representatives was guided in its formation and operations to provide a NASA-wide review and coordination of RTOP programs and submissions. The NDE program area was restructured to provide integrated programs, emphasize customer orientation, consensus decisions, and direct application or transition to field problems.

The multi-million dollar "NDE for Quality Assurance" program at LaRC was brought to a completion of the build-up of facilities and personnel resources, and then evaluated in terms of changing objectives, approaches, and individual programs in terms of meeting stated NASA-wide program needs. This resulted in a broadening of Code Q support to other Centers to improve the "Return on Investment" for NDE RTOP programs, which had not been satisfactory from the viewpoint of the SRM&QA Directors at the NASA Field Installations.

The Headquarters Oversight Steering Committee was established as a multi-code group involving Codes M, Q, R, and S to improve Headquarters communication and coordination of NDE efforts. A comprehensive NDE needs survey was conducted to provide a basis for new program efforts. The survey was collated and analyzed by a Vitro-LaRC team of experts and delivered to the Headquarters NDE Oversight Steering Committee. A series of Technical Interchange Meetings was inaugurated on the ViTS network for bringing NDE topics and latest state-of-the-art developments to the attention of Headquarters and field personnel. The basis for a broad restructuring of the NDE program area was established. Technical support and leadership for all of these activities was provided under the contract. Stability was provided to the NASA NDE community and Headquarters Code Q during a time in which there were four separate NDE program managers. The Vitro technical expertise remained constant during the 5-year period.

A comprehensive review and assessment of the on-orbit NDE and testing requirements for the Space Station Freedom program was conducted. This included reviewing the requirements stated in the SSP 30000 basic documents, including the WBS and work packages, an analysis of requirements and potential NDE techniques suitable for the space environment, the types of degradation and failure expected during the planned 30-year life of SSF, and a review of instrumentation used in the Russian Salyut series vehicles and the Mir space station complex.

Deliverables:

"NASA Nondestructive Evaluation (NDE) Working Group Organizational Meeting Proceedings," Proceedings of Meeting on April 14-16, 1993 at JSC, September 24, 1993.

"Nondestructive Evaluation (NDE) Program Restructuring," Status Report, February 22, 1993.

"Nondestructive Evaluation Program Restructuring Goals," Planning Report, November 10, 1992.

"Acoustic Emission Monitoring NDE Initiative Plan," Status Report, September 9, 1992.

"Acoustic Emission Monitoring NDE Initiative Plan," Planning and Status Report, July 22, 1992.

"NASA Nondestructive Evaluation (NDE) Oversight Steering Committee Charter," March 26, 1991.

"Survey of Nondestructive Evaluation Needs," Technical Report, April 16, 1990.

"Review of LaRC NDE Plan," Technical Memorandum, December 19, 1989.

"On-Orbit NDE Assessment [of] Space Station Freedom," Technical Report, March 31, 1989.

METROLOGY AND CALIBRATION

Technical leadership and guidance was provided for broadening the participation and interactions of the Metrology and Calibration Working Group, completing the revision of the NMI for the program area, quantifying the program goals and milestones for the Measurement Assurance Programs, and improving the process of long range planning. Technical assistance was provided for revising the "Metrology - Calibration and Measurement Processes Guidelines" which is scheduled for completion in 1994.

Deliverables:

NASA NMI 5330.9B, "Metrology-Calibration and Measurement Processes," Final Draft, July 27, 1993.

"Metrology and Calibration Working Group Charter," Final Draft, March 26, 1991.

MATERIALS AND PROCESSES

Under this task specific technical surveys and assessments were conducted and reports completed. Technical leadership and guidance was provided in the preparation of the revision of NASA NHB 8060 to produce NHB 8060.1C. Numerous drafts of materials and processes policy, procedural and process control documents were also prepared and distributed to responsible Center materials organizations for review. The policy document has been prepared as a final draft and will be submitted for formal review in 1994.

Vitro reviewed the materials selection and NDE methods used relating to the orbiter fuel door hinge cracking problem. We also assessed test requirements for Kapton insulation. NASA requirements and test procedures were compared with those of the Aerospace Industry, ASTM, SAE, and the Air Force to determine their ability to provide realistic data for selection of Kapton-insulated wire and proposed replacements in the Shuttle and other space applications.

A technical assessment resources study was conducted to compare the personnel resources devoted to safety, reliability, maintainability and quality assurance (SRM&QA) functions NASA-wide with those of other major Governmental and Industrial organizations. This study included over 26,000 NASA employees at Headquarters, Centers, and JPL, and compared the results with a survey of over 50 industrial, educational, and laboratory organizations with an aggregate of 263,000 employees, and non-NASA government agencies, including DOD activities, commissions, laboratories, and regulatory agencies with an aggregate of 63,000 employees. This is believed to be the largest such survey ever conducted on SRM&QA personnel resources. The NASA SRM&QA level of effort did not compare favorably with the overall average for all industries (5.3% compared with 6.8%), or with other government agencies (10.6%). The NASA resources devoted to SRM&QA showed a marked decline from the Apollo/Skylab period (late 1960's to early 1970's) to the time of the study (1989).

Vitro also conducted an analysis of the effects of restrictions proposed by the EPA and the Montreal Protocol on major sources and area sources emissions (which would include some NASA Center operations) of solvents, CFCs, and other chlorinated hydrocarbons.

Deliverables:

NMI 8077.XX, "Selection and Control of Materials and Processes for Space Flight Programs," July 19, 1993.

NHB 8060.1C, "Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion," Editor and Contributor, April 2, 1991.

Observations on Environment and Etching Procedures for Orbiter Fuel Door Hinge Cracks," Technical Memorandum, March 19, 1991.

"Kapton Wire Insulation Test Requirements," Technical Memorandum, December 19, 1989.

"SRM&QA Resources Study," Technical Report, February 3, 1989.

"SRM&QA Manning Study," Interim Technical Report, November 18, 1988.

"Impact of Proposed Amendments to the Clean Air Act of 1970 on NASA Flight Safety Operations," Technical Note, November 2, 1988.

NASA MECHANICAL PARTS PROGRAM SUPPORT

Mechanical Parts Control Program

The mechanical parts control program was established to prevent the problems of counterfeit and fraudulent parts and fasteners experienced by NASA and other federal agencies during the mid-1980s. Vitro participated in the development, monitoring, and research that followed the establishment of the program. The following activities are provided as examples:

- Assisted in the establishment of a working group, prepared a charter, and monitored the many activities addressed during the time period.

- Worked as part of the team that wrote, coordinated, edited, and delivered for publication the NMI 5320.7 "Basic Policy For Mechanical Parts Control."

Fastener Integrity Program

The problem of counterfeit and fraudulent fasteners has caused NASA and other government agencies to undergo extensive searches, and a large number of fasteners were required to be destroyed due to the inability to determine which fasteners were genuine and which were misrepresented. This caused NASA to establish an extensive fastener integrity program. Vitro was a participant in the following activities supporting the Code Q organization:

- Assisted in the development of a working group, developed a charter and monitored the specific research programs and technical management programs required to establish the fastener integrity program.

- Was an active participant in the planning and the establishment of criteria to design and develop a Fastener Information Management System (FIMS).

- Prepared and reviewed a series of position papers on the interpretation of MIL-S-8879C and assisted in the preparation of the Code Q policy letter, specifically outlining the responsibilities of NASA Centers and Contractors for dimensional inspection of both internal and external threaded fasteners.

- Monitored the research on finding a replacement for Cadmium as a coating for space and critical ground support equipment.

- Performed literature searches and reviewed company literature for uses of laser technology to measure thread and fastener profiles without actual contact. This technology has advanced to the point that the measurements can be made, digitized, and stored at costs that are competitive with the current methods of establishing threaded parts profiles. Several presentations were prepared to make the information available to NASA activities.

Fastener Quality Act

The Fastener Quality Act (PL 101-592) was enacted into law and a Fastener Advisory Panel was established as required by statute. NASA provided a representative to this panel and Vitro provided technical and management support for development of regulations to implement this law. The NIST was responsible for the publication of the regulation. The draft regulations have been circulated, reviewed and commented upon, but have not been published. The following facets of the project are identified:

- Reviewed the complete text and background of the law.

- Coordinated NASA comments of the proposed regulations.

- Prepared presentations for the NASA representative.

- Maintained a current status of legislation that proposed specific amendments pertinent to the law.

Mechanical Information Management System (MEPIMS)

NASA recognized the need to have a system of communication to be a part of the mechanical parts control program and established a project at GSFC to develop such a system as a part of the NASA Automated System (NAS). Vitro was a vital part of the planning, design, development, oversight, and technical review and acceptance. The following highlights are listed:

- Assisted in establishing the overall concept and design.

- Provided technical review and oversight of the actual construction and testing.

- Participated in meetings and telecons, and provided comments on technical progress reports.

- Acted as a technical witness for the demonstration and acceptance of the baseline system.

- Coordinated with all NASA Centers and prospective users to ascertain what functions were required and advised on the prioritization of the development of these capabilities.

- Coordinated with the Mechanical Parts Working Group to prepare a plan to accept the responsibility for maintaining the system after delivery and to manage the input of data and selecting the types of data and capabilities required.

Government-Industry Information Exchange Program (GIDEP)

NASA is a sponsor and one of the prime users of the GIDEP system and an active participant in the monitoring of the service provided and the improvements to the system. Vitro's participation in all facets of GIDEPs included:

- Acted as custodian for GIDEP Alerts, Safe-Alerts, Agency Action Notices, Problem Advisories, Diminishing Manufacturing Sources, and Urgent Information Requests.

- Maintained a computerized summary of all GIDEP Alerts, Safe Alerts, Agency Action Notices for rapid response to requests for data.

- Prepared a Monthly Summary of GIDEP data distributed to NASA Centers and selected contractors.

- Participated, and frequently hosted, in the GIDEP Management meetings.

- Coordinated with GIDEP representatives on technical aspects of the changes being made to the computer system that will allow real time, full search capability for all GIDEP data and provided interface with NASA Centers on service problems.

- Acted as Vitro GIDEP representative and performed specialized searches for the NASA staff as required.

- Provided the interface between GIDEP personnel and NASA personnel that are developing a NASA-wide access to GIDEP and the downloading of GIDEP data.

- Maintained a paper copy file of all incoming GIDEP alerts.

- Assured that a paper copy of all Safe-Alerts was promptly forwarded to Code QS for review and possible action.

NASA Alert Reporting System (NARS)

NASA recognized the need for an Alert system that would be responsive, closed-loop, and closely linked with the GIDEP system. This system is in the final stages of

development and will become a part of the NAS electronic data system. Vitro has provided a vital input to the development of this system; a few significant examples are provided:

- Actively participated in the development of specifications, recommended interface techniques, monitored the software design and development, monitored the progress, and coordinated with NASA Centers to assure that their needs were recognized and met.

- Participated in telecons, working group meetings, progress reviews, and center coordination meetings and acted as interface with GIDEP.

- Prepared for the Acceptance Test and will act as technical witness for the demonstration of the operational system.

As a part of the NARS system, NASA has developed a closed-loop NASA Preliminary Alert System (NPAS) that gives Code Q a method to rapidly provide NASA Centers with sensitive and time-critical information. This system allows electronic or hard-copy transmission to selected center representatives for their action as required. The system also allows answers to be returned and actions closed when warranted. Vitro was a part of the development of this system; selected accomplishments are listed:

- Assisted in the design of the NPAS and coordinated with the center GIDEP representatives to assure that needs were being met.

- Reviewed incoming information to determine if it was a candidate for the NPAS.

- Maintained an overview to assure that the information was being received, actions taken, and closing reports made.

Vitro assisted in preparing, coordinating, and distributing the following NMIs and NHB:

- NMI 5310.1D, "NASA Alert Reporting of Parts, Materials, and Safety Problems."

- NMI 5310.2C, "Participation in the Government-Industry Data Exchange Program (GIDEP).

- NHB 5310.3, "Procedures for NASA Alert Reporting of Parts, Materials, and Safety Problems"

Supplier Quality Research And Technology Operation Plan (RTOP)

A need was recognized by NASA that some system was required to objectively measure the performance of suppliers of parts, materials, and services. This RTOP was established to research the contractor and NASA community to ascertain how evaluations were being performed and how they could be improved to be more objective

and standardized between projects and Centers. Vitro has participated in this project, and some of the inputs are provided:

- Assisted in developing the guidelines in establishing the project.

- Coordinated with the Lead Center (JSC) in establishing a working group, a Statement of Work (SOW), a preliminary plan of action.

- Interacted with the working group to reschedule the project to accept related, more critical projects.

Contractor Metrics Process Action Team (CMPAT)

Mr. Goldin, NASA Administrator, established a requirement to develop a series of metrics for the evaluation of the 30 largest NASA contracts. These metrics were to be graphic presentations for use by the Administrator to brief the CEOs of the respective companies to show them how they are performing on NASA contracts. Code Q was made responsible for the Quality Metric. Vitro provided the following support in this effort:

- Attended the CMPAT meetings and at times represented Code Q in the meetings.

- Coordinated with the Lead Center (JSC) to reschedule work on the Supplier Quality RTOP and provide inputs for the project.

- Assisted in the development of the Quality Metric, participated in the RTOP Working Group meeting teleconferences, reviewed the draft output, and coordinated with centers and selected companies on facets of the project.

- Reviewed the proposed presentation technique and provided briefings and coordinated with activities that had problems understanding the Oregon Matrix technique.

- Coordinated with the CMPAT manager (Code H) to assure that the proper documentation was prepared and submitted to the NASA HQ Associate Administrators as part of the NHB 2340.4, " Contractor Metrics Handbook."

NASA Continual Improvement Implementation Plan (CIIP)

NASA established a requirement for a plan to assure that the continual improvement concept was exercised by all NASA activities. Code Q was tasked to provide a section to the implementation plan on Supplier Quality (Section 6). Vitro assisted in the preparation and provided the following support:

- Coordinated with Supplier Quality RTOP leader to reschedule the RTOP activity and provide an input for this project.

- Worked with the working group to prepare the Section 6 input for the CIIP.

- Participated in meetings to assure proper merging of Section 6 into the overall plan.

- Reviewed the Revised Low Award Selection Criteria and made recommendations to Code Q.

Assuring Dual Sources for Critical Suppliers

NASA was directed by the Office of Management and Budget (OMB) to make an annual report on the status of single or endangered sources of supply for critical parts, processes, or services. Code Q has been assigned to collect the reports from all NASA Program and Project Managers and prepare a consolidated report to OMB. Vitro participated in this effort in the following areas:

- Participated in meetings and briefings from Defense Contract Management Command (DCMC), a part of Defense Logistics Agency (DLA).

- Assisted in the preparation of briefings to the HQ Program Managers to describe the requirements of the report and the possibilities of utilizing support from DCMC.

- Reviewed the DCMC program and the data supplied on their current operation in performing this task for Department of Defense (DOD).

Metric Capabilities of USA Machine Shops Survey

Congress has mandated that all government agencies develop a schedule to convert to the use of Metric Measurements as the Primary Unit of Measurement. NASA is required to make a report to Congress annually on the progress made in this effort. NASA requested that Vitro conduct a survey to determine the current capability of machines shops in the USA to provide quality parts in metric dimensions. This survey was performed and a report was submitted to Code Q. The results of the study were presented at several meetings and briefings. An abstract of the report was published in a Metric Measurement Newsletter.

Cooperation on Quality Problems with NASA Office of Inspector General (OIG)

OIG notifies Code Q of any critical quality problems that they detect during their investigations. These problems are usually sensitive, since the investigation is still being performed. Code Q is responsible to review these alleged problems and determine if there is a potential for a problem within any NASA program or project. Code Q uses the NARS to communicate this information to the proper individuals, yet must protect the sensitivity of the information. Vitro assists Code Q in the evaluation of the information, preparation of communication to the field, coordination with field activities during their research, and the preparation of a report back to OIG advising them of the action taken and the result of the investigation if applicable. In providing this assistance,

Vitro coordinated with OIG, field representatives, and other agencies to perform independent research on some of the suspected individuals and companies. Alleged problems included defective ball bearings, ignition testers, pyrotechnic valves, and mechanical parts/fasteners. In many of these cases, no problem was detected.

Small Supplier Quality Assurance Assistance (SSQAA) Program

NASA has been encouraged by Congress to provide more of their contracts to small and disadvantaged companies. The problem that NASA found was that small organizations did not understand the quality documentation requirements demanded by NASA, and in many cases were reluctant to attempt to establish the required quality controls and documentation. In order to assist these prospective government suppliers, NASA requested Vitro to develop a process that would be simple, educational, economical, and timely to assist the new supplier in understanding and complying with the government quality requirements. Vitro took the following actions:

- Developed a plan, prepared a charter for establishment of a working group, organized a working group, and scheduled and participated in several meetings with NASA representatives, Prime Contractor personnel, Professional Association representatives, and Small Business Agency (SBA) personnel.

- Designed, developed, prepared software, created questionnaire, prepared users manual, and demonstrated the technique to prospective supplier users. This technique was designed to be used on a personal computer, to be very user-friendly, and to document the results of the questionnaire directly on a diskette for return and inclusion in a data base for future use by the government or large industrial customer. The questionnaire was designed to provide the supplier with insight of what quality requirements were necessary, and on most occasions why they were needed, and how to achieve them.

- After extensive testing within NASA and with the working group member organizations, Vitro defined and prepared a final questionnaire, diskette program, users manual, and mail-out package.

- Demonstrated and briefed the program at several NASA Small and Disadvantaged Business Conferences and provided the attendees with a diskette for their use and input to NASA.

- In cooperation with the NASA working group, SBA was convinced of the merit of the program, and it was implemented into their Procurement Automated Source System (PASS). It is currently available nationwide to any PASS member for direct electronic use as a means of evaluating the quality organization and documented capability of a prospective small supplier.

Interagency Working Group for Problem Parts and Suppliers

NASA recognized that all Federal agencies were having problems with parts and suppliers. They decided to take the lead in the establishment of working group of federal agencies to periodically meet and discuss their problems, exchange sensitive investigative information, and create a rapport for informal exchange of time-sensitive information. Vitro assisted in developing a charter, scheduling meetings, providing technical support for documenting the sanitized meeting minutes, and advising working group members of NASA points of contacts. The idea was described to OMB and a letter was prepared by OMB stating that all federal agencies should participate and that GIDEP be tasked to develop a secure special alert and communication system between the agency members.

International Coordination Meetings

NASA hosted ESA/NASA and NASDA/NASA meetings at Vitro which were attended by Vitro representatives. Vitro was tasked to provide meeting minutes and identify all action items and follow up on the actions taken. The Mechanical Parts action items were tracked and actions documented.

SURVEY/EVALUATION SUPPORT

The early efforts required analysis of NASA documented requirements that substantiate the Code Q oversight responsibility stated in NMI 1103.39 based on the organizational Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) functional requirements. Vitro compiled and delivered to the NASA task manager detailed reviews and analyses of NASA Management Directives, Program Directives, Code of Federal Regulations, and Federal Acquisition Regulations. One early task required review of all previous Engineering Division Reliability and Quality Assurance surveys and Safety Division surveys for corrective action closure status and provide results with recommendations for Code Q actions. The previous post Challenger accident Code Q survey of the Space Shuttle Return to Flight operations at Kennedy Space Center was a large review effort with status briefings and requests for corrective action status generated to complete the closures. Items remaining of concern to Headquarters were identified at each Center and considered for followup review in the new survey cycle. During the development of survey plans and schedules, the decision to implement the Field Installation on-site surveys was made. The transition was smooth due to NASA-contractor coordination; projected planning and implementation schedules were developed and approved by NASA.

The survey planning was implemented by Vitro with a programmed lead time for NASA management decisions as to scope, content, manning, timing, and technical support from Field Installations not being surveyed. The plan was prepared and the Survey Program Schedule was issued by the Associate Administrator to Institutional Program Management Codes and Center Directors and Safety, Reliability and Quality Assurance Directors. This was an ambitious schedule to survey all Field Installations and the Jet

Propulsion Laboratory (JPL) in a 2-year period. The undertaking was well planned and executed such that the first survey started as scheduled. The planning, preparation, and conduct milestones became the yardstick by which all NASA surveys were organized. The standard scenario consisted of scheduling a meeting of the Code Q Executive Management Council (Associate Administrator and all Division Directors) to review and identify the functional areas to be covered by the survey group and to select the survey Team Leaders. The team membership was selected from Headquarters, Field Installation, or corporate resources to provide knowledgeable, experienced personnel for each of the designated survey areas.

Vitro provided all coordination support for facsimile notices, telephone conferences, video conferences, and various meetings of the Code Q Executive Council, Survey Group and Team Leaders. In direct support of Code Q, Vitro accomplished the design and development of planning guides and forms, the receipt and distribution of resource material requested from the Field Installations, training presentation of administrative scenario and data requirements for the survey activity, preparation of draft and final individual plans, arrangements for on-site hotel meeting facilities, production of draft and final survey records and reports, tracking, analysis, and statusing of corrective action reports, and preparation of final closure status. In parallel with the survey planning, a task was assigned to create a Headquarters documentation tree relating the Quality Assurance management directives, both NMI and NHB, and the Safety management directives and federal regulations under Code Q responsibility. The relationship of each Center's management directives to the Headquarters directives was investigated and identified. A compilation of the Headquarters and each Center's management directives was obtained, reviewed, maintained, and used to provide copies to individual survey team members leading up to preparation for the Center visits.

Performance of this task during the contract term involved a biennial survey cycle scheduling each NASA Installation and JPL with a full baseline review of all active SRM&QA functional requirements. The master schedule promulgated by Code Q was maintained throughout the 2-year cycle with only one revision. This was a change in sequence for the Kennedy Space Center from the middle to the end of the schedule. The surveys were coordinated with the NASA Office of Inspector General and the resident representative at each Installation. The NASA Institutional Program Office Codes were advised by Code Q Associate Administrator letter as to the master schedule as well as advance notification before each survey was planned and executed.

Each survey cycle started with a meeting of the Executive Planning Council consisting of the Code Q Associate Administrator and all Division Directors and the designated Survey Coordinator. This meeting set the scope of the survey as to Team coverage and Areas to be Surveyed and recommended individual Team Leaders. Then, a Team Leaders meeting was held with the Chairman of the survey to further define the Areas to be Surveyed and select appropriate technical area staff to perform the survey. Subsequent survey group meetings were held to define the need for reference material to be requested from the Center and to develop tailored checklists which defined the extent of the known documented requirements by Federal Law, NASA Directive, and certain Center and State regulations. A sample of the various meetings leading up to the on-site

visit were videotaped, and a training video was produced for Code Q. This video was used to conduct training orientation for new NASA personnel who had not been exposed to the survey process during the preparation phase for each survey.

The survey approach, on-site requirements, and lodging accommodations were coordinated by the contractor for the entire survey group. An on-site organizational meeting was scheduled for the participants the evening before the start date at the hotel to check last minute arrangements and ensure all non-Headquarters participants were coordinated with their team leader before arrival at the Center.

During the on-site survey, the contractor provided a survey coordinator and administrative assistant to support the various team members in preparing typed Survey Records and access to reference documents. One innovative technique that was implemented and used to support a large volume of typing was the use of NASAMail to transmit files between Washington, D.C. and the Center. Handwritten drafts were sent by facsimile to the contractor facility, typed as individual record files, concatenated into one file, and sent via NASAMail addressed to the administrative assistant who downloaded the file and printed the final Survey Records for signature by the Center Contact, Surveyor, Team Leader, and Chairperson before the survey group departed. This provided a clear understanding of the discussion and recommendation entries by both Center and Headquarters participants. Within a week after the survey, the draft summary report sections were written and formatted by the contractor for review by Headquarters and sent to the Center for comment as to technical accuracy. The final report was then prepared for issue by the Associate Administrator to the Center, the Inspector General Office, and the Institutional Program Office. The Survey Records identifying Observations and Findings were organized into data packages and a computer data base was developed that provided status reports by various breakdowns. One report provided a listing of only Survey Records which were overdue based on the Estimated Due Date and was provided to NASA surveyors, team leaders, and the chairperson for emphasis to the respective Center.

A Center-approved SR&QA Corrective Action Plan was requested within 30 days after the final report was received and became the basis for the closed loop corrective action system. The individual response to each Survey Record was provided by Code Q to the contractor, and the assigned Survey Coordinator separated each response by surveyor and team and formulated a package for the NASA Survey Chairman to send by memo to the survey members. The memo requested the author's and Team Leader's assessment of the Center response with recommendation as to closing or not closing the Survey Record. Survey Corrective Action Plan Status Reports were prepared for response to the Center via NASA correspondence. The data base maintained all actions dated from conduct of the survey through the date of closure. The data files were updated routinely and provided to the NASA Division Director biweekly. The status reports identified Center, Date, Team Leader, Survey Record Number, Subject, Corrective Action Acceptance or Rejection Date, Estimated Completion Date, C/A Received from Center, and Team Leader and Division Director Approval Dates for closure.

The Center surveys and respective milestone dates are:

SRM&QA SURVEY PROGRAM

NASA CENTER	SURVEY DATE	FINAL REPORT	RECEIVE CAP	ACCEPT CAP	SURVEY CLOSED
JSC/WSTF	11/89	1/90	3/90	4/90	8/91
MSFC	1/90	3/90	6/90	9/90	3/92
SSC MSFC RO	3/90 3/90	5/90 5/90	6/90 7/90	7/90 9/90	1/92 1/91
JPL	5/90	8/90	10/90	1/91	10/92
GSFC	8/90	10/90	2/91	5/91	10/92
LaRC	2/91	4/91	5/91	7/91	12/93
LeRC	5/91	7/91	8/91	10/91	4/93
DFRF ARC	7/91 8/91	9/91 10/91	10/91 11/91	2/92 2/92	12/93 5/93
KSC (FMR)	11/91	3/92	5/92	8/92	OPEN-1

In addition to the Survey Report, the Vitro survey coordinator was instrumental in consolidating specific commendations and additional information from the surveyors that was considered to be a Lesson Learned. These items were drafted and formatted into a Lessons Learned Report and distributed to each Center SR&QA office for information and possible incorporation as desired.

All individual Survey Records and Center responses were filed for a permanent NASA record. At the termination of this contract, all Center surveys are closed except the last survey. The last survey was a Functional Management Review conducted at Kennedy Space Center in November 1991, and only one action recommendation is being held open. The open item is a large management reorganization and consolidation of the payload assembly process documented by both McDonnell Douglas procedures and NASA procedures. These procedures are used on the same assembly line by different employees and have different requirements and procedural activity that is being consolidated to increase efficiency and avoid possible confusion. The estimated completion date is June 1994.

With the Kennedy Space Center activity beginning the new concept of a Functional Management Review (FMR), NASA Code Q began to formulate plans to evolve to functional reviews in place of the full SRM&QA Surveys. The NASA Office of the Administrator was advancing the reorganization of the Function Management Program previously defined but never adequately implemented nor effectively utilized by the large cross-section of NASA management. There were at least two Headquarters Task Teams that started the reconstruction of the NMI. In the second group, reorganized after a change in senior management, the contractor supported both the coordination of the Headquarters Task Team

participation by Code Q and the individual Code Q establishment of a Functional Management Initiative in collaboration with all the NASA Center SR&QA offices.

The early effort involved formulating a draft FMR Guidelines strawman document and sending it to each Center SR&QA office for comment. There were a couple of telephone conferences to discuss the Code Q/Center approach, and the Code Q manager assigned to this item was changed three times. The Headquarters Task Team formed a subtask team to define the Roles and Responsibilities of each management entity. The contractor support continued and the effort expanded to provide coordination for the next Headquarters subtask team that was assigned to draft the revised NMI 1240.3 implementing the rewritten roles and responsibilities. The review comments and modifications were maintained and provided by Code Q to Code J for final approval and distribution.

During the last two task order periods, the coordination between Headquarters and the Centers was solidified to implement a direct approach to the Functional Management Self-Assessment Initiative. The Headquarters revision to the Functional Management Program was recommended to Vice President Gore's National Performance Review as an example of "Reinventing Government" and was accepted as one of the NASA Laboratories. Code Q is using the Functional Management Initiative Working Group to implement the self-assessment concept and individual Center accomplishment. The Center implementation plans are used to report the Code Q status via Code J to the Administrator. The working group collaboration is ongoing and will be pursued rigorously in the future to ensure that the revised program achieves the desired success and that programmatic weaknesses are identified and corrected.

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

Vitro personnel have contributed to the development and implementation of an effective NASA program for Electrical, Electronic, and Electromechanical (EEE) Parts. (EEE parts was a subtask under the Task Order 1000 Series until 1993; see Task Order 4000 for the most recent EEE parts activity.) Support has been provided in such areas as: the preparation and integration of EEE parts program documentation; organization, support, and participation activities for meetings, committees, and working groups; support of the review and integration of Research Technical Operating Programs (RTOPs); development and preparation of presentations and a film on NASA EEE parts programs and activities; support to and participation in field installation surveys; and parts investigations, analyses, reports, and database activities. The highlights of the activities performed for the EEE Parts Program task are summarized in the following paragraphs.

During the first year, NHB 5300.4(1F), "Electrical, Electronic, and Electromechanical (EEE) Parts Management and Control Requirements for NASA Space Flight Programs," was finalized and issued. Vitro contributed to the preparation of the provisions in that document and coordinated its review and approval by NASA field installations and Headquarters codes. Subsequently, proposed improvements of key provisions have been prepared and coordinated based on Inspector General investigations, changes in the state-of-the-art of EEE parts management practices, and discussions with NASA activities, other government agencies, and industry associations.

Vitro also revised the two key NMIs on EEE Parts. The review, approval, and issuance of NMI 5320.5B on the "Basic Policy for Electrical, Electronic, and Electromechanical (EEE) Parts" and NMI 5320.6B on "Implementation of NASA Standard Parts Program" were accomplished. These documents provide the basic requirements for the NASA EEE Parts Program.

A working group was organized and monitored to develop new and revised NASA NHBs on standard electronic packaging workmanship requirements. Vitro then coordinated the final review, approval, and issuance of the documents. These NHBs included "Requirements for Soldered Electrical Connections," "Requirements for Interconnecting Cables, Harnesses, and Wiring," "Requirements for Crimping and Wire Wrap," "Requirements for Printed Wiring Boards," "Requirements for Conformal Coating and Staking of Printed Wiring Board and Electronic Assemblies," "Design Requirements for Rigid Printed Wiring Boards and Assemblies," "Requirements for Surface Mount Device Assemblies," and "Requirements for Control of Electrostatic Sensitive Devices."

Efforts were also undertaken to promote the joint development and utilization of documents with other government agencies and industry associations. Vitro made numerous comparisons of NASA documents with key industry and government documents covering similar requirements and contributed to discussions with the AIA, NSIA, and Department of Defense to promote joint use of standards for EEE parts management, soldering, and electrostatic sensitive devices. Also, efforts were initiated to help develop a revised version of the Air Force Space Division MIL-STD-1546 on Requirements for Management of Parts, Materials, and Processes which may provide integration of requirements now contained in NHB 5300.4(1F). Recently, Vitro contributed to the preparation of a Memorandum of Understanding with the Air Force Space Division to jointly utilize standard documents in the future.

Vitro provided key technical and organizational support to meetings of NASA personnel, meetings with other government agencies and industry organizations, and meetings with the European Space Agency (ESA) and the National Development Space Agency of Japan (NASDA) on EEE parts. This included preparing meeting agendas and reports, organizing and coordinating the meetings, providing facilities, acting as a member of the NASA Headquarters team, and contributing technical advice and consultation.

Vitro was instrumental in organizing a NASA Parts Steering Committee to provide coordination and interchange of information among NASA field installations. Meetings of the steering committee were organized and coordinated at Vitro facilities and at Goddard Space Flight Center (GSFC), Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), Lewis Research Center (LeRC), Langley Research Center (LaRC), and the Jet Propulsion Laboratory (JPL). Recently, the importance of the steering committee was enhanced by providing it with the responsibility of approving and managing the efforts of the Research Technical Operating Programs for EEE parts.

Key working groups of the NASA Parts Steering Committee were also organized and coordinated. A working group on radiation has been successfully organized to coordinate the important efforts in this area at the Jet Propulsion Laboratory and the Goddard Space Flight

Center. Other working groups cover parts data bases, Monolithic Microwave Integrated Circuits (MMIC), advanced microelectronics, and standardization.

Vitro has also participated in and contributed to joint parts meetings with the ESA and the NASDA. Two meetings between ESA and NASA were hosted by Vitro, key Vitro participation was provided, and meeting minutes and action items were prepared and issued by Vitro. Also, Vitro personnel represented NASA Headquarters at an ESA Parts Conference in Noordwijk, Netherlands, presenting a paper on NASA activities and programs. Vitro also hosted two meetings between NASDA and NASA, providing key participation and coordination activities.

A joint committee of participants from NASA and the AIA and NSIA industry associations was organized, with several meetings hosted by Vitro. Participation was provided by Vitro in an EEE parts working group. Procedures were set up so that NASA documents could be forwarded to the NSIA and AIA representatives to obtain coordinated industry comments on NASA documents and standards.

Vitro also supported the participation of NASA representatives in a Space Parts Working Group that meets annually to provide interchange of parts information. The working group is jointly sponsored by NASA and the Air Force Space Division and includes participation by representatives other government agencies and from all major space industry contractors, subcontractors, and parts manufacturers. Organization of a NASA presentation for several meetings was organized and coordinated.

Recently, a United States Space Parts Committee was organized as an outgrowth of the Space Parts Working Group to review and improve space parts practices, procedures, and activities. Vitro personnel have supported the committee at the request of NASA, providing members of several working groups and helping to present the NASA viewpoint in deliberations and documentation.

Vitro personnel also provided support at meetings related to EEE parts sponsored by other NASA Headquarters offices and jointly prepared and presented papers with NASA personnel. These included a Space Transportation Conference at Williamsburg, VA, and a Memory Device Utilization Conference at Columbia, MD. Vitro representatives also periodically participated in meetings of the Space Station Parts Advisory Board and at meetings on parts problems related to the Space Shuttle, Mars Observer, the Hubble Space Telescope, and other projects.

NASA Headquarters provides significant funding to field installations to have their contractors develop and implement research technical operating programs (RTOPs) to provide improvements in EEE parts reliability, standardization, and technology utilization. Vitro has significantly aided the NASA EEE parts manager in selecting, monitoring, and managing the development and implementation of such programs.

A major RTOP involves parts standardization and data base activities at the Goddard Space Flight Center through a NASA Parts Project Office (NPPO). Vitro was instrumental in organizing meetings at Goddard at which the NASA personnel and their contractors who are

part of the NPPO provided presentations on the status of their activities. Also, support was provided in reviewing NPPO reports and activities and providing consultation to NASA Headquarters on effectiveness and recommendations for improvements and activities such as the issuance and updating of the NASA Standard Parts List MIL-STD-975 and comments to MIL parts specifications used by NASA.

A number of RTOPs on advanced technologies are being conducted at the Jet Propulsion Laboratory. Vitro has accompanied NASA Headquarters personnel on numerous visits to JPL to review the status of the programs. Vitro recommended the initiation of an Advanced Microelectronic Parts Program to provide recommendations to NASA projects or reliability of devices in new technologies and recommendations as to their use. This program has resulted in a major addition to MIL-STD-975, with Vitro supporting its integration with the NPPO. Vitro also significantly contributed to the development of other JPL programs such as Radiation, Test Structures, an ASIC Manual, X-Ray inspection of metallization, and surface mount technology.

Vitro has participated in yearly reviews of presentations by the RTOP managers and has provided recommendations for improvements and development of new programs. A database development program at the Lewis Research Center and a joint Microwave Monolithic Integrated Circuit program by Johnson Space Center and the Jet Propulsion laboratory are examples of successful programs which Vitro helped organize and put into effect.

NASA Headquarters also funds the Naval Surface Weapons Center at Crane, Indiana, to provide EEE parts activities. Vitro has provided significant actions in monitoring the NSWC efforts and recommending new and improved support activities. Vitro personnel participated in a visit to Crane and participated in periodic meetings to review status and plans. Visits to the Air Force Rome Laboratory and the Defense Electronics Supply Center (DESC) also had significant participation by Vitro personnel.

One of the initial tasks provided to NASA as part of the EEE parts program support was the preparation of a videotape on NASA EEE parts activities. Vitro personnel scripted the videotape and produced it, providing significant clips of EEE parts organizations and activities at NASA Headquarters, Goddard Space Flight Center, and Jet Propulsion Laboratory. The videotape was distributed to and presented at all NASA Field installations and to several Government agencies and contractors. The NASA EEE Parts Program videotape was praised by most viewers and is often used as an example of the type of v videotape other activities should prepare. It is periodically shown on NASA Select.

Many technical presentations and papers were prepared for NASA parts personnel for meetings, conferences, and briefings. Major presentations and associated technical papers were prepared for the NASA Space Transportation Conference and the ESA Parts Conference. Vitro also prepared briefings for meetings of the NASA Parts Steering Committee, the Space Parts Working Group, and meetings with Government Agencies and Industry. Briefing charts were prepared for many other meetings and periodic reports to management on a continual basis, as often as every week. Vitro personnel developed, prepared, and presented briefings on a program to streamline the management EEE parts by

minimizing Nonstandard Parts Approval Requests and utilizing major space contractor parts management programs and parts lists.

Vitro EEE parts personnel also prepared and presented monthly reports to NASA Headquarters personnel as part of the overall NASA support contract. These included monthly written status reports and monthly oral presentations.

Vitro personnel participated on the EEE parts teams for the NASA Headquarters product assurance surveys of Field Installations. Support was provided in development of checklists, preparation of reports, and resolution of findings resulting from the surveys. Significant participation was provided at many of the survey sites, including Marshall Space Flight Center, Lewis Research Center, and Jet Propulsion Laboratory.

A key aspect of the survey support was the synergy with other Vitro members of survey teams. Many of the findings were applicable to several areas, and Vitro efforts helped form a bridge between the areas. Also, the survey participation provided significant relationships for Vitro personnel with NASA personnel at the Field Installations. These relationships were important in providing support for many of the other tasks associated with the EEE parts program.

Vitro personnel performed or participated in parts investigations and analyses, resulting in the preparation of reports with significant findings and recommendations. The efforts were related to general problem areas such as GIDEP alerts, Inspector General investigations, and data base development, as well as project-related investigations for the Space Shuttle, Mars Observer, Hubble Telescope, Space Station, etc.

An important aspect of the EEE parts program task was related to GIDEP alerts. Continuous review of all GIDEP alerts on EEE parts was conducted, and monthly summaries of the alerts were prepared and distributed to Headquarters and Field Installation personnel. These summaries were included in parts newsletters which were distributed by the NASA Parts Project Office to NASA Field Installations and contractors. Also, many requests were received from NASA Headquarters personnel to perform specific searches of GIDEP alerts for specific parts and part manufacturers and to provide summary reports on the searches.

Vitro personnel supported investigations and analyses related to Inspector General findings. We provided reports and consultative advice for investigations of fraud related to items such as resistors, circuit breakers, and semiconductor devices. Significant contributions were made to testimony provided to Congressional committees by the NASA associate administrator. Also, support was provided in meetings pertinent to the investigations with representatives of the Inspector General and other NASA Headquarters offices and Field Installations.

Vitro supported many parts investigations related to specific projects. Vitro personnel participated in meetings on significant problem reports and provided recommended actions to teams formed to investigate specific problems. One effort was the review and discussions of proposals for the Space Station use of commercial parts and Class B parts. Inputs were provided to the team investigating hybrid microcircuit reliability in gyroscopes used on the

Hubble Telescope. Recommendations were provided in the investigation of possible sensitive switch failures related to Goddard Space Flight Center projects. Recent efforts were significant in supporting the Mars Observer investigation of possible failures of transistors, tantalum capacitors, and microwave devices.

Another task Vitro performed was related to the development of databases for EEE parts. Reviews were made of the efforts and outputs of the NPPO development of the EEE Parts Information System (EPIMS), including participation in meetings and demonstrations. Also, Vitro personnel were instrumental in the development of a Folio-based data system which provides for the full-text search of reports from such sources as GIDEP alerts and the JPL radiation data bank.

Specific general problem investigations were performed by Vitro personnel and reported on to personnel at NASA Headquarters and Field Installations. An example of this was a major investigation of failure modes of Philips resistors related to their use in NASA projects.

III. CONCLUSIONS AND RECOMMENDATIONS

NASA should consider having a single parts, materials, and processes program incorporating activities currently included in the Electrical, Electronic, and Electromechanical Parts; Mechanical Parts; Materials and Processes; Electronic Packaging; Non-Destructive Evaluation; and Metrology and Calibration Programs.

As this contract closes, the Functional Management Self-Assessment Initiative is programmed to be implemented over the next few years. The Functional Management Program is very important to NASA. It ensures that suspected material weaknesses and problems are resolved and positive results are shared. Accomplishing the oversight functions improves or corrects each functional discipline or process. Code Q defined responsibility for Functional Managers at Headquarters and Field Installations and established the initiative at the Installation level. While continuing to pursue the initiative at the institution level, Code Q must emphasize the Headquarters program manager oversight assistance and involvement.

There should be a uniform format for reporting self-assessment activity including results of both corrective actions and beneficial lessons learned, so that the individual Center reports may have recognizable commonality. Code Q should ask the Self-Assessment Working Group to define a common data base and oversee its creation, distribution, and operation to catalog and track self-assessment results at each installation. This will give the Center Directors and the Headquarters management a uniform view of the Center activity reports.

2000 SERIES TASK ORDER
SAFETY AND RISK MANAGEMENT

I. BACKGROUND FOR THE OVERALL TASK

From the beginning of the contract, the impetus of the 2000 series task orders has been to provide oversight over the safety aspects of the Space Flight Programs and over the institutional safety programs throughout the 9 NASA Field Installations. A major part of those efforts included creation of new safety manuals and revision of existing ones. Typically, the 2000 series task orders provided four types of technical support to the NASA Headquarters Safety and Risk Management Division (formerly the Safety Division):

- Analysis and assessment of selected NASA systems to ensure compliance with applicable safety standards — systems such as space nuclear power systems, the Space Station, the Space Shuttle, Unmanned Launch Vehicles, and payloads for both launch systems.

- Safety assessments to ensure institutional compliance with safety standards, regulations, and legislated codes/consensus standards. The span of effort included safety of flight explosives and ground support operations unique to spaceflight, facility design and operation, occupational safety, fire protection, aviation safety, and hazardous materials handling.

- Development of new policies, manuals, training courses, tools, and techniques. Included were such items as the basic safety policy for the Space Exploration Initiative; improved methods for performing Software Safety Analysis, Human Engineering Safety Analysis, and Risk Assessments; 3 computer-based systems for the NASA Safety Information System; automated support tools for creation and maintenance of Code QS safety documentation; 30 new safety manuals and NMIs; revisions to 16 existing safety manuals and NMIs; and 4 new safety training courses.

- Establishment and maintenance of the Code QS technical library in a configuration that would permit quick access to safety reports and correspondence by Code QS personnel and to the databases for tracking problems and extracting pertinent data for evaluation by QS engineers.

II. SUMMARY OF TASK ACTIVITY

This task order has consistently comprised 16 distinct areas:

Payloads System Safety Analysis*
Space Transportation System (Space Shuttle) Safety Analysis*
Aerosystems and Facilities
Space Station (Freedom) Safety*
INSRP (Nuclear Power System Safety) Support

NSIS (Safety Information Systems) Development
Risk Assessment
Software Safety*
Human (Factors) Engineering*
OSHA Safety and Fire Protection
Flight and Ground Operations Safety (Explosives Handling Safety and Emergency Preparedness)
Unmanned Launch Vehicle Safety and US System
Safety Library Document and Safety Data Base (Records) Maintenance
Aviation Safety
Operational Engineering Panel
Safety Documentation Development and Update
Safety Training Development

With the reorganization of Code Q in 1992, several safety areas (indicated with an asterisk) were deleted from the 2000 series of task orders, and others were added: Trend Analysis, System Assessment, Data Systems, and support for Prelaunch Assessment Reviews.

Throughout the contract, Vitro engineers developed and maintained a keen awareness of critical issues impacting mission readiness in order to provide technically competent input for NASA decisions. By continual participation in Design Reviews, Phase Safety Reviews, Prelaunch Assessment Reviews, meetings of the Intercenter Aircraft Operations Panel, meetings of the DoD Explosive Safety Board, meetings of the Interagency Nuclear Safety Review Panel, etc., we were able to offer timely recommendations in real time as new issues surfaced. Our dedication to these tasks was instrumental in moving George Rodney/Q and Richard Perry/QP to confer a certificate of recognition for "Support to the Office of Safety and Mission Quality" in June 1990. We succeeded because of participation in the following reviews, teleconferences, and meetings:

- Daily Space Shuttle teleconferences and meetings to stay abreast of Space Shuttle safety matters.
- Daily unmanned launch vehicle tagup meetings to stay abreast of unmanned launch vehicle safety matters.
- Payload Phase Safety Reviews to gain insight regarding the overall health of the payload safety process.
- Facility Safety Reviews to gain insight regarding the overall health of safety processes for the wind tunnels and other facilities.
- Space Station Preliminary Design Reviews to penetrate the complexities of and problems with its design safety program.
- Meetings of the Interagency Nuclear Safety Review Panel to track the progress of the Program Offices' assessments of radiological risks.
- Meetings with NASA's data base users to ascertain the real underlying requirements for each proposed NASA Safety Information System.

- Headquarters surveys of the NASA Field Installations to determine their compliance with federally mandated safety requirements.

- Project meetings at the NASA Field Installations that are developing new methods for Probabilistic Risk Assessment midwifing emerging risk assessment technologies.

- Meetings with NASA's software developers ascertaining the NASA environment and its potential impact on the adequacy of the software to provide safety.

- Meetings with NASA Field Installation safety personnel working Human Engineering safety issues.

- Meetings with NASA Field Installation safety personnel working suspended load crane safety issues, pressure vessel recertification issues, OSHA safety issues, etc.

- Meetings of the National Fire Protection Association working the Halon alternatives issue (among others).

- Meetings with NASA explosive safety officers working the issues of proper shipping and storage of chemical energy sources (hydrazine, ammonium perchlorate, and a variety of small solid rocket motors).

- Meetings of the NASA aviation safety officers at all the field installations staying abreast of aviation safety issues in the NASA environment.

- Various design reviews to obtain information to apply in technical assessments.

- Trend Analysis Working Group meetings to gain insight to facets of the major programs that may benefit from trend analysis.

- Meetings of the NASA Reliability and Maintainability Steering Committee to improve the NASA reliability program.

- Meetings with NASA Field Installation safety personnel to gather an understanding of underlying issues and developing the appropriate wording for revising NHB 1700.1(V-1), "The Basic Safety Manual."

In addition, the Vitro safety team has completed an impressive number of projects during this contract period in the following key areas:

Aerosystems and Facilities Safety: Provided updates to the NHB for Aerosystems Safety and the NHB for Facilities Safety, provided an update to the "Construction Safety" chapter of the Basic Safety Manual, participated in safety review meetings at three NASA Field Installations (ARC, LaRC, and LeRC), participated in wind tunnel project safety audits at these same three Installations, extracted failure data from the run records of the LaRC 8-foot wind tunnel in support of the probabilistic risk assessment performed by Code QS and provided a chapter for the final report explaining how the data was compiled, provided an evaluation

report on the DoD Facilities System Safety course, evaluated the safety aspects of wind tunnel rehabilitation and modification projects and provided comments to Lonnie Owen/QS, assessed NASA procedures and NASA Field Installation safety assurance programs for wind tunnel rehabilitation and modification projects, and participated in directors oversight committee meetings at the NASA Field Installations.

Payload System Safety Analysis: Provided support for a total of 105 payloads; evaluated of 269 payload safety data packages; developed and delivered to Code QS a working draft of NASA Safety Standard NSS/SY1740.X, "Payload and Cargo Element Safety Requirements"; and evaluated the Commercial Draft Specification of Standard Spacecraft/Launch Vehicle Interfaces for Medium and Intermediate Size Spacecraft.

STS (Space Shuttle) Safety — Efforts in this area have been outstanding from the beginning. Our goal has always been to provide real-time Mission Safety Evaluations at each major decision point in the launch flow. The "Special Service Honor Award" conferred on the Vitro team in July 1990 attests to our success in that endeavor.

We began by establishing a computer-based hazard tracking system. Then for 27 missions, we prepared and delivered up-to-the-minute Mission Safety Evaluation Reports immediately prior to each Prelaunch Assessment Review, each Flight Readiness Review, each Flight Readiness Firing, and each Launch-Minus-2-Day Review. Provided direct support to Jerry Moore/QS at KSC during each Flight Readiness Review, each Launch-Minus-2-Day Review, and each Launch-Minus-1-Day Review. Manned the Code Q Management Information Center for prelaunch support to Code QS at NASA Headquarters and to Jerry Moore/QS at KSC for problem assessment and resolution during the prelaunch hours for all 27 missions. Prepared and delivered the postflight editions of the Mission Safety Evaluation Report for 27 Space Shuttle missions. Supported the System Safety Review Panel and Program Requirements Control Board Reviews for at least one session for each of the 27 Space Shuttle missions. Provided an update to NSTS 22254, "Methodology for Conduct of NSTS Hazard Analysis." Developed a new initiative with Code QP and Vitro OSP personnel that proposed a forum for discussion and presentation of long-term Space Shuttle program enhancements.

Space Station (Freedom) Safety — Began this effort by developing a Space Station Freedom Safety Program Plan, a Hazard Analysis Methodology Report, a Database Requirements Report, a first draft of SSP 30315, "Space Station Users Requirements Document," and a first draft of SSP 30309, "Safety Analysis and Risk Assessment Requirements." Provided an evaluation of 37 PDR data packages, and participated in 29 Space Station Freedom Design Review meetings for which synopsis reports were prepared for Code QS. Provided an evaluation of 31 Space Station Payload Safety Review Data Packages. Developed proposed NHB 1700.7C, "Safety Policy and Requirements for Payloads." Conducted comparison of FMEAs and Hazard Reports for the JEM Pressurized Module and Exposed Facility in support of the JEM PDR. Assisted in the definition of the basic safety policy for the Space Exploration Initiative. Provided an evaluation of the following documents:

SSP 30XXX, "Space Station Freedom Integrated Safety Program Plan"

SSP 30599, "Safety Review Process for Space Station Freedom Program"

NHB 5300.4 (X), "NASA Assurance Terms and Definitions"	The Revised SSF MB-06/Stage 6 Integrated Fault Tree
COL-RQ-ESA-027, "COLUMBUS Product Assurance/Safety Technical Requirements for Payloads To Be Integrated into the APM Launch Configuration"	CR HH900106, "Safety Requirements Relative to Fail-Safe and Payload Failure Propagation"
CR BB003198A/SSP 30652, "SSFP Safety Requirements for On-orbit Operations"	The Safety Analysis Report for the Crew Health Care System

NSIS Development: Performed an Independent Verification and Validation of the software for the Mishap Reporting/Corrective Action System and the software for the Lessons Learned Information System. Developed a software tool to facilitate buildup of the Space Shuttle Mission Safety Evaluation Report. Developed a second software tool to facilitate maintaining an up-to-date Safety Training Catalog. Developed a third software tool, "The OSMA Document Management System Program," to facilitate incorporation of comments during the development or update of any OSMA document. Developed and provided a users guide for each of the three software tools. Worked on the NASA Code Q budget program software to restore the FY 1992 capabilities that were deleted when procedure was run to prepare the program to accept the FY 1993 budget data. Participated in NASA Code Q Budget Program Joint Application Development meetings. Performed technical evaluation and requirements analysis for elements of the Decision Support System. Performed a technical evaluation of Relational Database Management Systems versus Text Management Systems for supporting Code QS information search and retrieval; performed a follow-up study providing additional detail on full-text, variable-field-text retrieval systems. Completed development of the Code Q Correspondence Management System concept specification, the draft Code Q Travel Tracking Program Specification, and the draft Code Q Local Area Network Management Plan. Developed the Lessons Learned Information System functional test check list used to control the preliminary verification testing of the *INGRES* version of the system.

- Provided technical inputs to the system architectural design during in-process reviews held at the Assurance Data Systems Office, GSFC. Provided technical input to application development meetings on the Earth Observation System program development status monitoring, the Reliability Preferred Practices interface to Lessons Learned proposal assessment, the Potential Issue/Problem Identification Committee's proposal for an Independent Assessment Catalog program, and the draft Fastener Information Management System design.

- Assisted in bringing three systems through a complete development cycle -- the Mechanical Parts Information Management System, the EEE Parts Information Management System, and the NASA Alerts Reporting System. For each of these three systems we evaluated the draft Requirements Specification, developed a set of

test acceptance criteria to be used with the test procedure, prepared and distributed the Acceptance Test Traceability Report, worked with the PARAMAX in-house test team during the software functional verification that preceded the acceptance test, conducted the acceptance test and the acceptance demonstration, and prepared the Software Acceptance Test report.

- Downloaded, assembled, and presented data used in Prelaunch Assessment Reviews. Wrote queries to retrieve detailed problem reports (when required) from the various NASA problem reporting databases, retrieved pictures from NASA Field Installations (when required) depicting damaged hardware or defects, and continuously acquired performance information on newer versions of the data retrieval equipment, seeking potential system upgrades. Maintained and updated the charts in the Code Q Management Information Center to reflect several types of data -- trend analysis charts, technical issues, and generic trending. Drafted a document describing the entire Prelaunch Assessment Review process, including data creation, transmission, and display guidelines and requirements. Participated in a working group for automating the process of providing data support for the Prelaunch Assessment Reviews.

- Provided an evaluation of the Assurance Data Systems Office Software Development Guide, the requirements for the EEE Parts Information Management System, and the draft Concept Specification for the NASA Assurance Information System. Conducted Customer Acceptance Testing for the EEE Parts Information Management System and prepared the test report.

INSRP Support: Supported the development of the Safety Evaluation Report for both the Galileo and the Ulysses missions. Because these efforts had been forced into an extremely optimistic schedule, the production of these two reports to the White House required a great deal of close order drill in the final weeks. The degree of professional support provided by the Vitro team led to a letter of commendation from Chuck Mertz (then Director of the Safety Division) "for Outstanding Support to the Interagency Nuclear Safety Review Panel."

In addition to providing continual suggestions for evaluating radiological risks, the Vitro team made a number of significant contributions. Provided the minutes for several meetings between the Interagency Nuclear Safety Review Panel and the Program Offices for the Galileo, Ulysses, Cassini, and TOPAZ Missions. Provided technical input to Launch Abort Subpanel meetings and Power System Subpanel meetings (in fact, the Power System Subpanel conferred recognition on the Vitro team via an acknowledgement in their subpanel report for the Ulysses mission, "For material contributions to several working meetings.") Completed an NMI on the use of radioactive materials in space and updated the chapter of the Basic Safety Manual dealing with the Interagency Nuclear Safety Review Panel and the process for evaluating radiological risks of missions that use nuclear power systems. Provided an evaluation of the following items:

The Final Safety Analysis Report for the Galileo Mission

The Final Safety Analysis Report for the Ulysses Mission

Several versions of the TITAN IV Databook developed by the Cassini Program Office

The DOE Overall Safety Manual

The Radioisotope Thermoelectric Generator Safety Assessment for the Cassini Mission

The TOPAZ II Preliminary Safety Assessment Report

The Cassini Mission Environmental Impact Statement and its supporting studies

The Cassini Mission Earth Swingby Analysis

The draft test report, "Feasibility Investigation for Performing Fireball Temperature Tests"

The draft document, "Launch Approval Process Guidelines"

The Environmental Assessment for the Mars Environmental Survey Pathfinder Mission

Risk Management: In this area, Vitro was a major player in assisting Code Q in introducing to the NASA Field Installations the newly emergent technology for performing risk assessments using statistical methods. Our efforts won a letter of recognition "For outstanding risk assessment support to the Risk Assessment Office" in August 1990 and a second such letter "For exceptional support to the probabilistic failure analysis assessment team" in January 1992.

Assisted in the Code QS development of a workshop to disseminate newly evolved methodologies for Probabilistic Risk Assessment. Developed and executed a plan for enhancing the existing hazard analysis methods for the Space Shuttle. Provided extensive input into the INSRP uncertainty analysis for the evaluation process on the Ulysses mission. Evaluated several commercially available software programs for use in probabilistic risk assessment of system failure scenarios. Provided a position paper to Code QP on the required statistical precision of sample sizes to ensure an upper limit on uncertainty for their use during their NASA Field Installation surveys. Developed a prioritization scheme for Space Shuttle risks. Performed an evaluation of the JPL low-cycle fatigue estimation software code. Developed NMIs on future space debris limitations and on risk management requirements. Developed a position paper on reliability goals for the National Launch System. Developed a proposed revision to the Space Station Freedom risk assessment worksheet as presented in SSP 30309, "Safety Analysis and Risk Assessment Requirements." Developed a 3-year plan for activating the new risk assessment methodology throughout NASA. Provided an extensive review and rewrite of the Orbital Debris Handbook initiated by JSC. Coordinated the comment and rewrite effort for the Orbital Debris NMI and the Risk Management Policy NMI. Developed a list and rationale for future support projects in Risk Management/Risk

Assessment. Developed a draft of a probabilistic design survey for MSFC and for the Engineering Management Council. Prepared a general outline for a Risk Assessment Handbook. Coordinated (with MSFC, LeRC, and Symbiotics Technologies Inc.) the evaluation of the Workstation (software, databases, and user's guide) being developed under subcontract to Science Applications International Corporation.

Participated in the joint effort on the uncertainty analysis for loss of berthable attitude for the Space Station redesign. In particular, developed the debris impact numerics and model and authored the Extra Vehicular Activity input portion of the report. Reviewed and modified the briefing and results for final presentation to the Space Station Transition Team. (The Space Station option assessment was performed in conjunction with Mike Frank/SFA, SAIC, and two members of Code QS -- Pete Rutledge and Ben Buchbinder.) Provided an evaluation of the following items:

- Solid Rocket Motor failure rate quantification refinement
- The TITAN IV Databook
- The JPL methodology for certification of Space Shuttle Main Engines
- The MSFC risk assessment method for the aero-assist Flight Experiment
- The ARC risk assessment for life support systems
- The JSC Space Shuttle assured availability program
- The JPL probabilistic failure estimation methodology
- A statistical analysis for Intelsat satellite regulator reliability
- An assembly risk assessment document for Space Station Freedom
- The response surface methods for MSFC
- An air pallet risk trade study for the Advanced Solid Rocket Motor
- The system requirement design document for the National Launch System
- A Range Safety Study performed by ACTA for the Air Force
- The FSAR uncertainty analysis generated by the Ulysses Program
- The MSFC WeiBayes method of extending risk assessment data
- The Code QP method for statistical analysis for air quality surveys
- The JSC integrated risk assessment plan for Space Station Freedom
- The MSFC single-flight-reliability estimation method
- The MSFC probabilistic methods for factor-of-safety calculations
- A FMEA/CIL ranking method developed by the University of Virginia
- A study on the Space Shuttle orbiter strut failure probability
- The reliability design goals for the National Launch System
- The JPL goodness-of-fit study for the failure data used in its method
- The KSC assessment of the JSC Shuttle assured availability program

Monthly University of Virginia reports on Risk Ranking and Screening	The MSFC review of the JPL probabilistic failure assessment method
The LaRC method for reliability trend assessment of small samples	A proposed JSC Management Instruction on Risk Management
The JSC Orbital Debris assessment software	The JPL electro-optical probabilistic failure assessment proposal

Unmanned Launch Vehicles: Performed an evaluation of the Orbital Maneuvering Vehicle software and provided comments to Lonnie Owen/QS. Initiated effort to generate a system safety handbook for expendable launch vehicles. Provided prelaunch planning support as well as support during the final launch countdown for a total of 11 launches on a variety of unmanned vehicles. These efforts included the preparation and delivery of Mission Success Evaluation Reports immediately prior to each Flight Readiness Review as well as an update immediately prior to each launch. Completed preparation and delivery of seven postflight Mission Success Evaluation Reports. Participated in a number of preflight decision reviews:

Delta/EUVE vehicle-on-stand review	NASA Headquarters Mission Readiness Review for Scout/SAMPEX
Mars Observer Project Launch Readiness Review	Mars Observer Contamination red team follow-up review
Titan III/TOS preflight review	Titan III/TOS/Mars Observer Mission Readiness Review
Titan III/TOS/Mars Observer mission director's Flight Readiness Review	Titan III/TOS/Mars Observer launch management Coordination Meeting

Human (Factors) Engineering Safety Analysis: Reworked an existing Vitro methodology for performing human factors safety analysis and provided an Integrated Human Engineering/Safety Analysis Methodology for application to NASA development projects. Developed a draft Human Factors NMI, a preliminary NASA Handbook on Human Factors Safety, and a NASA Safety Standard, "Human Engineering Guidelines for Safety Assurance." Worked extensively with Code QS and the NASA Field Installations to initiate Human Factors Safety analysis efforts throughout NASA — a process that had been totally lacking prior to the onset of Vitro's contract. These efforts included the development of quarterly human engineering briefings that were presented periodically to various NASA Field Installation personnel gatherings, the evaluation of the JSC Human Factors/Safety Training course, and the development of program plans for a prototype Human Engineering Program and a prototype Human Error Avoidance Demonstration Program. Also provided evaluation and oversight of the Human Error Avoidance Demonstration Program. Enhanced a video of the KSC student intern's presentation of his NASA Human Factors Engineering evaluation. Also edited this

video (initially 1 hour and 15 minutes long) to create a 30-minute version and a 10-minute version for Code QS' use in familiarizing NASA leaders with potential Human Factors program benefits.

Software Safety: Reworked an existing (pre-NASA contract work) Vitro methodology for performing software safety analysis and provided a methodology for application to NASA software development projects. Worked extensively with Code QS and the NASA Field Installations to initiate software safety analysis efforts throughout NASA — a process that had been totally lacking prior to the onset of Vitro's contract. These efforts included participation in software safety audits at the NASA Field Installations, evaluations of software development plans, participation in working group meetings, preparation and presentation of briefings and papers, and assistance in the development of safety requirements for software development design reviews, and participation in Technical Interface Meetings to establish a safety database for software. Converted an existing set of Vitro software safety objectives and provided a set of NASA specific software safety objectives. Assisted in numerous investigations of anomalous incidents throughout NASA systems that were found to be the direct result of software coding errors or software design oversights. Developed a NASA Software Safety Requirements Document. Developed a software safety standard and completed a software safety status report to be presented by Code QS to George Rodney/Q. Completed development of a NASA Software Safety Plan. Completed the draft NASA Software Safety Program plan and the draft NASA Software Safety Guidelines. Participated in Space Station Freedom software safety meetings and teleconferences to finalize software safety requirements and software documentation needs. Provided an evaluation of the following items:

A Space Station Freedom Software Fault Analysis Requirements Document

The Software Safety Program Plan prepared by JPL

The Software Systems Safety Handbook prepared by JPL

Aviation Safety: Worked extensively with Code QS and the NASA Field Installations to ensure adequacy of programs for aviation safety. These efforts included the development of an NMI on the subject of aviation safety, the development of a chapter on aviation safety for inclusion in the Basic Safety Manual, the development of a comprehensive aviation safety officers reference guide, the development of an aviation safety policy document for Code Q, assistance to Code J in the development of their aviation safety policy document, the development of a position paper on crew safety, research for Code QS in preparation for the proposed development of a kit for use by Space Shuttle mishap investigation teams, the development of a mishap investigation "fly-away" kit to help prepare investigators and other people involved in accident investigation, the Preliminary Draft Mishap Investigation Team Administration Manager Checklist of Duties, participation in the semi-annual meetings of the Intercenter Aircraft Operations Panel, participation in the periodic meetings of the Interagency Committee for Aviation Policy, participation in periodic aviation maintenance meetings, participation in periodic aviation safety reviews at the NASA Field Installations, participation as a team member during the NASA Intercenter Aircraft Operations Panel review of the aviation operations

at five NASA Field Installations (GSFC, MSFC, DFRF, LeRC, and KSC), and preparation of a paper that Vitro presented during the annual NASA Aviation Safety Officers Meeting. Participated in the ARC Aircraft Science and Applications Program Annual Review meeting. Provided an evaluation of the following items:

Data on the F/A 18 mishap	NTSB mishap investigation checklists
Federal Aviation Administration mishap investigation checklists	DoD mishap investigation-related checklists

OSHA and Fire Protection: Worked extensively with Code QS and the NASA Field Installations to ensure adequacy of programs for facility safety, occupational safety and health, fire protection, and hazardous material safety throughout NASA. Our effort won a NASA "Special Service Group Award" in August 1990, a letter of recognition "For professional support to the SRM&QA survey at LaRC" in February 1991, and a Certificate of Appreciation from the Construction Specification Institute "For outstanding achievements" in October 1991.

The completion and distribution of NHB 1700.1 (V1-B), "NASA Safety Policy and Requirements Document" was the most significant of these efforts because it will serve as the foundation for all safety programs at all nine NASA Field Installations (and Headquarters) for the next decade.

Efforts included developing a 5-year operating plan for electrical systems analysis; developing a 5-year operating plan for Fire Protection Systems Analysis; evaluating the fire risk NASA-wide; revising RP-1, "Recommended Practice for the Fire Protection of Essential Electronic Equipment"; participating in the periodic meetings of the Federal Fire Forum; tracking NASA compliance with the EPA regulations on HALON; tracking fire regulations at other Federal agencies; monitoring the fire protection systems at the NASA wind tunnel facilities, and revising the fire protection chapter of the Basic Safety Manual. Completed the NASA Safety Standard for Fire Protection. Maintained awareness of issues relating to Fire Protection requirements by participating in the National Fire Protection Association (NFPA) Annual Meetings, the NASA Fire Protection Engineers Meetings, the OSHA Electrical Safety Course presented via the NASA Video Teleconferencing System, etc. Also participated in the meetings of the NASA Hazardous Substances Internal Coordination Committee.

Developed a new safety standard that was distributed to the NASA Field Installation Safety Directors under George Rodney's signature (NASA/WS-1740.10, "NASA Safety Standard for Underwater Facilities and Non-Open Water Operations"). Participated as a member of the NASA Certification Review Board that inspected the Underwater Test Facility of McDonnell Douglas Space Station Division for compliance with NASA's facility safety standards.

Revised NMI 8621.1F, "Mishap Reporting and Investigation" and NMI 8710.2A, "NASA Safety and Health Programs." Participated in numerous NASA Field Installation inspection trips and surveys. Developed an NMI on the NASA Safety Awards Program, a revision to the NASA Safety Standard for Lifting Devices and Equipment (NSS/GO-

1740.9B), and a revision to the NMI establishing the requirements for a safety program for pressure vessels and pressurized systems (NMI 1710.3C). Participated in a collaborative effort with the OSHA to complete an OSHA approved NASA Alternate Safety Standard for Suspended Load Crane Operators. Developed a revision to the NMI on NASA Safety and Health Programs (NMI 8710.A), a revision to the NASA form for reporting safety and health hazard abatement plans (Form 1584), a revision to the NASA form for reporting unsafe or unhealthful conditions (NASA Form 1390), and a revision to the instructions for NASA Form 1584. Developed a proposed NASA Form (and instructions) for employee reporting of alleged unsafe or unhealthful working conditions. Monitored OSHA compliance at the NASA Field Installations and at Headquarters and compiled the annual reports to OSHA. Prepared the Code QS input for NASA's annual report to OSHA and periodically prepared tables showing NASA injuries/illnesses and mishap losses for Code QS. Planned and participated in a NASA Lifting Devices and Equipment Safety Conference and prepared the minutes. Completed NSS/GO-1740.9B, "NASA Safety Standard for Lifting Devices and Equipment." Compiled periodic change packages for the documentation on NASA suspended load operations for Code QS to transmit to OSHA. Prepared a draft document describing the Operational Safety Functional Management Review Process including checklists for use by the NASA Field Installations when performing self-assessments. Completed NMI 1740.3D, "NASA Safety Program for Pressure Vessels and Pressurized Systems." Compiled a "Headquarters Operational Safety Management Reference Book" to provide easy reference to elements of NASA's Operational Safety Program to NASA safety personnel. Distributed the new OSHA Enforcement Directive, "Inspection Procedures for the Hazardous Waste Operations and Emergency Response Standard for 29 CFR 1910.120, Paragraph (q)" to all the NASA Operational Safety Managers. Maintained awareness of issues relating to OSHA requirements by participating in the OSHA 47th Annual Federal Safety and Health Conference, etc.

Participated in a total of 10 Operations and Engineering Panel meetings for which Vitro provided the minutes and maintained the status on Requests for Action. Participated in a workshop with the Operations and Engineering Panel. Participated in the 8-Foot, High-Temperature Tunnel delta Integrated Systems Review at LaRC. Participated in the Director's Oversight Committee meeting on the Unitary Wind Tunnel Modernization Project at ARC. Prepared an NMI to charter the Operations and Engineering Panel and coordinated the comments from the Code Q Division Directors and the SRM&QA Directors at the NASA Field Installations.

Developed a revision to the NMI on the subject of the NASA Emergency Preparedness Program (NMI 1040.3), a NASA Headquarters Emergency Preparedness Plan, a training program for all NASA Emergency Preparedness Program coordinators, and checklists for use during surveys of the NASA Field Installations. Participated in NASA Headquarters meetings with the Federal Emergency Management Agency and prepared minutes. Revised NMI 1590.2, "Notification and Alert System for NASA Officials During Nonduty Hours," to include provisions for ensuring that NASA meets the new emergency communication requirements mandated by the White House. Developed a draft Standard Operations Procedures for NASA's contribution to the Federal Emergency Management Agency (Aerial Reconnaissance) and distributed frequent Situation Reports

to all NASA Emergency Preparedness Coordinators regarding the 1993 Mississippi River floods for information purposes. Provided an evaluation of the following items:

Numerous requests for safety-related deviations or waivers	The NASA mishap reports
The NASA Suspended Load Operation Analysis/Approval Reports	KSC's procedure for handling approval of suspended load operations
The OSHA Reform Bill 115 and related data	The NASA Field Installation safety program self-evaluation reports
The Headquarters Emergency Evacuation Plan	The NASA Safety Training Center's new course on Fire Protection

Flight and Ground Operations: Worked extensively with Code QS and the NASA Field Installations to ensure adequacy of programs for explosives facility safety and explosives handling procedures throughout NASA. Our dedication and professional skill won a letter of recognition from the chairman of the NASA Steering Committee of the Liquid Oxygen/Liquid Hydrogen Explosion Hazards Program in April 1990 "For contributions to the liquid oxygen/liquid hydrogen explosion hazards program" and a second such letter from Wayne Frazier/Code QS in December 1990 "For excellent explosives safety support."

Efforts included the development of an NMI on the subject of obtaining shipping permits for rocket motors, the development of an NMI on the subject of explosive storage facility siting review and approval procedures, the development of an emergency exemption to the Department of Transportation to support the shipment of NASA explosive components, the development of a checklist for explosives storage and handling for use during NASA Field Installation surveys and audits, the development of strawman changes to 49 CFR 173, the development of NSS 1740.12, "Safety Standard for Explosives, Propellants, and Pyrotechnics," a revision to NSS 1740.14, "NASA Hydrogen Safety Handbook," a revision to NSS 1740.13, "NASA Oxygen Safety Handbook," research on an "expert system" (developed by ENSCO Corporation for the Joint Army Navy NASA Air Force (JANNAF) propulsion safety committee) to determine its applicability to NASA explosive classification systems, the development of a set of minimum test requirements for use in propellant development and test verification, participation (as the NASA representative) in the periodic meetings of the JANNAF explosives working group, participation (as the NASA representative) in the periodic meetings of the joint logistics chiefs, participation (as the NASA representative) in the periodic explosive hazard classification meetings of the Department of Defense Explosive Safety Board (DDESB), participation (as the NASA representative) in the periodic meetings of the Joint Ordnance Commanders Group (JOCG), participation in a number of NASA Field Installation surveys and audits, site checks of each ammonium perchlorate storage facility at the NASA Field Installations, and participation in the development of a solid rocket motor test plan for support of dual stacking operations in the Vertical Assembly Building at KSC. Assisted T. Mosikas at the Wallops Flight

Facility with procedures for storage and transportation of hydrazine for the Pegasus assembly and integration facility at the Facility. Participated in a Sounding Rocket and Balloon annual mishap review at the Wallops Flight Facility and a meeting concerning explosive proof wiring for working and storage facilities at the Facility. Assisted Wayne Frazier/QS, Jon Mullin/QS, and Code G with the NASA requirement to comply with the DoD Explosive Safety Manual or OSHA, researching 49 CFR Parts 100 to 177 (October 1991 version) to determine NASA requirements for shipping rocket motors in a propulsive state. Submitted the NASA Explosive Safety Standards as a Supplemental Standard to CFR 1910.109 the OSHA Standard on Explosive Safety. Worked the issue of the housing of non-essential personnel in the KSC Vertical Assembly Building. Attended a Critical Design Review at LaRC on the Ignition Supply System in connection with the NASP Concept Demonstration Engine Model in the 8-Foot, High-Temperature Tunnel. Attended the Critical Design Review for the Liquid Hydrogen Structural Test Facility at DFRF. Provided an evaluation of the following items:

NASA's aerosystems pyrotechnic devices

NASA's liquid propellants operations

NASA's solid propellants operations

The HEXDAM software program for siting new explosive storage facilities

The NASA-wide inventory of explosive components and their respective hazard classifications by DoD and DOT

The siting criteria being used by each NASA Field Installation for determining placement of explosive storage facilities

The Operational Safety Program developed by MFSC for the RSRM Propellant Safety Verification Test

A study concerning development of hazards classification data on propellants and explosives

A paper prepared by Sandia National Laboratories on the DOE plan for explosive waste disposal

The report by the Nevada Governor's Safety Committee on the Pacific Engineering Production Company mfg site explosion in May 1988

The "blast wall" requirements for the mixer/casting bldg at the NASA Yellow Creek facility

The burn pad requirements for the NASA Yellow Creek facility

The Large Solid Rocket Motor Demilitarization Disposal Plan drawn up by the Joint Ordnance Commanders Group

The Chemical Process Safety Report publication

Data on an incident at the Morton International facility in Nevada

The NASA Explosive Safety Orientation Course at JSC

Safety Library Document and Safety Data Base Maintenance: Worked extensively with Code QS and the NASA Field Installations to maintain (in a readily accessible system) the Safety Division's safety database. Our efforts resulted in a letter of appreciation from Chuck Mertz/QS in July 1989 "For outstanding service."

Efforts included periodic updating of the library, preparation of periodic bibliography reports, continuous additions to the database, periodic extracts of information for Code QS personnel both from the Code QS library and the libraries at each of the NASA Field Installations and at Headquarters, a revision to QS-DOI-91-001, "NASA Headquarters Mishap Notification Procedures," and two revisions to QS-DOI-91-002, "Directory of NASA Safety Personnel." Created budget tables for the Code Q Manager for Assurance Information Technology in preparation for her presentation to Safety Division Director. In support of the move to the new Headquarters Building, numerous boxes of records were transferred to the Federal Records Center; stamped CONFIDENTIAL and SECRET on over 60 classified documents when they were found to be improperly marked; contacted the NASA HQ Library to determine if they would retain the Mishap collection; reduced the size of the Technical Report Collection considerably by retaining only the front matter (i.e., cover, title page, table of contents, preface, and introduction) for reports that can be obtained from the NASA HQ Library, NASA Field Installations, or contractors; created a new file plan for each Q Code and distributed them to the appropriate personnel; pulled reports that had to be declassified or destroyed; created a new a list of classified materials; and investigated the possibility of transferring the Mission Safety Evaluation Reports to CASI/RECON, BWI to reduce the size of the collection and give the Mission Safety Evaluation report even greater visibility and distribution. Converted the format of a number of documents to permit revisions using the OSMA Document Management System developed by Vitro. (One document of note was converted for revision by the Joint Army Navy NASA Air Force explosive safety group — AFAL-TR-88-096 (Vols 1 & 2), "Space Propulsion Hazards Analysis Manual.") Created a compilation of documentation on Aviation Safety and distributed copies to Bill Comer/QS, Fred Gregory/Q, Tim McCarthy/JT, and the members of the Intercenter Aviation Operations Panel. Using the Mishap Reporting/Corrective Action System, generated various safety reports for the Code Q Manager for Assurance Information Technology. Indexed, labeled, and filed materials in the Code QS Safety Software Library and created an inventory of materials, including the software name, version, numbers of copies, license numbers, and application.

Trend Analysis: This subtask was part of the 2000 series task orders for only the last 15 months of the contract. During that period of time, Vitro completed a draft document,"Qualification by Similarity Guidelines," that establishes uniform criteria for determining applications of this cost-saving approach to qualification. We also prepared a paper clarifying the application and definition of functional, hardware, and item criticality. Completed RP-1290, "NASA Trend Analysis Procedures" and performed an evaluation of the Space Station Freedom Trend Analysis Guide. Began developing a functional management review checklist/survey for determining if the NASA Field Installations are meeting SR&QA technical assessment requirements. The following investigations were made as part of the Trend Analysis effort:

The Secondary Seal Cavity Pressure Transducer Failure	Qualification by similarity
Space Shuttle Main Engine pressure sensor failures	The payload bay floodlight
Window Cavity Conditioning System (WCCS) check valve failures	The misapplication of the hardware criticality field in the MSFC failure reporting databases
Space Shuttle Main Engine open problem adverse trends	

Reliability and Maintainability: Participated in the January 1, 1993, Reliability and Maintainability Steering Committee meeting where we baselined eight new practices. Distributed meetings minutes and provided a letter announcing the next meeting to Code QS for distribution. Hosted and participated in the May 18-20, 1993, Reliability and Maintainability Steering Committee meeting where we baselined an additional 15 new practices. Distributed the initial printing of Supplement #2 of the Preferred Practices to the participating Field Installations along with requested copies of the original document and first supplement. Completed resolution of action items from the May meeting with NASA Field Installation members of the Committee. Conducted a meeting of the Systems Effectiveness Subcommittee on September 9 and 10 at Vitro to finalize the format of the draft, "Proven Design Techniques for Effective Maintenance Planning." The format of the document was finalized and presented the last week of September to the parent Committee. Minutes of the meeting and the update of the draft Strategic Plan were completed.

- Provided course preparation materials to LeRC to support development of the NASA-wide Reliability Training course currently planned under Code Q funding.

- Drafted a summary position paper for the NASA/Russian Space Agency panel for the Annual Reliability and Maintainability Symposium in January 1994 and distributed it for review by the Russians and Carl Schneider/QW. All comments were incorporated and the paper was submitted for publication in the symposium proceedings. Secured pledges for funding for the Russians' transportation and lodging and reserved Aeroflot flights for their travel. Prepared a request for their visas to the U.S. Embassy in Moscow. Prepared and delivered support packets for use by Fred Gregory/Q at the symposium panels and the session he chaired. (ANSER Corporation acted as our interface with the Russians.)

Technical Assessments: This subtask was part of the 2000 series task orders for only the last 15 months of the contract. One of the assessments performed by Ken Wong prompted Dr. Greenfield/QT to confer a letter of appreciation in May 1993 "For a commendable assessment report."

We revised NMI 8070.xx, "Verification of Space Flight Systems," based on comments received from reviewers at NASA Field Installations and Headquarters. Consolidated NASA-wide responses and review comments on the draft MIL-STD-1540C, "Test Requirements for Booster, Upper Stages, and Space Vehicle." Incorporated comments to the Lessons Learned Strategic Plan and Implementation Plan made by the NASA Field Installations. Wrote two chapters in the draft document "Dynamic Test Tailoring Guidelines." We also performed the following Independent Technical Assessments:

- Brake/Skid-Control Servovalve Jammed Open Failure Mode
- Aft Compartment Emergency Venting System
- Space Shuttle Orbiter Skin Corrosion
- Impact Damage to the Orbiter Windows
- The Use of Ammonia as the Working Fluid in the Space Station Freedom Thermal Control System
- International Standardization of Environmental Testing for Space Programs
- Dynamic Testing Guidelines and Tradeoffs
- Vibroacoustic Testing Guidelines and Tradeoffs
- Requirements for Structural Factors of Safety

In addition to the above assessments, we also investigated a number of other anomalies:

- Shuttle Freon Coolant Loop Leakage Problems
- Shuttle Orbiter Vertical Tail Attachment Oversized Bolt-holes
- Oxidizer Preburner Augmented Spark Igniter Purge Check Valve Failure That Resulted in an On-pad Abort of STS-55
- Anomalies of the Pyro-valve Used on the CLUSTER Test Article by the European Space Agency
- Shuttle Orbiter Structural Corrosion
- Space Station Freedom Fracture Control Cost Reduction Considerations
- Shuttle Wing Leading Edge Pinhole Erosion

Systems Safety Training Development: Developed course materials (including instructor guides, transparencies, and handouts) for four safety courses:

- Program Managers Safety Course
- Middle Managers Safety Course
- System Safety Managers Orientation Course
- Mishap Investigation Course

The Middle Managers Course was presented to NASA personnel as a pilot course, and the Program Managers Safety Course continues to be presented as part of the overall

NASA training program for program managers. The final delivery of the Mishap Investigation Course training material was a first draft.

Another significant contribution made by Vitro under this subtask was the development of the concept for a computer-based system to facilitate maintenance of an up-to-date Safety Training Catalog. (The development of the actual software tool for achieving this end was reported as part of the NASA Safety Information System subtask.)

Safety Documentation Development and Update: The primary effort during this contract has been the updating of the Basic Safety Manual, now to be known as NHB 1700.1 (V1-B), "NASA Safety Policy and Requirements Document." As such, the manual was coordinated through a number of cycles of revision and distribution to the NASA Field Installations for review and comment. Our efforts in maintaining steady progress toward its completion inspired Wayne Frazier/QS to confer a letter of appreciation in April 1991 "For outstanding support in documentation and training."

Another significant contribution made by Vitro under this subtask was the development of the concept for a computer-based system to facilitate incorporation of comments during the development or update of any NASA safety document. (The development of the actual software tool for achieving this end was reported as part of the NASA Safety Information System subtask.)

Under this subtask, Vitro also performed final production on 29 "first-time-ever" safety NMIs, handbooks, and standards that were developed as part of the technical efforts already noted in earlier paragraphs of this report:

NASA Safety Standard NSS/SY1740.X, "Payload and Cargo Element Safety Requirements"	A Range Safety Plan
The final report of the Ad Hoc Committee, "The Status Report of the STS Safety Risk Assessment of the Ad Hoc Committee," dated July 1988	NSS 1740.11, "NASA Safety Standard for Fire Protection"
A Hazard Analysis Methodology Report for Space Station Freedom	A Database Requirements Report for Space Station Freedom
A first draft of SSP 30315, "Space Station Users Requirements Document"	A first draft of SSP 30309, "Safety Analysis and Risk Assessment Requirements" (for Space Station Freedom)
Proposed NHB 1700.7C, "Safety Policy and Requirements for Payloads" (for Space Station Freedom)	NMI 1700.8, "Space Debris Limitations"

An NMI on the subject of the use of radioactive materials in space

A draft methodology for application of software safety analysis techniques to NASA software development projects

A draft set of NASA specific software safety objectives

A draft NASA Software Safety Requirements Document

A draft NASA Software Safety Standard

A Human Engineering/Safety Analysis Methodology

Draft NMI 8070.xx, "Basic Policy and Procedures for Human Engineering"

Preliminary NHB 1700.1, Vol. 6, "Human Engineering Handbook for Safety Assurance"

A NASA Safety Standard, "Human Engineering Guidelines for Safety Assurance"

The Safety 2000 Document

NASA Safety Standard NASA/WS-1740.10, "NASA Safety Standard for Underwater Facilities and Non-Open Water Operations"

The NASA Headquarters Emergency Preparedness Plan

An alternative OSHA Safety Standard for KSC cranes

An NMI on the subject of obtaining shipping permits for rocket motors

An NMI on the subject of explosive storage facility siting review and approval procedures

NSS 1740.12, "Safety Standard for Explosives, Propellants, and Pyrotechnics"

An NMI on the subject of aviation safety

An aviation safety officers guidebook

A draft document, "Qualification by Similarity Guidelines"

This subtask also provided for the final production on Vitro-developed revisions to 17 other safety NMIs, handbooks, and standards that were made as part of the technical efforts already noted in earlier paragraphs of this report:

An NHB for Aerosystems Safety

An NHB for Facilities Safety

NSTS 22254, "Methodology for Conduct of NSTS Hazard Analysis"

NMI 8621.1F, "Mishap Reporting and Investigation"

NMI 8710.2A, "NASA Safety and Health Programs"

NMI 1040.3, "NASA Emergency Preparedness Program"

NMI 1710.3C, "Safety Program for Pressure Vessels and Pressurized Systems"

NASA Safety Standard NSS/GO-1740.9B, "NASA Safety Standard for Lifting Devices and Equipment"

RP-1, "Recommended Practice for the Fire Protection of Essential Electronic Equipment"

Volume 9 of NHB 1700.1, "Fire Protection"

NSS 1740.13, "NASA Oxygen Safety Handbook"

NMI 8070.4A, "Risk Management Policy for Manned Flight Programs"

NMI 8070.xx, "Verification of Space Flight Systems"

QS-DOI-91-001, "NASA Headquarters Mishap Notification Procedures"

QS-DOI-91-002, "Directory of NASA Safety Personnel"

NSS 1740.14, "NASA Hydrogen Safety Handbook"

RP-1290, "NASA Trend Analysis Procedures" (was NHB 8070.5)

SUBCONTRACTS AND CONSULTANTS

Vitro successfully elicited assistance from 11 subcontractors in the specialized safety area during the course of the Vitro contract to meet emerging NASA and OSMA requirements:

Planning Research Corporation (PRC)

Through a series of subcontracts with PRC, Vitro acquired for Code QS assistance in the Code Q independent risk assessment for the Galileo mission, an update for PRC's computerized fault tree for potential Space Shuttle accidents, an integrated risk assessment software package for estimating the accident risks for the Ulysses mission, and a reliability estimate for the TITAN IV launch vehicle.

BDM International, Inc. (BDM)

Through a single subcontract with BDM, Vitro acquired for Code Q a conference paper on the Space Station risks associated with space debris, an associated bibliography, and a speech on the same subject for George Rodney.

Lloyd Philipson

Through a series of consulting agreements with Lloyd Philipson, Vitro acquired for Code QS assistance in the Code Q independent risk assessment for the Ulysses mission, refinements in the Space Shuttle accident probability model, and an evaluation of an Air Force Range Safety Analysis.

Pickard, Lowe, and Garrick

Through a series of subcontracts with Pickard, Lowe, and Garrick, Vitro acquired for Code QS an evaluation of a report on the Space Shuttle orbiter thermal protection system, "The Probabilistic Risk Analysis Model and Preliminary Observations." We also

acquired an evaluation of hazard assessment techniques currently used in the Space Shuttle program as opposed to emerging technologies for quantitative risk assessment. The final report was delivered on November 7, 1988, "Enhanced Hazard Analysis for Space Systems."

The University of Virginia

Through a series of subcontracts with the Center for Risk Management of Engineering Systems at The University of Virginia, Vitro acquired access to two new risk assessment technologies for Code QS -- the Partitioned Multiobjective Risk Method for Extreme Value Events and the Evaluation of Identification and Ranking Methods for FMEA/CIL Items.

Safety Factor Associates (SFA)

Through a series of consulting agreements with SFA, Vitro acquired for Code QS enhancements in the Space Shuttle accident probability model, major contributions to the joint Code Q/M reliability model for the Space Shuttle, assistance in the Code Q evaluation of the MSFC Assured Shuttle Availability model, several workshops for NASA personnel to become proficient in the new techniques for probabilistic risk assessment, assistance in the development of the appropriate failure estimates by the Failure Probability Splinter Group for use in the TITAN IV launch vehicle Databook for the Cassini Mission, an "Uncertainty Analysis" that was the basic source for the error bars placed on the final results of the nuclear safety evaluation performed by the Interagency Nuclear Safety Review Panel in their report to the White House on the radiological risks of the Ulysses mission, assistance in the Code Q independent risk assessments for both the Galileo and Ulysses missions, two Bayesian analysis software modules for use in Probabilistic Risk Assessment, assistance in an integrated risk assessment of the Micro-rover for the Mars Environmental Survey mission, assistance to the Radioisotope Thermoelectric Generator Working Group, assistance to the Interagency Nuclear Safety Review Panel for the Cassini mission, and a calculational model for the Space Station assembly integrated risk assessment. Provided a report entitled "Model for Uncertainty Analysis of Frequency of Failure to Attain HTC for Space Station Transition Options A-1 and A-2." Also provided a diskette with the model described above. (The Space Station option assessment was performed in conjunction with SAIC, Bob Weinstock/Vitro, and two members of Code QS -- Pete Rutledge and Ben Buchbinder.)

Technical Analysis, Inc. (TAI)

Through two separate subcontracts with TAI, Vitro acquired for Code QS an Ordnance Siting and Certification Plan and the expert services of Jim Wiggins, who participated as a member of the Ad Hoc Committee on its 1988 evaluation of the Space Shuttle risk management system. The Ad Hoc Committee developed a final report, "The Status Report of the STS Safety Risk Assessment of the Ad Hoc Committee," dated July 1988.

Operations Research, Inc. (ORI)

Through a single subcontract with ORI, Vitro acquired for Code Q the expert services of Joyce McDevitt, who participated as a member of the Ad Hoc Committee for its 1988 evaluation of the Space Shuttle risk management system. The Committee developed a final report, "The Status Report of the STS Safety Risk Assessment of the Ad Hoc Committee," dated July 1988.

Louis J. Polaski

Through a single consulting agreement with Mr. Polaski, Vitro acquired for Code Q the expert services of Louis J. Polaski, who participated as a member of the Ad Hoc Committee for its 1988 evaluation of the Space Shuttle risk management system. The Committee developed a final report, "The Status Report of the STS Safety Risk Assessment of the Ad Hoc Committee," dated July 1988.

Symbiotic Technologies, Inc. (STI)

Through a single subcontract with STI, Vitro acquired for Code Q a survey of probabilistic design methods and the initiation of an evaluation of the commercially available *PROBAN* software program and *NESIS,* a software program developed on a LeRC contract. Both software programs are for use in performing probabilistic structural analysis.

Science Applications International Corporation (SAIC)

Through a single subcontract with SAIC, Vitro acquired for Code Q a series of seminars on risk assessment and risk management (along with tutorial materials). Seminars were given at NASA Headquarters, at JSC, and at LeRC. We also acquired an evaluation of three candidate launch vehicle architectures proposed by MSFC for the advanced space transportation development program — a "Shuttle forever" architecture, an integrated cargo transfer return vehicle/personnel launch system architecture relying on an expendable launch vehicle with 50,000-pound launch capacity to low Earth orbit using Saturn F1A and J2 engines, and a medium cargo transfer return vehicle architecture in which a 90,000-pound-capacity vehicle is derived from the 50,000-pound core.

We also acquired a PC-based Excel™ software module for generation and analysis of event trees and consequence trees (part of the prototype Space Systems Reliability Data workstation NASA acquired under another SAIC subcontract through the Air Force). Under the Vitro subcontract with SAIC, we procured several demonstrations and trial uses of the entire workstation for NASA Headquarters managers and Vitro personnel. We also procured a User's Guide for the entire Workstation.

Participated in a top-level assessment of the two most viable options for the proposed Space Station redesign to ascertain the relative programmatic risks. (The Space Station option assessment was performed in conjunction with Mike Frank/SFA, Bob Weinstock/Vitro, and two members of Code QS — Pete Rutledge and Ben Buchbinder.

III. CONCLUSIONS AND RECOMMENDATIONS

The Vitro Safety team has grown to understand the variety of difficulties that hinder the Code QS efforts to bring real improvements to NASA Safety Programs. Our efforts over the past 6 years have been devoted to improving the ability of the program managers to make informed decisions regarding safety and to improve the handbooks and manuals used throughout NASA on a daily basis. The following recommendations were derived from our comprehensive analysis of NASA safety programs:

- During our many visits to the NASA Field Installations on safety surveys and audits, it became clear that one Field Installation (LaRC) enjoyed far better support for the safety programs from the "Program" side of the house. We suspect the excellence of LaRC's safety program is due to a single difference in their management approach. The SRM&QA Director at LaRC has a 20% input to the annual performance appraisal for each of the other department heads.

  OSMA may wish to have the NASA SRM&QA community consider allowing each of the SRM&QA Directors a 20% input to the annual performance appraisals for their respective department heads. Additionally, Code Q may wish to suggest a similar Code Q input into SRM&QA Directors evaluations.

- One of the most significant contributions Vitro made to the Safety and Risk Management effort was to advance our expertise in software safety. A great deal has been accomplished to introduce the new idea within the NASA Programs that software has become intensively involved in systems designs and can no longer be treated in the old, familiar manner. However, perhaps it is time to step-up the program. NASA should consider seeking out an experienced software safety person to add to the Code QS staff. NASA Code QS could also benefit from the experience of an on-staff Fire Protection expert.

- In the 6 years of this contract, we have witnessed wide fluctuations in Code QS's travel budget. The reduced number of trips to the NASA Field Installations in the lean years severely hampered Code QS's ability to perform its function. A great deal of interaction is really needed, if we are to understand the problems faced by the safety personnel in the field. Consider giving the travel budget higher priority in the future.

- Safety is most effective in the years before CDR. This holds true for the Space Station as well. We cannot help feeling that insufficient attention is being given to that effort, and soon it will be too expensive to correct any safety problems in the design. Consider applying a larger portion of the Code QS (or Code Q) effort to the oversight of the Space Station safety program.

- Our Explosive Safety expert is already on record regarding the blast wall that is in the plans for the mixer/casting building at the Yellow Creek Facility in Iuka, MS. Although funding has been temporarily eliminate that facility, the blast wall remains

in the design. Our expert feels the $3 million could better be spent elsewhere because OSHA does not require such a wall and because there is no real evidence that the wall could protect the workers on the "safe" side.

3000 SERIES TASK ORDER
PAYLOADS AND AERONAUTICS

I. BACKGROUND FOR THE OVERALL TASK

In the beginning of the contract, three task areas (systems assessment, trend analysis, and data systems) were formed to assess and communicate to top NASA management safety, reliability, maintainability, and quality assurance (SRM&QA) problems that could impact mission success. Because these three functions are synergistic activities requiring a coordinated effort, the Systems Assessment and Trend Analysis Division (Code QT) was formed in 1990 to consolidate these efforts. Vitro support to the new Code QT was provided under the 3000 series task order. Prior to 1990, the Data Systems/Trend Analysis and Systems Assessment were two separate divisions where Vitro support was provided under 3000 and 4000 series task orders, respectively.

In support of Code QT, the Vitro tasks encompassed the following:

- ***Data Systems***: Evaluate, develop, and implement NASA SRM&QA data base/information management systems. Manage, operate, and maintain a headquarters-level SRM&QA management information center (MIC). Provide data systems support for the Space Shuttle prelaunch assessment review (PAR) process. Operate and utilize problem reporting and corrective action systems to write queries/extract data to support engineers conducting trend analyses and technical assessments.

- ***Trend Analysis***: Develop, implement, and assess NASA trend analysis programs at Headquarters, Field Installations, and contractor sites. Develop, revise, and update documentation (management instructions, handbooks, standards) for use as Agencywide guidelines and procedures for performing trend analysis. Perform trend/correlation analyses to identify adverse trends and anticipate potential problems.

- ***Systems Assessment***: Conduct independent technical engineering assessments at the system, program, and element level. Provide an independent "second look" at engineering issues/concerns in the SRM&QA areas for Code Q. Participate in and provide technical backup for design reviews, flight readiness reviews, and test readiness reviews. Prepare an assessment report that includes problem description, information collected, analysis results, conclusions, and recommendations for resolution of problem areas.

In December 1992, a Code Q reorganization resulted in a reassignment and revision of task orders. The systems assessment, data systems, and trend analysis functions were transferred to the Safety and Risk Management Division (Code QS) under the 2000 series task order. Code QT was renamed as the "Quality Management (Payloads) Division." This new organization was established as a direct interface with the Payload Program Offices for all OSMA functions. With an Agencywide goal of conducting all

missions "better, faster, cheaper," the new Division was created to ensure that limited SRM&QA resources were utilized more effectively throughout the life cycle of a payload development program. Particular emphasis was directed towards a more active involvement of Code Q in the early phases of the program.

In January 1994, Code QT was again renamed/changed to the "Payloads and Aeronautics Division." The roles and responsibilities of this new division have not yet been fully defined, but will encompass SRM&QA activities for both Expendable Launch Vehicle (ELV) and Aeronautics programs in addition to the continuing support for NASA Payload programs.

II. SUMMARY OF TASK ACTIVITY

DATA SYSTEMS/TREND ANALYSIS/SYSTEMS ASSESSMENT

Data Systems

Vitro increased the use of information technology in support of Code Q meetings. Vitro was heavily involved in the design of a system to improve the overall effectiveness of the PAR process through expanded use of automation. Vitro evaluated numerous software and hardware packages for potential use in automating the PAR process. PAR automation tools using NeXT workstations, various software packages, and peripherals were integrated by Vitro. Vitro coordinated the installation of equipment for still-image capture and transmission and installation of the BARCO projection television in the Code Q Management Information Center (QMIC) to support meetings and presentations.

Vitro staff were extremely responsive in writing queries to extract data from the Program Compliance Assurance and Status System (PCASS)/Problem Reporting and Corrective Action (PRACA) systems to support technical assessments being conducted by both NASA and Vitro engineers. The Vitro data systems staff, as experts in PCASS/PRACA operation and utilization, provided training to numerous Code Q, Code M, and Vitro engineers. Vitro identified data integrity problems (e.g., missing, incomplete, or incorrect codes/data) within the PCASS/PRACA data bases. Subsequently, a major effort was undertaken by the NASA Field Installations to improve data accuracy and completeness within their PCASS/PRACA data bases.

Vitro maintained, managed, and operated a SRM&QA QMIC to display correlated technical and management data to identify trends and potential programmatic impacts. For each launch, a briefing book executive summary containing QMIC charts was prepared for the Code Q Associate Administrator. Vitro assisted in the development and implementation of a significant problem reporting system to track/monitor significant problems and bring them to the immediate attention of top NASA management. This system was helpful in tracking the status and disposition of several hundred significant problems that had to be resolved prior to the Space Shuttle return to flight.

Trend Analysis

Vitro assisted NASA in developing and updating the following trend analysis documentation:

- NMI 8070.3, "Problem Reporting, Corrective Action, And Trend Analysis Requirements" (establishes the NASA policy and requirements for the conduct and reporting of trend analysis).

- NASA Reference Publication (RP-1290), "NASA Trend Analysis Procedures" (provides uniform guidelines for implementing and conducting trend analyses for aeronautics and space programs).

- NASA-STD-8070.5, "Trend Analysis Techniques" (describes mathematical/statistical techniques).

In addition, Vitro authored a Space Station Trend Analysis Guide. This document identifies trend analysis documents, activities, projects, and resources that are available and applicable to the Space Station. This guide was distributed to the NASA Field Installations for review and received favorable comments.

Vitro played a key role in the inception and development of the NASA Trend Analysis Working Group (TAWG), which provided a forum or mechanism for developing and disseminating state-of-the-art trend analysis knowledge, tools (statistical software), and techniques. Vitro prepared trend analysis presentations, meeting minutes, and agendas and reviewed trend analysis proposals, projects, and activities. Support for the TAWG meetings resulted in a significant increase in trend analysis projects and activities.

Vitro conducted many trend analyses to assess or identify recurring problems. For example, Vitro assessments concerning failure trends and state-of-the-art technology for spacecraft data recorders, gyros, and deployable mechanisms/structures were prepared and commended by upper Code Q management.

Technical Assessments

Vitro assessed numerous technical and critical issues associated with the Orbiter, Solid Rocket Motor, Solid Rocket Booster (SRB), Space Shuttle Main Engine and External Tank, Space Station, payloads, and specific engineering issues (e.g., spacecraft testing). (Note: Vitro completed more than 180 technical assessments. At the end of each fiscal year, selected assessments were bound and provided to Code QT for future reference and archival purposes.) Technical Interchange Meetings were held periodically in which Vitro personnel provided briefings of interim and final results of current technical assessments to upper NASA management including the Code Q Associate Administrator.

Several letters of commendation were received by Vitro personnel for outstanding performance or accomplishment of urgent and critical assessments. Two Vitro employees who supported Code QT were honored with the prestigious Manned Flight

Awareness (MFA) award. Vitro engineers were also selected for monitoring and participating in special investigation teams and technical committees that included the following: Task Force 10 for Geostationary Operational Environmental Satellite (GOES), Galileo High Gain Antenna (HGA), Advanced Technology Satellite (ACTS) Transfer Orbit Stage (TOS), HST Gyro Failure Review Board, and Space Station Electrical Grounding Tiger Team.

Many of the technical assessments received high visibility or contributed to the decision-making process. For example, during the STS-37 prelaunch assessment of the cracks in the hinge of the ET doors, a Vitro stress analysis indicated negative margins of safety. This analysis/assessment, which addressed launch mission risk, provided Code Q management rationale for delaying the launch until the problem was corrected. Other critical Shuttle-related topics assessed by Vitro included software, instrumentation (transducer crack), and SRB aft skirt factor of safety issues.

Vitro evaluated and analyzed the Shuttle avionics systems (software/hardware) issues and performed independent assessments of problems and recommended corrective actions. In support of Space Shuttle flight readiness reviews, Vitro provided Code Q with a software readiness package/assessment prior to each launch. These assessments provided Code Q with rationale for accepting the Certification of Flight Readiness. Furthermore, Vitro maintained and updated a flight software manifest related to the Shuttle flight schedule and significant software changes.

Highly complex and technical Space Station issues were identified by Vitro and brought to the attention of the Space Station Deputy Director. Vitro identified and assessed critical Electrical Power System (EPS) stability and plasma contactor issues and concerns. Vitro identified the need for fully reviewing the EPS design and the need for IV&V analysis and enhanced systems testing. Vitro worked with Level II (LeRC) in developing an EPS secondary stability change request (CR) that would develop criteria to ensure system-level stability. EPS stability issues raised were instrumental in the formation of an Engineering Design Council tiger team. In addition, a Vitro assessment (Low Earth Orbit Plasma/Space Station Electrical Power System) led to a series of investigations that resulted in the procurement/development of a plasma contactor.

QUALITY MANAGEMENT (PAYLOADS)

Vitro conducted a study on vibroacoustic testing risks and tradeoffs. A technical paper was prepared based on this study and was presented at the Spacecraft Launch Vehicle Dynamics Environments Technical Interchange Meeting as well as at the ESA/ESTEC Environmental Testing for Space Programs Symposium. Vitro is preparing a dynamic test tailoring guidelines document as a follow-on to the vibroacoustic study. Vitro personnel are members of special aerospace advisory panels for professional organizations such as the Aerospace Testing Seminar Advisory Panel.

Vitro conducted an assessment that surveyed and evaluated NASA, U.S. Air Force/DoD, and aerospace industry guidelines and practices on the use of qualification by similarity

to reduce testing of space flight hardware. Because the assessment identified differences in content and level of detail guiding use of qualification by similarity among these organizations, Vitro developed and proposed uniform NASA-wide guidelines on qualification by similarity.

As part of NASA's goal of reducing the cost of scientific space missions, Code QT conducted a workshop aimed at reducing the cost of quality. Personnel from each Field Installation, major NASA contractors, NASA Headquarters, and academia participated in this 3-day workshop at the University of Maryland. Vitro was an active participant in the development and coordination of this highly successful workshop. The success of this initial effort has led to a continuing initiative at each of the payload Field Installations.

Vitro assisted in revising NASA Management Instruction (NMI) 8010.1, "Classification of NASA Payloads." The intent of the revision was to provide payload developers increased flexibility in determining how best to maximize existing SRM&QA resources while still maintaining an acceptable level of risk. The revised NMI is still in draft form, but will continue to be a necessary component in implementing an effective payload SRM&QA program.

In response to a request by the Code S Program Office, Vitro assisted Code QT in evaluating the impact to the overall reliability of the Earth Observing System if EEE parts requirements were reduced. Vitro provided the results of this assessment to the Program Office and assisted them in the decision-making process.

At the request of the Submillimeter Wave Astronomy Satellite (SWAS) Program Manager, Vitro assisted Code QT in conducting a reaction wheel study. The purpose of the study was to evaluate a Project decision to change the proposed design and to eliminate spare components. The results of the study presented to the Program Manager indicated the Project was proceeding in an appropriate manner.

III. CONCLUSIONS AND RECOMMENDATIONS

Vitro has been very responsive in meeting the changing requirements of Code QT over the life of the contract. Despite numerous reorganizations, downsizing, and restructuring of tasks, Vitro has effectively realigned its staff to provide the right skill mix to meet the needs of Code QT. Vitro has contributed significantly to the areas of data systems, trend analysis, and systems assessment. The data integrity of the PCASS/PRACA systems has improved significantly. This has facilitated and enabled performance of more accurate trending. The development of NASA trend analysis documentation and establishment of the TAWG has significantly increased trend analysis activities and projects throughout NASA. Many Space Shuttle, Space Station, and payload-related systems/technical assessments prepared by Vitro received high visibility and have contributed to the SRM&QA decision-making process.

The efforts of Code QT and Vitro have gained increased visibility in the Program Offices under the new Quality Management (Payloads) Division. This new visibility has allowed

the Code QT/Vitro team to become a value-added contributor to the development of NASA payload programs.

The new direction the Payloads and Aeronautics Division is taking must ensure OSMA continues to increase its involvement in the early phases of the Payload Development programs. This increased visibility and participation in the early decision-making process will be required if NASA is to maintain an acceptable level of risk with increasingly limited resources. The OSMA should be actively involved in payload program activities throughout the duration of the program (from early development through integration and launch). Also, Code QT needs to maintain the SRM&QA function as an aggressive contributing element in the planning, development, and implementation of the Payload, ELV, Upper Stages, and Aeronautics programs. NASA should maintain a process that clearly defines, evaluates, and articulates the impact of program decisions on mission risk throughout program life cycles. This process should include oversight, independent assessment, performance of contract (RFP and SOW) reviews, and active participation as members of Program Design Review Boards, Change Boards, System Effectiveness Review Boards, Flight Readiness Review Boards, and Launch Management Teams.

4000 SERIES TASK ORDER
ENGINEERING

I. BACKGROUND FOR THE OVERALL TASK

OSMA develops and advances Agencywide engineering standards and practices that form the backbone of NASA's safety and mission assurance capability. OSMA's programs in software engineering and assurance, applied technology, systems engineering, and metric transition contribute directly to engineering standards. OSMA also assesses flight readiness of Shuttle software. OSMA's systems engineering and metric transition efforts are integrated with national initiatives (involving other government agencies) to improve the competitiveness of U.S. industry in international markets.

This task began in January 1991, shortly after the Technical Standards Division's organization, and included efforts in engineering standards, metric transition, and advanced technologies. Task 1000 previously incorporated the engineering standards and metric transition activities. In 1993, the scope of the task order expanded to include software engineering and assurance, electronic part packaging, and EEE parts, when these technical areas became responsibilities of the newly named Engineering Division. Earlier these activities were supported by Tasks 1000 and 3000.

II. SUMMARY OF TASK ACTIVITY

For all engineering programs, Vitro's proactive engineers developed sensible plans and independently reviewed work done by the Field Installations and outside organizations. We developed new OSMA procedures for expediting the preparation of technical documents. We assisted with the organization of and participated in high-level NASA steering committees and workshops. Vitro's staff met with the OSMA staff to plan activities and worked as a team to provide responsive, timely, and consistent support. Our accomplishments were documented in Monthly Technical Progress Reports, informal monthly highlighted briefings, and specific technical reports.

TECHNICAL STANDARDS

To improve OSMA's processes for developing, revising, adopting, and tailoring standards, Vitro helped Code QW develop the NASA Standardization Procedures Handbook (NHB 8070.XX). The new development process is superior to current approaches because:

- The Agencywide NMI/NHB process is more difficult and time-consuming and is not specifically designed for standards.
- The more direct Field Installation processes do not yield uniform standards.

While NHB 8070.XX is not yet ready for the final approval and concurrence process, we used it on a trial basis for some software-related documents.

METRIC TRANSITION

Public Law 100-418 and Executive Order 12770 require all Federal agencies to adopt the metric system of measurement. Compliance is important because this national initiative brings higher productivity and international competitiveness to U.S. industry. OSMA leads an Agencywide metrication effort and maintains high-visibility contacts with the Congress, the Department of Commerce, and other Federal agencies. OSMA, with help from Vitro, established the NASA Metrication Planning Group (NMPG) at Headquarters to plan the Agency's metric transition and coordinate its implementation. Using Vitro's sound advice, OSMA modified NASA's metric use policy, prepared a metric transition plan, and compiled annual reports to the Congress.

The Administrator approved NMI 8010.2A, "Use of the Metric System of Measurement in NASA Programs," in June 1991 and NASA's Metric Transition Plan including a Metric Waiver Process in February 1992. The policy made OSMA responsible for "establishing procedures to implement this policy"; the plan assigned three activities to OSMA: overall leadership of NASA transition activities, administering the plan's waiver process, and identifying requirements for metric standards. The NMI was an update of the earlier policy that incorporated changes required to comply with Public Law 100-418 and Executive Order 12770. Vitro reviewed plans and reports prepared by individual program offices and Field Installations, looking for sound engineering practices and consistency among programs, Field Installations, and Federal agencies, and identified items for OSMA that required clarification or improvement. When OSMA received a waiver request, we evaluated it using the same criteria and suggested activities to OSMA that the development program could perform to expedite NASA's metric transition.

Vitro assisted OSMA with preparation of the annual metrication report to the Congress. This report, submitted to the Congress in January, covers progress in the past year and outlines activities planned for the current year. In addition, we helped OSMA prepare a June 1992 metrication status report to the Department of Commerce. In drafting these reports we used our knowledge gained from familiarity with NASA's transition plan, participation at meetings, and contacts with the NMPG. Our efforts for OSMA have contributed to good relations with the Congress, the GAO, and the metric program office at NIST.

Vitro supported and documented meetings of the NMPG that are scheduled on an as-needed basis. We also assisted OSMA with about one meeting per year for the Field Installation coordinators, and teleconferences as needed.

ADVANCED TECHNOLOGIES

OSMA manages applied technology programs for aerospace batteries and pyrotechnically assisted systems. These programs require preparation of program plans, handbooks, and other documents, development of databases, and general technical and administrative support for meetings and workshops. Vitro worked with the managers of applied technology programs to plan meetings and other support activities. Our staff helped

OSMA develop, review, and revise key documents. We also provided advice to the NASA program managers to ensure that NASA pursues relevant development activities.

For the pyrotechnically assisted systems (PAS) program, Vitro assisted the OSMA program manager with the development of both a program plan and a program implementation plan. Vitro participated in PAS Steering Committee meetings and prepared minutes of these meetings. Vitro also participated in meetings of the aerospace battery program Steering Committee and undertook the task of publishing the proceedings of the 1987 and 1988 NASA Battery Systems Workshops.

SOFTWARE ENGINEERING AND ASSURANCE

Avionics System Software

For each Shuttle flight, Vitro prepared a Shuttle Software Assessment in Support of the Flight Readiness Review (FRR). This effort evaluated software changes, discrepancies, and late flight software patches. The reports contained detailed descriptions for the Shuttle Avionics, Space Shuttle Main Engines (SSME), and Ground-Launched System Software in support of the Flight Readiness Review (FRR) and the Safety and Mission Assurance Certification of Flight Readiness.

During the development of new Operational Increment (OI) flight software, Vitro reviewed software changes and discrepancies in all program phases, including initial requirements, development, embedded verification and validation, and final operation, and prepared technical assessments. For example, in November 1992, Vitro provided a status report and analysis of the major software Change Requests during baseline, development and mission preparation phases of the OI-22 flight software that was scheduled to fly with STS-57 in April 1993. Vitro maintained and updated OSMA's flight software manifest relating the Shuttle flight schedule to significant software changes; this chart was delivered to Codes Q and M for monthly program reviews.

Vitro also evaluated and analyzed software and hardware issues for the Shuttle avionics systems, performed independent assessments of problems, and recommended corrective action to OSMA. For instance, Vitro provided assessments of software development and independent verification and validation requirements during the PDR and CDR reviews for the new Day-Of-Launch I-Load Update Version II (DOLILU II) Processor. In addition, we reviewed and analyzed the development of Multifunction Display Electronic System (MEDS) software and hardware during the PDR and informed OSMA of issues and concerns, and reviewed and assessed the implementation of the Global Positioning System (GPS) project for the orbiter.

Deliverables:

"Shuttle Software Assessment," separate reports for each STS flight (49, 50, 46, 47, 52, 53, 54, 56, and 55) manifested with the Operational Increment (OI-21) flight software.

"Shuttle Software Assessment," separate reports for each STS flight (57, 51, 58, 61, and 60) manifested with the Operational Increment (OI-22) flight software.

"Software Defect Analysis Assessment," VC-OSC-T-017(92), dated April 24, 1992.

"Software Change Request Implementation Process Failure Assessment," VC-OSC-T-018(92), dated May 29, 1992.

"STS-49 On-Orbit Flight Software Anomalies Report," VC-OSC-T-020(92), dated May 29, 1992.

"DOLILU II Preliminary Design Review (PDR) Status," VC-OSC-T-021(92), dated June 19, 1992.

"Autoland Detailed Test Objective (DTO) Status," VC-OSC-T-026(92), dated August 31, 1992.

"Autoland Detailed Test (DTO) Status," VC-OSC-T-029(92), dated September 22, 1992.

"STS-52 Late Flight Software K-Load Patch," VC-OSC-T-033(92), dated October 16, 1992.

"STS-52 Late Flight Software Patch Status Report," VC-OSC-T-033(92), dated October 16, 1992.

"Technical Assessment, Flight Software Operational Increment (OI-22) Status Report," VC-OSC-T-036(92), dated November 23, 1992.

"Assessment of AP-101S General Purpose Computer (GPC)," VC-OSC-T-070(92), dated January 2, 1993.

"DOLILU II Critical Design Review (CDR) Status," VC-OSA-T-008(93), dated February 22, 1993.

"DOLILU II Delta Critical Design Review (CDR) Status," VC-OSA-T-028(93), dated August 2, 1993.

"GPS Software Implementation Status Follow-up," VC-OSA-T-001 (94), dated January 6, 1994.

"DOLILU II System IV&V Implementation," Report, dated March 19, 1992.

"RMS Fault-Detection Error Annunciations," Report, dated May 11, 1992.

"STS-49 Orbit Rendezvous Fault Message Annunciation," Report, dated May 14, 1992.

"SASCB Discussion, Orbit Targeting Implementation," Report, dated July 13, 1992.

"PASS and BFS DRs (108538 and 108539) Possible Main Engine Bell Collision," Report, dated October 6, 1992.

"KCR Tracking and New Implementation Procedure," Report, dated November 6, 1992.

"SAIL Integration Avionics Verification for the OI-22 FSW," Report, dated April 19, 1993.

"STS-57 FSW Patch Threats," Report, dated March 11, 1993.

"STS-71 Spacelab - MIR Mission Docking," Report, dated May 17, 1993.

"Engineering Directorate FSW Process Review for OI-22 baselined (CR 90243C)," Report, dated June 8, 1993.

"Implementation of Shuttle GPS Software," Report, dated June 8, 1993.

"Assessment of a Change Request (CR) for Major Flight Software Enhancements to OI-23, 24, 25, and 26," Report to Codes Q and M dated July 19, 1993.

"BFS NO-GO and Suspect Changes," Report, dated August 20, 1993.

"DR 108676 BFS Unable to Transmit on Flight Critical Buses While Engaged," Report, dated October 21, 1993.

"CR 90476A - Wraparound Yaw Jet System W/Program Test Input (PTI) Effector," Report, dated November 16, 1993.

"Presentation on Overall Review of the MEDS Project to OSMA," Presentation, dated November 18, 1993.

"STS-58 BFS Payload TMBU Processing Error," Report, dated November 23, 1993.

Software Assurance

During the entire contract period, Vitro provided comprehensive support for the initial Software Engineering Program and the Software Assurance Program plans. An early effort assisted NASA in preparing, coordinating, and publishing NMI 2410.10, the basic NASA policy for software management, assurance, and engineering. Various Software Management and Assurance Program (SMAP) conferences, meetings, teleconferences, and videoconferences were supported. Software engineering expertise and experience was provided for developing, coordinating, editing, publishing, and disseminating software engineering and assurance documentation, including:

- NASA Software Acquisition Life-Cycle
- NASA-STD-2100-91, NASA Software Documentation Standard
- NASA-STD-2201-93, Software Assurance Standard

- SMAP-GB-A201, Software Assurance Guidebook
- NASA-STD-2202-93, Software Formal Inspections Standard
- NASA-GB-A302, Software Formal Inspections Guidebook
- SMAP-GB-A301, Software Quality Assurance Audits Guidebook.

Technical reports were prepared, as required, such as the Software Configuration Management Standard Study, October 1993. A recent emphasis was the identification and evaluation of voluntary industry standards, standards from other Federal agencies, and international standards regarding software on a continual basis. Where appropriate, use of applicable voluntary standards was recommended.

ELECTRONIC PARTS PACKAGING

Vitro coordinated, edited and distributed three quarterly reports covering activities of the RELTECH Committee comprising Air Force Rome Laboratory, Naval Surface Warfare Center, U.S. Army Research Laboratory and NASA. To accelerate issuing reports, a new format was developed for reporting activities and results. Vitro participated in various RELTECH meetings such as the Committee meeting in Denver (August 1993) and RELTECH/ICWG meetings in New Orleans (November 1993) and Fort Lauderdale (January 1994). Minutes for each Committee meeting were prepared, edited, and distributed.

Vitro participated in RELTECH technical assessments/surveys of the following companies:

- Texas Instruments (Memory Cubes and MCM Foundry), Dallas, TX
- IBM, East Fishkill, NY
- Martin Marietta, Orlando, FL
- Integrated System Assemblies, Woburn, MA.

At our suggestion, RELTECH completely revised its survey activities and developed guidelines specifying what areas and subjects are to be covered and the type of information required.

Vitro attended and participated in the following technical conferences and meetings:

- MCM-D & L, Ogonquit, ME, June 1993
- Advanced Microelectronics Qualification/Reliability Workshop, August 1993
- International Electronics Packaging (IPC) Conference, September 1993
- Electronics Industry Quality Council, October 1993
- International Society for Hybrid Microelectronics, November 1993
- Government Microcircuits Applications Conference, November 1993.

We gave the NASA presentation at the Workshop on MCM-L Reliability, held in conjunction with the 1993 IPC Conference.

ELECTRICAL, ELECTRONIC, AND ELECTROMECHANICAL (EEE) PARTS

Support for the EEE Parts Program area included technical assistance and expertise in the preparation of procedures and policies, evaluation of Center and contractor programs, and technical support for technical meetings. (This report covers EEE parts activity after this technical area was added to this task; prior activity is covered in the Task Order 1000 final report.) Technical leadership and guidance was provided in the restructuring of the NASA Parts Steering Committee (NPSC), EEE Parts Research and Technology Projects, and the EEE Parts Radiation Program. This effort was accomplished through the development of new NPSC Committee charter and Briefing Book format, the development of the Integrated Radiation Hardness Design Assurance (IRHDA) working group charter and strategic plans. Technical direction was provided in redirecting the large JPL and GSFC RTOP programs to be more responsive to NASA Center and NASA program needs. Vitro also provided technical direction was provided in redirecting and eliminating program waste from the EEE parts radiation programs and GSFC and JPL, and restructuring the programs into a multi-center IRHDA working group to share program costs between Headquarters, Centers, and other federal space agencies. The restructuring of the NPSC and IRHDA program areas accomplished the integration of similar program elements at each Center into a coordinated strategic effort, emphasized a customer orientation of the EEE Parts Program elements, consensus of decision making with participation from all NASA center EEE parts and Radiation community experts, and the direct application or transition of center field problems into the EEE Parts and Radiation program elements.

The multi-million dollar "EEE Parts and Radiation Effects" RTOP program at JPL and GSFC was brought under strategic planning control, and included each of the NASA participating centers in the NPSC. The strategic planning activity was evaluated in terms of the changing objectives of the EEE Parts program and new implementation of the IRHDA program, establishing objectives and deliverables designed to meet the requirements of all NASA Centers (not just JPL and GSFC), and evaluating the individual program elements of the EEE Parts and IRHDA programs to determine their successfully meeting the stated NASA-wide center and program needs. This resulted in a broadening of Code Q support to other Centers to improve the return-on-investment of the EEE parts and IRHDA RTOP programs, which had been an ongoing area of disagreement and dissatisfaction from the viewpoint of the SRM&QA Directors at the NASA Field Installations and Program Directors of Space Station Freedom (SSF) and Space Transport System (STS).

Vitro provided technical assessments and oversight to the ongoing systems development effort of the Electronic Parts Information Management System (EPIMS). Planning and funding decisions were coordinated between Vitro and NASA Code Q management elements to review and coordinate complementary funding and management initiatives between the EPIMS and its mechanical parts equivalent, Mechanical Parts Information Management System (MePIMS). Coordination requirements and planning meetings were held with representatives of all NASA Field Installations to address system planning deficiencies not addressed by GSFC Center management of EPIMS and MePIMS.

Vitro also performed assessments of the impact of power transistor (2N3421 - Unitrode) and tantalum capacitor (Sprague) failure scenarios for Mars Observer failure investigation team at NASA HQ and Naval Research Laboratory (NRL) (September-October 1993).

Deliverables:

"Electrical, Electronic, and Electromechanical (EEE) Parts Management and Control Requirements for NASA Space Flight Programs," NHB 5300.4(1F), July 1989, Editor and Contributor.

"Implementation of NASA Standard Electrical, Electronic, and Electromechanical (EEE) Parts Program," NMI 5320.6A, revised NMI 5320.6B, October 1991, Final Draft.

"Basic Policy for NASA Space Flight Program Electrical, Electronic, and Electromechanical (EEE) Parts," NMI 5320.5A, revised NMI 5320.5B, May 1991, Final Draft.

"EEE Parts and Reliability: Data Sharing Survey," Briefing and Stand-alone Data Survey Compilation Diskette, October 1993, for distribution to AIAA/NSIA Coordination Meeting and US Space Parts Strategic Steering Committee.

"NASA EEE Parts Program - Integrated Radiation Hardness Assurance Program (IRHDA) Independent Review Briefing Book," August 1993. Editor and Contributor.

"NASA EEE Parts Program Briefing Book - Review and Prioritization of EEE Parts Program Tasks," NPSC Meeting, Lewis Research Center (LeRC), July 27-28, 1993. Editor and Contributor.

"Radiation Hardness Design Assurance For Space Electronics Systems In The 'Better, Faster, Cheaper' Era," May 1993 - August 1993. Editor and Contributor.

"NASA Strategic Committee on Space Parts Radiation Hardness Assurance," February 1993.

"Space Electronic Parts Infrastructure Assurance (SEPIA): Development Strategy," September 1992.

"Parts Manufacturer Survey Evaluation Guide Book," Final Draft, February 1994.

"RADATA DATABANK: A Full Text Retrieval Infobase," FolioVIEWS data retrieval version of JPL's RADATA Databank, prepared by Vitro and Labat-Anderson, October 1991.

"GIDEP DATA Base: A Full Text Retrieval Infobase," FolioVIEWS data retrieval version of GIDEP Alert database, prepared by Vitro and Labat-Anderson, October 1991.

"Grade 2 Parts for the EOS Program," December 1992.

III. CONCLUSIONS AND RECOMMENDATIONS

Over the life of Task Order 4000, Vitro has been responsive to OSMA's changing requirements. We have reorganized our staff to make our organization a reflection of OSMA's. While the scope of our effort has been altered to reflect OSMA's budget reality, we have made significant contributions to each technical area. These accomplishments, described above, have enabled Code QW to expand its budget and staff and to better serve other NASA programs. Based on our experience working with Code QW, plus our familiarity with the other NASA programs, we make the following recommendations to Code QW:

- ***Engineering Standards***: The use of appropriate standards is the foundation of NASA's assurance capability. NASA and Code QW need to increase use of voluntary and DoD standards, reduce reliance on institutional standards and, where necessary, develop Agencywide standards. Code QW should complete the development of and then implement an improved process for developing standards and establish a management system for NASA standards.

- ***Metric Transition***: Code QW needs to update the NASA Metric Transition Plan to reflect the current program responsibilities, budgets, and schedules. Joint efforts with other government agencies should be expanded to make better use of limited resources and yet make the fastest reasonable progress on the adoption of the metric system.

- ***Advanced Technologies***: Code QW currently supports selected advanced technologies. Code QW should consider developing a well-defined procedure for identifying new areas that deserve support.

- ***Systems Engineering***: Code QW participates in several system engineering initiatives, including the Systems Engineering Process Improvement Team (SEPIT), the System Engineering Working Group, the Program Excellence Team, and the National Initiative for Product Data Exchange. Code QW needs to maintain basic program management information (e.g., goals and objectives, deliverables, schedule, and budget) on the status of cooperative programs, specifically in a form appropriate for management briefings. In addition, Code QW must identify national systems engineering issues and additional opportunities for cooperative programs.

- ***Software Engineering and Assurance***: Code QW's goal is to assist program planning to the critical evolving areas of NASA software safety, engineering, assurance, and IV&V technology development. The effort covers NASA's program life cycle, from requirements definition, through design, test, and independent verification and validation (IV&V), to operations and maintenance. In the future, Code QW should

bolster its technical expertise for directing the IV&V Facility, technical assessments, and preparation of software standards, guidelines, and metrics.

- ***Electronic Parts Packaging and EEE Parts***: Code QW should consider integration of these activities into a broad parts, materials, and processes effort.

5000 SERIES TASK ORDER
QUALITY AND PRODUCTIVITY AWARENESS PROGRAM/SRM&QA CAREER DEVELOPMENT AND TRAINING

I. BACKGROUND FOR THE OVERALL TASK

After contract award, it was readily apparent to OSMA that a vehicle was needed to obtain support for the Quality and Productivity Improvement Programs Office (Code QB). Hence, a Quality and Productivity Awareness Program/SRM&QA Career Development and Training task order was established to provide this support. Code QB was officially established by the NASA Administrator to operate under the Associate Administrator for Safety, Reliability, Maintainability, and Quality Assurance (Code Q). The Office plays a significant role in advancing NASA's image as a leader in national quality and productivity by promoting quality and productivity improvement programs within NASA and its contractor community and sharing these improvement initiatives with other government agencies, educational institutions, the business and industry community, and professional associations and societies. The task order required Vitro Corporation to assist Code QB in establishing NASA as a center of excellence through firm support of Code QB's quality and productivity initiatives; in particular, the establishment of efficient and effective training and development programs for NASA's SRM&QA personnel.

II. SUMMARY OF TASK ACTIVITY

Vitro provided technical and administrative support for the SRM&QA Career Development and Training (CD&T) Program and for the Quality and Productivity Awareness (Q&PA) Program.

SRM&QA Career Development and Training (CD&T) Program

The SRM&QA Career Development Program (CDP) Plan involved implementation of an agency SRM&QA CD&T Program. The primary objective of the program was to provide a structured framework for the training and development of a sufficient number of SRM&QA engineers and technical specialists to meet NASA's immediate and projected SRM&QA workforce requirements. A secondary objective was to provide, to the maximum extent possible, career opportunities that generally satisfy the personal aspirations of the agency's SRM&QA employees. Therefore, the NASA SRM&QA CDP Plan was designed to establish NASA as a center of excellence in the training and development of SRM&QA personnel, meeting both individual and Agency needs. Vitro planned, coordinated, and implemented all activities associated with the SRM&QA CD&T Program. Vitro supported and coordinated the Career Development Working Group (CDWG) activities. Vitro also assisted, as required, the NASA Centers in the formulation of center career development and training plans and assisted Code QB in monitoring center career development activities.

The NASA SRM&QA CDP Plan required each Center to have its own career development program or system in place and in writing. This latitude was designed to allow the Centers to tailor their career development program activities to fit center-unique needs. Also, each Center's SRM&QA Director was required to report the status of that Center's career development activities to the Associate Administrator for SRM&QA each year. The NASA SRM&QA CDP Plan also specified the format for the report.

Vitro also assisted Code QB in identifying and analyzing agency training and development requirements and sources of training and development activities to fulfill those requirements. Vitro developed a mechanism for coordinating the planning and development of agency SRM&QA training so as to more effectively identify unfunded training requirements and existing training course development initiatives that would fulfill those requirements. Vitro collected, analyzed information, and made recommendations regarding SRM&QA CD&T Program improvements, as required by Code QB. The primary sources of information were other government agencies, educational institutions, and industry, as well as the broad base of experience within NASA.

Vitro conducted a survey of government and industry SRM&QA Training and Development (T&D) Programs. The *Survey of SRM&QA Work Force Training and Development Programs in Selected Industrial Establishment and Government Organizations* report was designed to document successful long-term T&D programs used in aerospace and aerospace-related industries for all personnel in general and SRM&QA personnel in particular. Vitro contacted a wide variety of industrial and government organizations that have demonstrated successes in SRM&QA and related technical fields to describe their SRM&QA T&D programs and activities. The survey report provides important information to be used to refine the NASA SRM&QA Career Development and Training Programs, as well as in aiding other organizations in designing their own SRM&QA T&QA programs. These long-range T&D strategies play a major role in ensuring a sufficient supply of professional engineers and discipline specialists for SRM&QA.

Vitro also established and maintained an automated SRM&QA Training Courses Compendium (TCC) Data Base. The TCC Data Base is a compendium of courses, degree and intern programs, documents, and organizations associated with safety, reliability, maintainability, and quality assurance, and such related topics as risk analysis/management, integrated logistics support, and configuration management. This data base was designed for use in association with the NASA SRM&QA CDP and other SRM&QA T&D efforts by assisting supervisors and training personnel in determining sources of SRM&QA T&D activities and materials. Following data base program development and validation, data entry was accomplished. Vitro coordinated and installed the TCC Data Base at all NASA Code Divisions and shipped the TCC Data Base to all NASA Centers complete with the Installation and User's Guide.

Vitro also established a SRM&QA CD&T Library to provide a resource center of materials to support NASA's SRM&QA CD&T activities. These materials include

general books on career development, career counseling, training, and similar topics; college catalogs outlining numerous SRM&QA course and degree programs; catalogs and pamphlets regarding NASA professional development opportunities at Headquarters and the centers; brochures concerning commercially available SRM&QA training; and related items. The library was located at Vitro's Maryland Avenue office and was open for use by NASA personnel on a walk-in basis. Library materials could also be checked out to NASA personnel at field center locations.

Quality and Productivity Awareness (Q&PA) Program

The Quality and Productivity Awareness (Q&PA) Program included numerous quality and productivity initiatives for which Code QB was responsible. Vitro assisted Code QB in promoting these initiatives. Promotional activities were limited to the preparation of articles, presentation material, posters, brochures, and pamphlets. Vitro arranged for the development and preparation of a Quality and Productivity presentation package complete with graphics/viewgraphs for use by the Code QB Director. Vitro also arranged for the development of a Quality Awareness Training Program for NASA Headquarters Code Q Supervisors and the conduct of such training.

In addition, Vitro provided technical support for preparation of documents and publications such as the Quality and Productivity Awareness Newsletter. This support entailed creative writing/editing of technical and quality awareness material as required by the Q&PA Program. Vitro also established and maintained a reference library of books, pamphlets, documents, and papers in support of the Q&PA Program.

III. CONCLUSIONS AND RECOMMENDATIONS

The Quality and Productivity Awareness Program/SRM&QA Career Development and Training task orders spanned the period of February 22, 1988 through August 15, 1989, at which time it was transitioned to another contractor, Information Dynamics, Inc. (IDI) under a SBA 8(a) set-aside contract. Milestone charts (see attachment) for this period detail the activities and status of all deliverables. All government-furnished material held by Vitro Corporation in support of the Quality and Productivity Awareness Program/SRM&QA Career Development and Training task order was transferred to IDI, with Mr. Arthur Palmer of the NASA Code QB Office acknowledging receipt on August 15, 1989.

Due to the decentralized nature of the SRM&QA Career Development and Training (CD&T) Program, the success or failure of the overall Agencywide NASA SRM&QA CDP will depend heavily on training and development efforts at the Centers. This places a heavy burden on the Centers, since they must develop, implement, and support a viable CDP, and on Code Q, since it must measure success or failure largely through its evaluation of the Center programs. It was Vitro's opinion that, at the time of task transition to IDI, two center CDP plans were excellent (ARC, LeRC); two were good (KSC, SSC); two were inadequate (GSFC, MSFC); and two were not yet developed (JSC, JPL). One Center (LaRC) insisted that it would not participate formally. All

Centers must develop program plans as viable as those at ARC, LeRC, KSC, and SSC for the overall Agencywide program to succeed.

5000 SERIES TASK ORDER
SOFTWARE INDEPENDENT VERIFICATION AND VALIDATION SUPPORT

I. BACKGROUND FOR THE OVERALL TASK

In 1992, NASA began construction of a Software Independent Verification and Validation (IV&V) Facility in Fairmont, West Virginia. The Facility serves as a NASA resource and center of excellence for software IV&V research, application, and training that enhance project support to the NASA mission. This series of task orders was created to provide the IV&V Facility (Code QV) with software IV&V expertise to assist in the development, integration, and operation of the Software IV&V Facility. Vitro provided software IV&V support from November 8, 1993 through February 10, 1994.

II. SUMMARY OF TASK ACTIVITY

The Vitro software IV&V staff personnel assisted in planning and development of the first NASA IV&V workshop, which was held December 13-16, 1993 and attended by over 150 software IV&V experts. This subtask entailed defining the scope and thrust of the workshop, identifying and obtaining commitments from candidate speakers and workshop leaders, preparing announcements, and other assistance as required. Vitro personnel also was asked to co-chair the Criticality session.

Vitro also assisted in preparing a Software IV&V Strategic Plan to integrate the overall requirements and proposed products associated with the Software IV&V Facility.

Vitro was asked to assist in developing an interim Statement of Work for the International Space Station Alpha IV&V effort to be performed by the Software IV&V Facility. This subtask entailed planning activities to be performed between February 1994 and September 1994.

III. CONCLUSIONS AND RECOMMENDATIONS

Deliverables were accurate and timely, and fully satisfied NASA requirements. The requirements of task order were well defined; therefore, no recommendations are provided.

6000 SERIES TASK ORDER ADMINISTRATION

I. BACKGROUND FOR THE OVERALL TASK

After contract award, it was readily apparent that a vehicle was needed to obtain the administrative and financial reporting requirements associated with the contract. Hence, a separate task order for Administration was established. The Administration task order encompassed the full spectrum of administrative and financial support needed to provide quick response to NASA Code Q requirements. The Administration task order required Vitro Corporation to employ personnel with expertise in task order management, budgeting and cost performance reporting, subcontract/consultant administration, resources management, logistics, security program administration, government property administration, facilities management, information management system, and conflict of interest avoidance. The Administration task orders spanned the period of February 22, 1988 through February 10, 1994. Staff support task orders (formerly 8000 series) became a part of this series in August 1992.

II. SUMMARY OF TASK ACTIVITY

Vitro Corporation Administration staff personnel provided financial reports as required under NASA Headquarters contract NASW-4311 and associated task orders using the Contractor Financial Management Report (NASA Forms 533M and 533Q) and a specially generated and formatted biweekly report (see attachment). The Contracting Officer (CO) and the Contracting Officer's Technical Representative (COTR) approved the reporting formats in content and design, and also established the delivery schedule. The biweekly reports provided a cost breakdown by major elements, and included manpower and budget information required to successfully manage the contract. On their own initiative, Vitro Administration staff personnel also designed, developed, and produced budget and cost graphs (see attachment) on a biweekly basis. The graphs were extremely useful in managing and controlling contract costs as trends were easily identified. The COTR readily recognized the value of the graphs and made them a task order deliverable. The standard NASA monthly and quarterly financial reports, specialized biweekly budget and cost reports, and biweekly budget and cost graphs enabled NASA to properly monitor contractor cost performance at the task order and job summary level (hours and cost). The financial reports also furnished the Vitro Program Manager and his staff with the data needed for planning, budgeting, and cost control. The quality and timeliness of these reports were superior.

Vitro established a system for identifying and tracking NASA Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) contractual conflicts of interest. A procedure was established to identify all potential conflicts of interests in the pursuit of new business and to obtain CO approval. No conflict of interests were experienced throughout the performance of the contract.

In the area of subcontract/consultant administration, Vitro was highly effective in obtaining specialized short-term support in a timely and effective manner through subcontract/consultant agreements in areas where we did not have the in-house expertise.

On a monthly basis, Vitro Administration personnel updated, reviewed, and submitted the Government Property Report to the Corporate Property Office for subsequent submittal to the Government. All Government equipment was returned to NASA prior to the contract completion date.

After the merger of SRM&QA support (see 8000 series task order) into this task order in 1993, Vitro continued to provide technical writing and editing support for management reports, presentations, and other special projects for the Code Q management and engineering staff. Vitro also provided technical editing, word processing, and publications preparation support for assigned documents generated for/by Code Q management and engineering staff as described in other tasks, including NASA Management Issuances, NASA Handbooks, position papers, and technical reports. Vitro also assisted management and engineering staff in the preparation of Code Q presentation materials (viewgraphs, slides, brochures, insets, etc.) for management reviews and technical presentations. Critical deliveries included NHB 1700.1, "Safety Policy and Requirements Document," NSS 1740.12, "NASA Safety Standard for Explosives, Propellants, and Pyrotechnics," and quarterly reports summarizing the accomplishments of the RELTECH Steering Committee and Teams.

Vitro also continued its administrative support to the Aerospace Safety Advisory Panel (ASAP). The main thrust of this support focused on assisting the Panel in generating the ASAP Report. In 1993, Vitro employees were recognized for excellent publication support to the Space Shuttle Main Engine (SSME) Assessment Team, an ad hoc task forced created by ASAP to conduct a thorough assessment of the risks that the SSME poses to the safe operation of the Space Shuttle.

In the latter phase of the contract, Vitro provided support for the maintenance and upgrade of administrative data systems (e.g., budget systems, action tracking systems, etc.) to meet Code Q management and engineering requirements.

III. CONCLUSIONS AND RECOMMENDATIONS

The deliverables were accurate and timely, and fully satisfied NASA requirements to monitor the SRM&QA contract to the task level. Additional support in tangible areas other than scheduled requirements was provided in an expedient and professional manner. The majority of the requirements of the Administration task order were well-defined as they are standardized throughout NASA. This is especially the case in the area of financial reporting. Therefore, no recommendations are provided.

7000 SERIES TASK ORDER
PROGRAM MANAGEMENT

I. BACKGROUND FOR THE OVERALL TASK

Shortly after contract award, the NASA Code Q management requested that a separate task order for Program Management be established whereby NASA Code Q would have more direct visibility into the overall Vitro management activities at a program level. This separate task order also gave NASA Code Q a more direct instrument under which to evaluate the Vitro Program Manager's performance and effectiveness.

II. SUMMARY OF TASK ACTIVITY

The Program Management task was essentially one of managing the entire Vitro support effort, paying particular attention to providing responsive and quality technical support within budget. This was fully accomplished during the contract period.

Vitro provided all the technical, engineering, and management skills/disciplines necessary to assist NASA Code Q in its overall mission being responsive to task direction from Code Q. Vitro performed these functions with a skill mix that continuously evolved to fulfill changing Code Q requirements as Code Q itself adapted to a changing NASA environment. Vitro adapted its organizational structure and staffing throughout the life of the contract to reflect the changes required by Code Q. Vitro assigned personnel with indepth experience attuned to the needs of Code Q. When needs changed, Vitro rapidly responded by utilizing Vitro corporate resources and subcontracted with highly talented specialists or other contractors. This enabled Vitro to quickly adjust staffing levels and skills to meet short-term workload variations and requirements.

Responsiveness to Code Q was crucial and Vitro was most effectively located within close walking distance to NASA Headquarters. The ability to personally interface with Code Q staff on a daily basis without losing productive time in travel was invaluable and advantageous to Code Q.

Vitro gained an understanding of the "protocol" involved (e.g., that OSMA must approve and in some cases make the initial contact) when interfacing on a technical level with elements at a Field Installation or with associated program-related contractor personnel. Vitro established numerous important SRM&QA points of contact at the nine NASA Field Installations and with supporting SRM&QA and program contractors and used these contacts on a daily basis to support Code Q.

Vitro developed significant integration processes and actively participated in Space Shuttle SRM&QA continuous process improvement-related activities at the NASA manned spaceflight Field Installations. Space Shuttle enhancement reviews suggested by Vitro were implemented to integrate long-term SRM&QA Field Installation process improvement efforts. Vitro produced the Space Shuttle Safety and Mission Assurance

(S&MA) Operating Plan and a process improvement matrix for Space Shuttle S&MA to assist in controlling process improvement activities. Vitro helped develop a Code Q Process Improvement Plan to help integrate Code Q process improvement efforts and to advocate SRM&QA improvements to the Space Shuttle program.

Vitro assisted Code Q in assessing and communicating complex Space Station Electrical Power System (EPS) stability issues to Space Station program managers. Vitro performed critical design evaluations of the Day-Of-Launch I-Loads Uplink (DOLILU) processor systems software development, providing OSMA with a strong rationale for advocating an Independent Verification and Validation (IV&V) activity leading to the Space Shuttle Project Office funding a full IV&V effort. Vitro assisted Code Q in identifying critical dynamical issues related to the rendezvous and docking aspects of the forthcoming U.S./Russian Spacelab/Mir Mission (SLM). Vitro also introduced the idea for and assisted Code Q in implementing an integrating function, the Potential Issue/Problem Identification Committee (PIPIC), for independent assessments that require coordination and support across a number of different functional areas. Vitro developed procedures/software for document management that are now in use within Code Q.

Vitro personnel have received over 200 awards, commendations, and recognitions from Code Q and other NASA and NASA-related industry organizations. Some of these awards are for engineering support to technical interagency panels such as the Aerospace Safety Advisory Panel (ASAP), the Interagency Nuclear Safety Review Panel (INSRP), and the Aerospace Industries Association (AIA)/National Security Industrial Association (NSIA)/NASA Liaison Panel. Further awards resulted from our support to the Jet Propulsion Laboratory (JPL) Radiation Effects and Testing Group, where Vitro engineers helped JPL in their increased focus on electronic, electrical, and electromechanical (EEE) parts. The Vitro Safety and Engineering Assurance Group twice received the NASA Headquarters Special Service Group Honor Award. Vitro personnel also received personal recognition for technical assessments and support to Code Q, which included commendations for risk management/assessment and probabilistic failure analysis recognized at NASA Headquarters and Marshall Space Flight Field Installation, technical support to the LOX/LH2 Explosion Hazards program, technical assessments on space flight data recorders and qualification of hardware by similarity, and development of software policies and standards. Vitro conducted a prelaunch assessment of cracks in the hinge of the External Tank doors on STS-37R. This assessment provided Code Q with technical rationale to delay the launch until problems were corrected. The Vitro engineer who performed the assessment was later honored with the Manned Flight Awareness Award, one of five such prestigious Manned Flight Awareness Awards received by Vitro personnel during the tenure of the contract.

III. CONCLUSIONS AND RECOMMENDATIONS

The Vitro contract effort has been managed extremely well. Vitro overcame a start-up problem to provide outstanding support to NASA Code Q, providing them with special and unique SRM&QA expertise not resident within NASA Headquarters. ***During the***

entire period of the contract, Vitro's effort was always under budget. In addition, Vitro has had eight "excellent," two "very good", and one "good" award fee ratings over the duration of the contract,. The "good" rating was for the very first 6-month period when Vitro was in the startup phase of the 6-year effort. It should be especially noted that Vitro's "excellent" performance was maintained for a majority of a significant "downsizing" period, in which the Vitro staffing was essentially reduced from a high of approximately 102 persons to a final staffing of approximately 48 persons, a 53% cut in personnel. During these trying times, Vitro personnel maintained extraordinary professionalism, continuing to provide outstanding support to NASA Code Q.

A significant factor in Vitro's providing outstanding support to Code Q has been the sense of "teamwork" instilled amongst NASA and Vitro personnel. We are firmly convinced that the "team" concept begun under Mr. George Rodney and further enhanced/encouraged under Col. Frederick Gregory is the reason for not only Vitro's outstanding performance, but also the successes attained by NASA Code Q. It is only when the people working on a program/project really feel that they are an essential part of it, do they perform at their best. Such a relationship must continue.

Vitro encourages and recommends that NASA Code Q continue and expand upon the "team" concept already established between Code Q and its support contractor. NASA should not establish a relationship that keeps its support contractor at "arms length"; "teamwork" leads to better communication, which in turn leads to increased performance, which ultimately benefits NASA and the contractor as well.

8000 SERIES TASK ORDER
SRM&QA STAFF SUPPORT

I. BACKGROUND FOR THE OVERALL TASK

Shortly after contract award, OSMA (Code Q) management determined that a separate task order for SRM&QA Staff Support was needed. As a result, Vitro formed a Technical Support group was formed to provide administrative support directly to the Associate Administrator, Deputy Associate Administrator, and their immediate staff. Shortly thereafter, this support was matrixed across all task orders. In 1992, at the request of the COTR, all technical support was consolidated under Institutional and Resources Management (Code QM). The SRM&QA Staff Support task orders spanned the period of August 11, 1988 through August 10, 1992, at which time they were transitioned to the Administrative Support Task.

II. SUMMARY OF TASK ACTIVITY

During the contract period, Vitro provided office automation and local area network systems, technical editing, word processing, and publications preparation support for a wide range of assigned documents generated for and by the Associate Administrator, Deputy Associate Administrator, and Code Q division managers as described in other tasks. This effort included NASA Management Instructions and Handbooks, Safety Standards, Guidebooks, position papers, management plans, technical assessments, technical specifications for ADP/T products and services, and technical reports. Vitro also assisted management and engineering staff in the preparation of Code Q presentation materials (viewgraphs, slides, brochures, insets, etc.) for numerous high-level management reviews and technical presentations, and provided support for special studies. This work was frequently accomplished under very tight deadlines and with minimal direction from Code Q.

Vitro supported and assisted in the development of several major Code Q speeches; namely, an "NDE for the Nineties" speech, Chapter 9 of the AIAA Handbook on Astronautics, the "Road Map To Excellence" speech for the NSIA Conference, the "TQM in Perspective" and "TQM — The Move From Product to Process Control" speeches for the First Total Quality Management Symposium, speakers' notes and vugraphs for the NASA Management Training course, a speech for Mr. George Rodney for the Reliability and Maintainability Symposium; development of an independent study in response to Congress Roe's letter concerning control of SRM&QA program funds, development of position papers on five Augustine Report recommendations, development of a technical paper/speech on Space Product Assurance in the 1990s for delivery at ESTEC; the "Testing in the Twenty First Century" speech for the 12th Aerospace Testing Seminar; the "Assuring Safety and Mission Success for Space Station Freedom" paper and speech for the International Symposium on Reliability and Maintainability; and the Critical Safety Assurance Factors for Manned Spacecraft" paper for the 41st Congress of the International Astronautical Federation (IAF).

Vitro also provided technical writing and editing support for the Hubble Space Telescope Board of Investigation and the Human Error Incidents review at KSC; and development of designs, color renderings, line-drawings, and 3-D concept models for the George M. Low, NASA Quality and Excellence Award, Trophy.

Vitro provided administrative support to the Aerospace Safety Advisory Panel (ASAP). This effort consisted of providing editorial, graphics, original cover art as well as computer graphics, and publications engineering support to the Panel to assist them in developing the ASAP Annual Report and supporting the annual briefing to the Administrator. Vitro's graphics staff developed a unique report cover depicting the particular theme of the year's work.

Vitro personnel provided support for the OSMA File/Records Conversion task. We were able to use our comprehensive knowledge of file management systems to assist in the development of Division file management plans. This laid the groundwork for Code Q to continue this task in-house.

Vitro also provided support for the maintenance and upgrade of administrative data systems (e.g., budget systems, action tracking systems, etc.) to meet Code Q management and engineering requirements.

The Vitro technical support staff was recognized for outstanding performance of critical writing and editing assignments. Included were the prestigious Manned Flight Award (MFA) and letters of commendations for outstanding and professional support to the Office of the Associate Administrator for Safety and Mission Quality (now Mission Assurance), Interagency Nuclear Safety Review Panel, and ASAP. One employee was cited for excellent writing support to NASA quality and productivity improvement programs.

III. CONCLUSIONS AND RECOMMENDATIONS

Deliverables for this task order were accurate, timely, and fully responsive to Code Q's requirements. A significant factor in the success of Vitro's Technical Support effort for Code Q has been the sense of "teamwork" between NASA and Vitro personnel. Vitro recommends that Code Q continue to expand and improve this "team" concept.

9000 SERIES TASK ORDER
SPACE FLIGHT SAFETY AND MISSION ASSURANCE

I. BACKGROUND FOR THE OVERALL TASK

This task series was originally formed to provide the NASA Programs Assurance Division (Code QP) with engineering and technical support for the Space Shuttle Program, Space Station Freedom (Level I), Spacelab, Expendable Launch Vehicles/Upper Stages (ELV/US), Payloads, and for Aeronautics and Space Exploration activities. The primary purpose of this support has been to enhance Code QP's ability to maintain a current knowledge and understanding of program status to support reviews of major problems, issues and concerns, and flight readiness. Code QP also required technical support for related program efforts such as the modification of program Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) documents.

In December 1992, a Code Q reorganization resulted in the Payload Programs being transferred to the Quality Management (Payloads) Division (Code QT). In addition, the Space Shuttle safety group within the Safety Division (Code QS) was transferred to the Space Flight Safety and Mission Assurance Division (Code QP). The Division assumed the responsibility for the Mission Safety Evaluation (MSE) reports, and the safety tasks transferred within Vitro to this task order.

In January 1994, the Expendable Launch Vehicle/Upper Stage (ELV/US) programs, the Aeronautics (Code R) programs, and the Advanced Concepts and Technologies (Code C) programs were transferred to the Payloads and Aeronautics Division (Code QT). Again, Vitro resources have been adjusted to support the new realignment of tasks for the NASA Code Q Divisions.

II. SUMMARY OF TASK ACTIVITY

Vitro's approach has been to assign engineers, with directly related experience, to participate in reviews such as management, planning, engineering assessment, status, processing, change control, design, and flight readiness, with the objective of ensuring SRM&QA concerns were identified and appropriately addressed. Vitro also provided technical support for the modification of program documents, and sent qualified individuals to support all Level I/II Program Requirements Control Board (PRCB) telecons and related program technical meetings. Typical products were quick response technical assessments of SRM&QA issues and concerns, bi-weekly reports, monthly reports, trip reports, and special topic technical reports on significant issues, such as process-related problems. Vitro also modified numerous documents for Code QP, and recommended changes to program documents to enhance the SRM&QA requirements effectiveness.

Space Shuttle Program

The Vitro engineering team has very been successful in providing technical assessments and reports of SRM&QA issues and concerns for the many Space Shuttle missions flown throughout the contract period. The NASA Associate Administrator for Safety and Mission Assurance (Code Q) commended the entire Vitro engineering support team for Code QP as follows: " The proof of your competence and one of the products that reflects your ability to succinctly summarize the key issues for top management, is the Biweekly Report."

Space Shuttle documents, such as the Contingency Action Plan and the Launch and Mission Support Plan, have been significantly revised to reflect the changes in Code Q management and processes. Vitro engineers developed a Space Shuttle Program Enhancement Review Process plan and Operating plan to define a review process that would assist Code QP in advocating SRM&QA changes for the long-term enhancement of the Space Shuttle Program.

One of the key Vitro Space Shuttle engineers developing these plans was honored as a Manned Flight Awareness Honoree for his outstanding technical contributions and judgment and the development of an Enhancement Review Process Plan in support of the Space Shuttle Program, thus contributing to each mission's success.

Space Shuttle Mission Safety Evaluation (MSE) Report

Since the MSE and safety efforts were transferred to this task, the MSE report process has been evaluated using Continuous Process Improvement techniques to enhance the product. The results of two customer surveys and the process review led to a restructuring of the Vitro process to improve the quality and technical accuracy of the MSE report. Significant format changes have been made to facilitate Vitro engineers in updating and changing information, while reducing production costs. The Vitro engineer who managed this effort was recently honored by NASA as a Manned Flight Awareness Honoree, in recognition of his efforts to provide the SRM&QA and Space Shuttle Program communities with a single source of risk assessment information, as a contribution to each mission's success.

Space Station Freedom (Level I)

The Space Station Freedom was restructured and redesigned in August 1993 as the new International Space Station Alpha. Much of the work completed during the many Preliminary (PDRs) and Critical Design Reviews (CDRs) held prior to that time is being re-evaluated in light of the new design and cost constraints. Some of the significant efforts Vitro engineers performed on CDRs for the Canadian Space Agency (Remote Manipulator System), and the Italian Space Agency (Mini Pressurized Logistics Module) will endure, since the International Space Station Alpha is not expected to impact these International Partner elements. The RIDs were written against the CDR documents to enhance the SRM&QA requirements effectiveness. Since the new contract does not require Space Station support, this work has been turned over to NASA.

Another significant Space Station effort involved the stability requirements for the Space Station Electric Power System (EPS). Vitro engineers have identified potential instabilities caused by the inadequate specification of load impedance characteristics. While the EPS design for Space Station Freedom is being changed for the International Space Station Alpha, the same problems exist with the impedance specifications. Support for this work will continue during the transition of the support effort to NASA.

Expendable Launch Vehicles/Upper Stages, and Spacelab

Vitro engineers have participated in the full range of design, flight readiness, and range safety reviews for the many ELV/US and Spacelab missions flown during this contract. Significant areas of achievement include assisting Code QP in the coordination of the commercial ELV launch SRM&QA policy with DOT, USAF and NASA, and the commercial ELV community. Vitro engineers were instrumental in gaining program and Code Q support for the Laser Initiated Ordnance program. Their technical expertise was used to support the special teams formed to investigate the TOS ACTS Super*Zip Anomaly on STS-51 and the Tethered Satellite Anomaly on STS-46. Again, their technical expertise and the exceptional technical support to Code QP has been noted in letters of commendation.

Vitro engineers have formed a process improvement team to address the long-term and flight-to-flight issues associated with each type of ELV program. The result of their efforts is the Safety and Mission Assurance Review Telecon (SMART) Operating Plan. This plan recommends a process to Code QP for reviewing significant SRM&QA issues and concerns for each ELV mission, similar to the Space Shuttle Prelaunch Assessment Review. The review will include the NASA and industry ELV SRM&QA community to discuss issues related to both the specific mission, the launch vehicle, and the launch facility. The intent is to aid the SRM&QA community in coordinating process improvements that will contribute to mission success.

Payloads and Missions

At the time the payloads and mission programs transferred to the Quality Management (Payloads) Division (Code QT), the Vitro engineering support had been providing detailed, rapid-response, technical assessments of SRM&QA issues and concerns. Also, the engineers reviewed and recommended changes to NASA documents, such as NASA contract SRM&QA requirements, to enhance the effectiveness of SRM&QA requirements imposed on their Payloads programs. Their recommendations spanned the full range of the Payloads program design and mission life cycle, from the Phase A/B conceptual design processes to the flight performance.

Since the transfer of the Payloads programs to Code QT, the Vitro engineers assigned to support Code QT have assisted in the development of a Cost of Quality seminar. Engineers on the Code QP task supported that effort, with the intent of expanding the emphasis beyond Payload programs to include the Space Shuttle, Space Shuttle/Mir, International Space Station Alpha, and Spacelab programs.

Aeronautics and Space Exploration Programs

Significant efforts for this program area include assisting Code QP in the establishment of SRM&QA requirements within the Code C Centers for the Commercial Development of Space (CCDS) Programs, and establishing safety requirements for commercial customers flying experiments on the Space Shuttle. Vitro engineers have assisted Code QP in establishing SRM&QA requirements for the Shuttle/MIR program with their Russian Space Agency counterparts. Significant technical issues have been identified with the docking dynamics between the Space Shuttle and the Mir Space Station, with the Space Shuttle plume impingement, and with the Mir attitude control system. These issues are being worked as part of the Shuttle/Mir programs effort, and will continue to be worked as part of the new contract. Vitro's unique technical support for these issues has been recognized by Code QP.

Special Program Support

As part of this contract, and part of the Payloads program effort for this task, Vitro provided special optical engineering quality assurance support to the NASA Associate Administrator for Safety, Reliability, Maintainability, and Quality Assurance, Code Q, during his participation on the Hubble Space Telescope Board of Investigation (also know as the Allen Committee). The Board was formed to determine how the error was made in the Space Telescope's Primary Mirror during its manufacturing process, and remained undetected until the telescope was placed into orbit. Vitro supplied engineering and management support for this effort, and contributed to the "SRM&QA Observations and Lessons Learned" report published in October 1990. The optical support continued during the redesign effort and First Servicing Mission flown on STS-61 in December 1993 to correct the optics. Due to the successful quality assurance efforts of the Vitro optical subcontractor, the Advanced X-Ray Astrophysics Facility (AXAF) program has requested Code Q to provide similar independent optical quality assurance for their program.

III. CONCLUSIONS AND RECOMMENDATIONS

While the requirements for technical and engineering support for the programs will remain, the direction within NASA has been to work more closely with each program to solve process problems. Vitro has recommended and will continue to recommend recurrence control for process problems as they are identified by our technical evaluations and assessments. NASA should incorporate the Space Shuttle Enhancement Review program approved during this task period, as time permits. Due to the fact that the Space Shuttle Program is a mature program, costs savings can only result by reviewing the SRM&QA processes to determine which processes provide the best value, and changing those that provide the least. Similarly, the SMART program for the ELV programs should be implemented to provide a forum for discussing mutual SRM&QA issues within the ELV SRM&QA community. Vitro engineers, in conjunction with the Division Director, have been drafting an Operating Plan for the Space Shuttle Program to provide a forum within Code Q for discussing and coordinating all of the RTOP

programs and field installation programs that impact that program. With the diverse efforts currently being performed within Code Q, and a need to reduce program costs while providing a complete program of support for the Space Shuttle Program, this forum will provide a process for advocating SRM&QA changes to the Program Office. Quality products such as the Cost of Quality seminar should be expanded to programs other than Payloads. The real value of the Cost of Quality concept is that it complements the Continuous Process Improvement techniques, while providing a process to focus improvements based on useful metrics.

10000 SERIES TASK ORDER
SPACE STATION FREEDOM PROGRAM
SAFETY AND PRODUCT ASSURANCE SUPPORT

I. BACKGROUND FOR THE OVERALL TASK

The NASA Space Station Freedom Program Office Level II Safety and Product Assurance Office (DSQ) responsibility was for the planning, direction, implementation, and evaluation of SSFP systems assurance including systems safety, reliability, maintainability, and quality assurance including software product assurance. DSQ provided for overall independent technical review of SSFP/projects to ensure development efforts and mission operations were being conducted on a sound engineering basis with proper controls and attention to development risk. In addition, DSQ performed review and oversight activities to help ensure that the design and operational procedures prepared for the SSF payloads and experiments were accomplished to preclude the occurrence of hazards that could cause loss of life or injury of the crew; cause loss of, or significant degradation to the SSF; and in normal operations, cause damage to other elements. DSQ also was responsible to ensure that the Director and Deputy Director, SSFPO, and other principal officials were aware of SRM&QA matters pertaining to the technical execution and physical readiness of the SSFP and related projects.

Vitro provided DSQ with the necessary technical and managerial skill and expertise in providing multi-discipline support in the principal functional areas of safety, reliability maintainability, and quality assurance (SRM&QA).

II. SUMMARY OF TASK ACTIVITY

This task series required Vitro to provide management, safety, reliability, quality assurance, and software produce assurance support.

Management Support

Vitro provided technical engineering support to perform assigned engineering tasks as directed by the Safety and Product Assurance Office Managers. Vitro helped to ensure that the Level II Space Station Freedom Program engineering activities complied with program requirements by providing superior independent technical assessment and oversight of the Level II/III S&PA guidance, direction, and priorities established by DSQ managers.

Vitro management was totally committed to the development and implementation of (1) a safety program that supported the challenges of safely establishing, operating and maintaining space station; (2) a reliability/maintainability program that identified, corrected, or controlled critical design weaknesses, repair requirements, and resources; (3) software defined and developed to a level of quality consistent with program

requirements and goals; and (4) a quality assurance program that verified compliance with the Space Station Freedom program requirements.

Safety Support

Vitro safety engineers supported evolution of SSF program safety documentation (SSP 30000, Section 9, Program Definition and Requirements Document; SSP 30309, Safety Analysis and Risk Assessment Requirements; SSP 30599, SSFP Safety Review Process; SSP 30688, SSFP Integrated Safety Program Plan; SSP 30652, SSFP Payload Safety Requirements; SSP 30685, SSFP Hazard Data base System Requirements Definition Document) through participation in the development of major program safety requirements and review of draft documents to ensure comprehensive inclusion of programmatic safety requirements. Vitro safety engineers interacted with program participants to review and integrate draft modifications in response to programwide reviews, and prepared and presented CRs to the Integration Management Review (IMR), pre-Space Station Control Board (SSCB), and SSCB. Vitro also monitored progress of the documents through the SSFP review and approval process.

The Vitro safety engineers performed independent Change Evaluations (CEs) of more than 300 CRs to modify existing Space Station documents or baseline new documents. In many instances, the safety engineers worked with the program engineers who were the proponents of CRs to revise them in an effort to remove any adverse safety impacts prior to presentation to the SSCB. The safety engineers performed independent assessments of Level II Systems Engineering and Integration safety products for the Space Station Safety Office. Chief among these were assessments of the Integrated Safety Preliminary Design Review (ISPDR) Integrated Safety Assessment Report, the Man-Tended Capability (MTC) Phase Review Integrated Safety Assessment Report, the Integrated Risk Assessment Reports for Stages 1 through 4, and the Program Incremental Design Review (PIDR-93).

Vitro safety engineers actively participated in Space Station Freedom (SSF) level, Work Package (WP) level, prime contractor, Kennedy Space Center (KSC), and International Partner (IP) design reviews of flight hardware/software, ground support equipment, data systems, engineering support centers, and processing facilities. The safety engineers attended design presentations, reviewed design documentation, performed design assessments, developed Review Item Discrepancy (RID) reports, and participated on design review teams to disposition RIDs. At major milestone reviews (e.g., ISPDR, MTC Phase Review, and the Program Incremental Design Review), Vitro was responsible for performing independent global safety risk assessments. Using insights gained during participation in major milestone reviews, the safety engineers assisted the Safety Manager in developing safety risk assessments and presentations. Review participation included three major milestone reviews: the ISPDR and the MTC Phase Review and the Program Incremental Design Review. Other reviews supported included the WP-2 Distributed Systems Preliminary Design Review (PDR), the Canadian Space Agency (CSA) Interim Design Review (IDR), the WP-2 Delta PDR, the CSA Delta PDR, the KSC Ground Handling Equipment PDR, the KSC Core Electronics Contract PDR, the CSA Engineering Support Center PDR, the CSA Mobile Servicing System

Software Delta IDR, the WP-1 Delta PDR, the Central Software Facility/Central Avionics Facility System Requirements Review, the Communications and Tracking System Ground Support Equipment PDR, the Flight System Software Requirements Review, the National Space Development Agency (NASDA) Japanese Experimental Module PDR, the European Space Agency (ESA) Attached Pressurized Module System Requirements Review, and the CSA Space Station Remote Manipulator System CDR.

The Vitro safety engineers assisted in the development and implementation of the Freedom Safety Review Panel (FSRP), which is still used to conduct independent safety reviews of the Space Station Manned Base (SSMB) configuration/operations for each stage of the SSMB construction and development. The safety engineers provided technical review of the Safety Compliance Data Packages (SCDP) from each WP or IP. Vitro safety engineers supported the FSRP chairman at each safety review by identifying/recording issues, concerns, and required actions; researching requirements; preparing summary reports, and assuring the accuracy of, and concurrence with, the minutes of the joint FSRP/Payload Safety Review Panel (PSRP) safety reviews.

Vitro safety engineers supported development of safety associated SSF programwide data bases through participation in various Technical Management Information System (TMIS) Joint Application Development conferences and the conduct of programwide data base needs assessments. Safety engineers interfaced with program participants to establish data collection, system business processes, process work flow, business priorities, data needs, data flow and, used the information to develop chapters for the data base requirements definition document. The safety engineers conducted user acceptance testing of data base functionality and user interfaces and reviewed user documentation for accuracy and comprehensiveness.

Vitro safety engineers actively supported the Space Station Safety Office in the conduct of four major safety-related trade studies. The studies addressed Space Station emergency egress scenarios, module arrangement, and translation paths; manual power switches to control electrical power to module equipment and payload racks; proper settings for ground fault interrupters; and fire detection and suppression system components definition and locations. The studies required extensive coordination with Space Station Work Package 1, 2, and 4 engineers, IPs, contractors, consultants, industry sources, and NASA activities.

Reliability and Maintainability Support

The Vitro Reliability and Maintainability (R&M) team was deeply involved in the attainment of mission success and the goal to assure that the Space Station will be reliable and maintainable over its life span. Vitro R&M engineers participated in every facet of the Space Station program — from basic requirements definition and the generation of plans to very detailed engineering analysis through the use of mathematical simulation models. Vitro provided R&M engineering capabilities in direct support providing rapid response to many problems and action requests. Vitro R&M engineers demonstrated an innate sense of responsibility and urgency, which resulted in an

appreciation of teamwork, continuous process improvement, and interactive participation required for a meaningful SSF product assurance program. Specific examples of direct SSF program participation included:

- Submission of many Review Item Discrepancies for R&M requirements which surfaced at the Integrated System Preliminary Design Review, the Man Tended Capability Phase Preliminary Design Review, and the Program Incremental Design Review-93.

- Submission of CRs for the Program Definition and Requirements Document, Section 9 Data Requirements and baselining of the Level II R&M Program Plan, evaluation of numerous CRs dealing with design requirements; and complete traceability of R&M requirements from SSP 30000, Sections 3 and 9 down to Level III Contract End Item specifications.

- Documentation and planning tasks, including the total development of a comprehensive Reliability & Maintainability Program Plan (TSS 30579) for Level II; development of S&PA support plans for the ISPDR, MTC Phase PDR, and MTC CDR.

- Closure of many action items dealing with subjects as diverse as the CSA ground segment and design review traceability; development of an R&M data base for audits, findings, observations, and corrective actions; development of the Level II S&PA Verification Assessment Plan to be included as a volume of the Program Master Verification Plan, SSP 30666, and development of a NASA Handbook for the preparation of FMEA/CILs, which if implemented will affect every NASA program.

Work performed by the R&M team in an oversight role include team membership and leadership during Level II, Level III, and IP technical milestone and design reviews; audits and R&M data reviews at the WPs and IPs; IP meet-or-exceed reviews and data exchange agreements; verification assurance; analysis of the SSF two-failure-tolerant attitude control function design; training in the Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) Data Base for review and analysis of failures; and S&PA representation in the working group which analyzed the various DC-to-DC Converter Unit location options.

Management activities included active participation in the Redundancy Management Panel; program, DSQ and R&M stand-up meetings; Electrical, Electronic Electromagnetic (EEE) Parts Advisory Board, Program Verification Panel; Mission Integration Review group; PDR and CDR planning groups; model development and analysis working group; TMIS data base and application meetings, including the Failure Environment Analysis Tool/Digraph Development Group; and the program SRM&QA Managers' teleconferences.

Vitro's technical analytic endeavors include the performance of availability modeling through the construction of reliability block diagrams and the calculation of availability

figures for SSF survival functions using a Monte Carlo simulation model, the assessment of changes in availability due to redesign changes in MTBF and MTTR, and the identification of weak links in the design. The Event Time Availability Reliability Analysis (ETARA) model was used to calculate the reliability and availability of the early Space Station Freedom Stages (1-6). The purpose was to make design tradeoffs for a number of configurations of the survival functions and stage durations. It was found, for example, that maintenance flights would be needed if Stage durations exceeded 3 months, and that reliability was significantly enhanced by using actively cooled dc-dc converters.

Additionally, Vitro R&M engineers participated in a select team evaluation of SSF R&M data bases, and made the recommendation that all program offices utilize a consistent method to assess Orbital Replacement Unit failure rates, life limits, and repair times. Vitro R&M engineers performed an independent assessment of the SSF Master Verification Requirements and the Verification Responsibility Matrix. They also actively participated in the KSC Cargo Element Lifting Assembly CDR, the delta Software Requirements Review for the SSF Central Software Facility and Central Avionics Facility, the Ground Systems Program Review, the KSC SSF Processing Facility Ammonia Servicing System, the KSC Removable Overhead Access Platform, the ESA System Requirements Review, the NASDA Japanese Experiment Module PDR, and the CSA Engineering Support Center CDR.

Vitro R&M engineers interfaced with the Space Station IPs on a frequent basis. We participated in the European Space Agency Preliminary Requirements Review at the ESA Technical and Engineering Center in Noordwijk, in the ESA/NASA meets-or-exceeds meetings, with National Space Development Agency of Japan in the Redundancy Management Panel, and with CSA at numerous requirements and design reviews of the Space Station Remote Manipulator and the Special Purpose Dextrous Manipulator. The R&M section has many contacts within the IPs organizations which allows it to have quick and effective communications with the IPs.

The Vitro R&M support team had extensive interface in the SSF program, including organization, levels, management structure, and a working relationship with key personnel at NASA Headquarters Code Q, all the Work Package centers and prime contractors, the Space Station Engineering and Integration Contractor (SSEIC), KSC, and the IPs. SSF experience included hands-on development and analyses dealing with requirements, documents, controls, and configuration management procedures. The team has thorough knowledge of the phased process of the SSF development, design review, production, acceptance, verification, launch-to-orbit, and operation of the SSF over its life span.

The entire reliability, maintainability, and verification assurance programs, including those tasks of the Systems Engineering and Integration group, are well known, as is the establishment of the requirements of SSP 30234, the FMEA/CIL requirements for Space Station program, and the FMEA/CIL assessment activity in major design reviews. This unique knowledge permitted Vitro to establish a history of proven R&M accomplishments across the full spectrum of R&M engineering.

Quality Assurance Support

Vitro Quality Assurance (QA) engineers supported the evolution of the SSF design and program documentation through the continuous evaluation, assessment and independent oversight of requirements traceability to the manufacturer level; Engineering Change Packages (ECPs) and CRs; design presentations and design data packages; technical documentation; data system integrity and capabilities; and WP Centers/IPs/Prime Contractors/KSC operations and procedures.

Vitro QA engineers supported the goal of advancement of world class QA principles and techniques by developing and maintaining QA program requirements through the initiation of program CRs and formulation of CEs). The QA Engineers supported the SSFPO S&PA Office in the maintenance of the following program baselined documents for which the office is the book manager:

- SSP 30000, Section 9, "Program Definition Requirements Document."
- SSP 30223 "Problem Reporting and Corrective Action System Requirements for the Space Station Program."
- SSP 30521 "Safety and Product Assurance Audit Survey Plan."
- SSP 30523 Safety and Product Assurance Information Planning Group (IPG) Overview Document."
- SSP 30524 "Problem Reporting and Corrective Action (PRACA) System Requirements Definition Document (RDD).

Vitro QA engineers actively and intensely participated in SSFP, WP Center, Prime Contractor, KSC, and IP design reviews of flight hardware/software, ground support equipment, data systems, engineering support centers, and processing facilities. The QA staff attended design presentations, performed assessment of designs, reviewed design documentation, developed RID reports, and participated on design review teams to disposition RIDS. Through these activities, the QA staff ensured that program QA requirements are incorporated throughout program/center/company specifications and standards. To enhance design review productivity, the QA staff utilized the Automated Requirements Management System (ARMS) to verify requirements traceability and the Automated RID Tracking System (ARTS) to track RID dispositions.

Vitro QA engineers ensured that program requirements were incorporated in and properly flowed down to all applicable lower level documents, standards, and specifications. Vitro engineers supported the Configuration Management Office, as a representative of the S&PA Office, on all Requirements Traceability Audits. Requirements traceability was also accomplished during evaluations of CRs and by participation in design reviews and various working groups. Additionally, the QA staff ensured that all new requirements were verifiable and that the requirements identified in ARMS were incorporated in the Master Verification Data Base (MVDB).

Vitro QA engineers performed special assessments and analyses upon request of the S&PA Office. The QA staff assessed the adequacy of the records retention program of all SSFP Participants (SSFPPs); identified issues with the definition of high strength fasteners throughout NASA and the aerospace industry; performed comparisons of terminology between the NASA SSFP and the ESA Columbus Program; conducted reviews of NASA workmanship standards; assessed the quality program of WP Centers in preparation for S&PA audits; identified issues with the use of conflicting units conversions by NASA and IP; assessed the adequacy and implementation of Fastener/Quick Disconnects/Electrical Connectors requirements on the program; evaluated the compatibility of NHB 5300.4 (1D-2) and SSP 30000 Section 9, Chapter 4.0 requirements; and reviewed numerous engineering analyses. Vitro QA engineers actively participated in the QA Technical Interchange Meetings (TIMs) and presented results and overviews of its subject activities.

Vitro QA engineers supported development and maintenance of QA associated SSF programwide data bases through participation in Joint Application Development (JAD) conferences, TMIS Application Technical Reviews, TMIS Branch level reviews, TMIS Operations Readiness Reviews, TMIS Control Boards, and various other working groups. Vitro QA engineers worked with program participants to establish data collection system business processes, process work flow, business priorities, data element needs, and data requirements. In conjunction with the NASA Office of Primary Responsibility (OPR), IBM, Boeing, and TMIS, Vitro QA engineers developed user scenarios, data models, entity relationship diagrams, process decomposition diagrams, and data tables. Vitro QA engineers conducted user acceptance testing of data base functionality and user interfaces and reviewed user documentation for accuracy and comprehensiveness. Vitro QA engineers evaluated the Requirements Definition Documents for most TMIS data systems for S&PA related data processing impacts and acted as the representative for the S&PA Office on the development of the Test, Operations, Maintenance Requirements and Specifications (TOMRS) system.

Vitro QA engineers supported the NASA OPR on the development, evolution, and maintenance of the Problem Reporting and Corrective Action (PRACA) System and Data System (PDS). The Vitro QA engineers identified and defined user requirements, performed system assessments, conducted user acceptance testing, assisted in development of CRs, assisted in disposition of CEs, evaluated design approaches, and coordinated activities of the PRACA development team. Vitro QA engineers coordinated and participated in PRACA JAD conferences, PRACA Process Improvement Team (PPIT) meetings, PRACA Design Review Team (DRT) meetings, and various telecons. Vitro QA engineers assisted in the maintenance and evolution of SSP 30223, "Problem Reporting and Corrective Action System Requirements for the Space Station Program," and SSP 30524, "Problem Reporting and Corrective Action (PRACA) System Requirements Definition Document (RDD)." Vitro QA engineers supported the NASA OPR at the TMIS Control Board (TCB) and SSCB and played an important role in PRACA meet-or-exceed evaluations of the NASDA, ESA, and CSA. Vitro QA engineers performed extensive data element comparisons and business process assessments for the meet or exceed evaluations for both the NASDA and ESA. Vitro QA engineers also played a significant role in assessing the feasibility of adapting and

converting the Johnson Space Center (JSC) Space Shuttle (SS) PRACA process to utilize the SSFP PDS. Vitro QA engineers assisted in the development of Nonconformance Reporting (NCR) capabilities, In-Flight Anomaly (IFA) reporting, and Corrective Action Assistance Request (CAAR) processing capabilities in the SSFP PDS. Vitro QA engineers supported the development of future capabilities, such as problem trending and analysis.

The Vitro QA engineers supported verification activities through the review of the program verification requirements in SSP 30000, Section 12, "Space Station Program Master Verification Requirements"; SSP 30467, Volume II, "Space Station Program Master Verification Requirements: Master Verification Implementation Requirements"; and SSP 30468, Volume II, "Space Station Combined Elements and Integrated Systems Process Requirements: Combined Elements and Integrated Systems Verification Implementation Requirements." Through various means, Vitro QA engineers assured that verification responsibilities are considered and planned by all program participants. Vitro QA engineers supported various verification working groups and meetings such as the Program Master Verification Requirement (PMVR) review and the Stage Verification Working Group.

Software Product Assurance

The Vitro Software Product Assurance (SPA) engineers actively supported evolution of SSF program software documentation based on requirements of SSP 30000, Program Definition and Requirements Document, Section 9, Product Assurance Requirements, Paragraph 5, Software Product Assurance, in support of the SSF Level II SPA office. This was accomplished through participation (via independent assessment) in the development and implementation of software requirements on the program, and the review of draft documents to ensure traceability of programmatic S&PA requirements. Vitro SPA engineers assured that software product assurance concerns were addressed in software documentation. Vitro SPA engineers coordinated with other SSF directorate activities, including IPs, to review and integrate changes to requirements, design, and verification/test documentation. Vitro SPA engineers performed research using various documents from NASA, American Institute Aeronautics and Astronautics, Federal Aviation Administration, Institute of Electrical and Electronics Engineers, private industry etc., in order to utilize the latest "state-of-the-art" techniques and information. The Level II SPA activity was recognized as the software management focal point for issues related to software safety, requirements verifiability, and other issues associated with software. Vitro SPA engineers established sound working relationships through interface and coordination with Level I, Level II, WP, IP, and contractor and subcontractor personnel, to derive 'real issues' and bring them to management's attention.

Specific examples of direct SSF program S&PA participation include SSF program reviews and performance of review-related tasks, including:

- Evaluation of program requirements and IP "meet-or-exceed" requirements.

- Proactive engineering support in Requirements Traceability Audits conducted for the purpose of evaluating traceability or flowdown of requirements to the Work Package Centers and CSA and their major contractors and the submittal of Audit Evaluation Reports.

- Engineering assessment of Level A Integrated Flight Software Architecture Requirements to assure that the Fault Detection Identification and Reconfiguration requirements meet the criteria for catastrophic and critical hazards for time-critical events.

- Participation in industry and government research related to Software Reliability; provided suggestions to the program on a consistent approach for software reliability on the program.

- Active involvement in the Software Fault Analysis Working Group and the finalization of the Software Fault Analysis Plan.

- Evaluation and review of major contractor SPA plans for compliance with requirements in Section 9, DR SSQ-SPA-001.

- Active engagement in TIMs with NASA Headquarters and WP Centers.

Vitro SPA engineers were actively engaged in the NASDA Software Design Review and developed RIDs in support of the program effort. Especially of note was the RID that precipitated the NASDA SPA TIM, involving the identification of deficiencies in the NASDA SPA plan that did not meet the intent of DR SSQ-SPA-001.

Vitro SPA engineers were actively involved in the development, evaluation, or support of ongoing engineering efforts in CFR; Level II SPA plan; safety definitions working group; PRACA software non-conformance issues; software metrics; Ada coding standards; and scope of Independent Verification and Validation (IV&V) activities.

Vitro SPA engineers supported all NASA software assurance activities, including developing documents, defining assurance activities, and supporting the NASA Software Steering Committee. Documents that Vitro S&PA had a significant role in developing included NMI 2410.10, "NASA Software Management, Assurance and Engineering Policy"; NASA-STD-2201-93, "Software Assurance Standard; SMPA-GB-A201, Software Assurance Guidebook"; and SMAP-GB-A301, "Software Quality Assurance Audits Guidebook." Vitro also participated in the development of the Implementation Plan for the IV&V Facility in Fairmont, WV.

III. CONCLUSIONS AND RECOMMENDATIONS

It is recommended that NASA Headquarters develop, in conjunction with all NASA Centers, a set of Agencywide Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) requirements documents or handbooks that would apply to every NASA

program, project, and organization. The requirements document should standardize every aspect of the total SRM&QA program but yet allow for tailoring or deviating in certain areas for special conditions. The Agencywide requirements concept would eliminate the need to develop requirements for each NASA program and allow personnel to easily work across programs.