NASA Conference Publication 3348

Second Aerospace Environmental Technology Conference—Executive Summary

A.F. Whitaker, M. Clark-Ingram, and S.L. Hessler, Editors

Summary of a conference held
in Huntsville, Alabama
August 6–8, 1996

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National Aeronautics and Space Administration
Marshall Space Flight Center • MSFC, Alabama 35812

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FOREWORD

The mandated elimination of CFC's, halons, TCA, and other ozone-depleting chemicals and specific hazardous materials has required changes and new developments in aerospace materials and processes. The aerospace industry has been involved for several years in providing product substitutions, redesigning entire production processes, and developing new materials that minimize or eliminate damage to the environment. These activities can be, for the most part, defined as environmental impact avoidance technology through the introduction of environmentally friendly replacement materials and processes and are consistent with achieving the Administration's goals for "sustainable development" technologies. This Conference has offered an opportunity for aerospace scientists and engineers to assess this evolving technology, which, in many cases, is in the implementation phase.

The current emphasis within environmental technology is on replacement cleaning solvents including aqueous media, their application verifications and implementations, compliant coating technologies including corrosion protection systems and removal techniques, chemical propulsion effects on the environment, and the modifications to relevant processing and manufacturing specifications and standards. Already, many applications of materials and processes have been affected by this new environmental technology. This volume synopsizes those results and implications. It is not a substitute for detailed conference papers to be published in 1997 or those that may be found in professional journals.

We would like to acknowledge those individuals who served on the Conference Steering Committee:

Paul Schuerer, Chairman
Ann Whitaker, Technical Program Chairman
DeWitt Burns
Ralph Carruth
Marceia Clark-Ingram
Beth Cook
Stephania Darby
Ben Goldberg
Gene Goldman
Arthur Henderson
Mary Kitchings
Tamara Landers
Ron Mize
Gail Murphree
Tom Owens
Glynn Rountree
Tom Staab
Freda Summers

Finally, we would like to thank the many people who helped make this Conference such a success: Marshall Space Flight Center Director, Dr. Wayne Littles; NASA/MSFC's Materials and Processes Laboratory and Propulsion Laboratory personnel; NASA Chief Engineer, Dr. Dan Mulville; EPA Director of the Emission Standards Division, Bruce Jordan; the other Conference-sponsoring organizations including the NASA Headquarters Office of Space Flight; the NASA Operational Environment Team; the AIAA; the SAMPE Space Manufacturing Thrust Committee; the National Center for Manufacturing Sciences; the American Society of Metals, International; Aerospace Industries Association; the Air Transport Association; the EPA; the University of Alabama's Office of Conferences and Marketing; and all the Government, industry, and academic investigators.

Robert J. Schwinghamer, Conference Chairman

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SESSIONS

List of ACRONYMS, ABBREVIATIONS, and SYMBOLS

Acronyms and Abbreviations

AP	Ammonium perchlorate
CAAA	Clean Air Act Amendments of 1990
CARC	Chemical agent resistant coating
CFC	Chlorofluorocarbon
CFC-11	Trichlorofluoromethane
CFC-113	Trichlorotrifluoroethane
CO_2	Carbon dioxide
CTG	Control techniques guidelines
EHS	Environmental health and safety
EMIS	Environmental management information system
EMS	Environmental management system
EPDM	Ethylene propylene diene monomer
ET	External tank
FPL	(An etch)
FTIR	Fourier transform infrared
FY	Fiscal year
GATT	General Agreement on Tariffs and Trade
HAP	Hazardous air pollutant
HAZMAT	Hazardous materials
HCFC	Hydrochlorofluorocarbon
HCl	Hydrochloride
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether
HMIS	Hazardous materials information system
HTE	High transfer efficiency
HVLP	High volume low pressure
ICBM	Intercontinental ballistics missile
IPA	Isopropyl alcohol
IR	Infrared
IRMNS	Integrated remote monitoring and notification system
IVD	Ion vapor deposition
MCA	Vertrel® MCA
MEK	Methyl ethyl ketone
MIDIS	Multi-band identification and discrimination imaging spectroradiometer
MSDS	Material safety data sheet
MTV	Magnesium Teflon® viton
NAFTA	North American Free Trade Agreement
NAS	National aerospace standard
NBR	Nitrile butadiene rubber
NESHAP	National emission standard for hazardous air pollutants
NIR	Near infrared
NMP	N-methyl-2-pyrrolidone
NPDES	National pollutant discharge elimination system
NPR	National Performance Review
NVR	Non-volatile residue
ODC	Ozone depleting chemical
ODS	Ozone depleting substance
OSEE	Optically stimulated electron emission
PCA	Principal component analysis
PFC	Perfluorocarbons
PLA	Partial least squares analysis
RSRM	Reusable solid rocket motor
RTV	Room temperature vulcanizing
SERDP	Strategic Environmental Research and Development Program
SFL	Solid film lubricant
SIP	State implementation plan
SMT	Vertrel® SMT
SNAP	Significant New Alternatives Program
SRB	Solid rocket booster
SRM	Solid rocket motor
SSME	Space Shuttle main engine
TCA	1,1,1 trichloroethane
TCE	Trichloroethylene
UV	Ultraviolet
VMS	Volatile methyl siloxane
VOC	Volatile organic compound
XF	Vertrel® XF

Organizations

AETC	Aerospace Environmental Technology Conference
AIA	Aerospace Industries Association
AIAA	American Institute of Aeronautics and Astronautics
ARC	Ames Research Center
ASC	Aeronautical Systems Center
ASTM	American Society for Testing and Materials
BDM	Braddock Dunn McDonald
DLA	Defense Logistics Agency
DoD	Department of Defense
DOE	Department of Energy
DSCR	Defense Supply Center Richmond
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
GM	Geiger Mueller
GSFC	Goddard Space Flight Center
ISO	International Standards Organization
JANNAF	Joint Army-Navy-NASA-Air Force committee
JG-APP	Joint Group on Acquisition Pollution Prevention
JSC	Johnson Space Center
KSC	Kennedy Space Center
LaRC	Langley Research Center
LeRC	Lewis Research Center
MSFC	Marshall Space Flight Center
MTC	Modern Technologies Corporation
NASA	National Aeronautics and Space Administration
NASA HQ	National Aeronautics and Space Administration Headquarters
NCMS	National Center for Manufacturing Sciences
NOET	NASA Operational Environmental Team
OSHA	Occupational Safety and Health Administration
PAL	Precision Analytical Laboratory
SAIC	Science Applications International Corporation
SAMPE	Society for the Advancement of Material and Process Engineering
SEP	Societe Europeenne De Propulsion
SSC	Stennis Space Center
TRW	Thompson Ramo Woolridge
U.S.	United States
UAH	University of Alabama in Huntsville
USAF	United States Air Force
USMC	United States Marine Corps
USBI	United Space Boosters, Inc.
UTC	United Technologies Corporation

Measurements and Symbols

~	Approximately
°	Degrees
°C	Degrees Celsius
°F	Degrees Fahrenheit
ft^2/min	Square feet per minute
Hz	Hertz
kg	Kilogram
lb	Pound
lb/gal	Pounds per gallon
mg	Milligram
µm	Micrometer
ppm	Parts per million
%	Percent
psi	Pounds per square inch
rpm	Revolutions per minute
scfm	Standard cubic feet per minute
-T#	Temper number

OVERVIEW: KEYNOTE,

PLENARY OPENING SESSION

The aerospace community has launched a concentrated effort to develop materials and processes that are environmentally friendly and fully compliant with legislation aimed at protecting our environment. Every two years, this Aerospace Environmental Conference provides a forum for new developments in these areas, allowing knowledge to be shared across a broad range of technical experts representing many organizations.

A welcome to the conference was presented by the Keynote speaker, Dr. Wayne Littles, Director of NASA's Marshall Space Flight Center. He noted that, although only affected by 6500 tons of the 300 million tons of hazardous waste processed each year, the aerospace industry is a proactive leader in addressing such issues, a challenge that must be met while maintaining design, reliability, and safety levels. The conference itself represents an important effort that will benefit and protect human civilization. "The most fantastic picture that I have ever seen is from the Apollo spacecraft as it was going toward the Moon, looking back to Earth and seeing the Blue Planet hung in the dark void of space," said Dr. Littles. "It makes you understand how careful we must be with our planet and our environment. Some views demonstrate that we have not been as kind to our Planet as we should be, and we're here to do our part to ensure that our work does not contribute to environmental damage." He thanked the many who are making progress in developing new and innovative ways to comply with environmental regulations. NOET is coordinating NASA's efforts to comply with EPA environmental standards, to eliminate redundancy in contractor programs and operations, to develop employee prioritization trade studies, and to enhance communication among NASA, its contractors, other Federal agencies, and the aerospace community. At NASA/KSC, the materials and processes laboratories and their contractors pioneered efforts to eliminate CFC-113 from precision cleaning and cleanliness verification in oxygen systems. At NASA/MSFC, the materials compatibility laboratory has analyzed the impact of proposed regulations on the way we do business, working closely with EPA to develop workable strategies for compliance. NASA/GSFC, LeRC, and MSFC participate in the Space Mechanisms Working Group, which is assessing the potential effects of Freon-free high performance bearing surfaces. NASA's contractors are also doing an outstanding job. From 1992 to 1996, Thiokol reduced TCA usage in SRM manufacturing from 1 million pounds by a factor of 10. Rocketdyne has converted to aqueous-based cleaning processes for the SSME. Lockheed Martin developed new compliant blowing agents for the thermal protection system and for new critical cleaning and verification processes. USBI is identifying environmentally-compliant handwipe cleaners for SRB production refurbishment activities. Rockwell is developing new materials, processes, and ways to do business. Many interagency activities are also seeking solutions to common environmental challenges. NASA must eliminate undesirable materials and processes while remaining focused on the engineering challenge of making such changes without degrading the safety and reliability of critical systems. NASA strives to achieve perfection and "once we get a design that works, we have a strong tendency to stay with it," explained Dr. Littles.

Keynote Speaker

Dr. Wayne Littles, Center Director, NASA/MSFC

Chair, Plenary Session

Dr. Ann F. Whitaker, Deputy Director, Space Sciences Laboratory, NASA/MSFC

Plenary Speakers

P1.1 Bruce Jordan, Director, Emission Standards Division, EPA

P1.2 Robert J. Schwinghamer, Associate Director (Technical), NASA/MSFC

Luncheon Speaker

Dr. Dan Mulville, NASA Chief Engineer, NASA Headquarters

Yet now NASA must move away from some precision cleaners and materials heavily represented in Space Shuttle systems, many predating the Apollo era. As a result, environmental compliance is an integral part of major changes being made to improve Shuttle performance.

The first Plenary speaker was Bruce Jordan, Director of the Emission Standards Division for the EPA, who reviewed successes to date for the air toxics program (which was designed to reduce emissions from hazardous materials into the Earth's atmosphere) as mandated by the Clean Air Act Amendments of 1990. The 2- and 4-year standards have already been promulgated as legal requirements. Implementation of these two standards alone will prevent more than 1 million tons of toxic air pollutants from entering the environment, as well as keeping 2.5 million tons of organic compounds out of the atmosphere, thereby reducing the production of ground level ozone (i.e.: smog) and particulate matter. EPA is now developing 7-year standards, which encompass approximately 40 more source categories, and preliminary efforts are underway for the development of 10-year standards. As these standards were being developed in 1994 and 1995, the U.S. Congress weighed their potential impacts on both the environment and the American business community. Overall, public opinion clearly indicated that U.S. citizens do not want Congress to remove regulatory vehicles that help ensure cleaner air and water in this country. However, the business community believes that excessive regulations impede their ability to remain globally competitive. Mr. Jordan stated that it is very fitting for the technical community to come together to find satisfactory solutions to these problems. He discussed the process by which his office makes policy during the development of environmental standards, a philosophy used during the roundtable rulemaking process for the Aerospace NESHAP. Its building blocks include assessing the effects of proposed regulation on the U.S. population and related industry groups, while remaining within the constraints of the CAAA; encouraging collaborative involvement among industry, vendors, and citizens; maintaining open and honest communication; emphasizing cost effectiveness; and collecting the best data available.

The second Plenary speaker was Robert J. Schwinghamer, Associate Director (Technical) of NASA/MSFC, who reported environmental technology status for NASA. "Without three decades of unstinting pressure on Government and industry, the Western world today might actually be in the kind of ecological difficulty that conventional wisdom assumes it to be in," noted Schwinghamer. "Instead, we are on the verge of the greatest ecological renewal that the Earth has ever known." Challenges are being faced in the arena of large liquid and solid chemical propulsion systems, where effective replacements must be found for CFC-113 and TCA. NASA and its contractors eliminated the use of over 9 million pounds of CFC's from 1990 to 1994. Inroads are being made into TCA use, where the waste stream was reduced by about 20%. In 1994, liquid propulsion was down to about 257 million pounds of total CFC use (0.8%) and about 15 million pounds of total CFC-113 use (less than 10%), while solid propulsion accounted for about 691 million pounds of total TCA use (0.5%) in the U.S. Common pollution avoidance technology is being developed by the Joint Group on Acquisition Pollution Prevention (JG-APP), an interagency consortium including NASA and the U.S. Air Force, Navy, and Army, which reflects an increasing trend in proactive environmental practices.

The Luncheon speech was given by Dr. Dan Mulville, NASA Chief Engineer, who noted that NASA's enterprises face many environmental challenges, including "how we develop replacement technologies to support our missions and how we ensure that the missions have taken all proper precautions in moving toward more environmentally friendly materials." NASA is being challenged to communicate these issues more effectively, both internally and externally, as well as to have closer ties with industry and other Government agencies in the development of more environmentally compatible systems. In addition, such working relationships are necessary to support the continued viability of the Space Station, which is a key element of NASA's long-term strategy for the space program, as well as Mission to Planet Earth, a major program that is providing an unprecedented level of sustained and detailed information about the Earth's ecosphere to the scientific community and international policy makers. "One of the most important contributions that we can make nationally is to provide data that leads to enhancement of the environment," stated Dr. Mulville. "Our commitment today will have an extraordinary impact into the 21st century."

SESSION A1

SOLID ROCKET MOTOR MANUFACTURING AND DISPOSAL TECHNIQUES

During this session, four papers provided an overview of environmental technology investigations in areas associated with SRM systems and their manufacture.

Eliminating the Use of ODS's in SRM Manufacturing was discussed by G. Sheaffer of The Aerospace Corporation. This paper discussed how four large U.S. manufacturers collaborated to detail success stories from their efforts to reduce and eliminate ODS's. By 1994, ODS use had been reduced by approximately 1.6 million pounds per year compared to the baseline year (1989). Full technical details may be found in a handbook developed through the use of surveys and site visits, which details success stories and lessons learned, as well as case studies and details of ODS elimination, technical challenges that still hinder full ODS elimination, and descriptions of corporate elimination practices.

Environmentally Benign Cleaning and Degreasing Methods for the SRM Industry were presented by J.E. Cocchiaro of Johns Hopkins University. This paper provided a review of the open literature concerning replacement cleaning materials technologies used by the SRM industry. Ample information is available concerning the selection methodologies employed by industry, as well as vapor degreasing alternatives, corrosion issues associated with aqueous cleaning, and studies of hand wipe operations. The replacement materials programs have generated some useful data for the SRM industry in the area of quantitatively defined margins of safety for associated cleanliness requirements. However, Cocchiaro noted that the reported literature has tended to neglect some areas, specifically effects or alternative cleaning methods on bondline aging characteristics and stress corrosion cracking of metallic cases induced by components of alternative cleaners.

Solid Propellant Environmental Issues were addressed by M.D. Le of Phillips Laboratory. This paper discussed the Solid Propellant Environmental Issues project, which was initiated to demonstrate acceptable technologies that may enhance continued production of SRM's through compliance with environmental regulations. In Phase I, current and anticipated regulations were identified, as well as emerging compliance technologies. In Phase II, a baseline database was established by documenting the fabrication of an 800-lb motor using existing process technologies. In Phase III, evaluation and downselection were delineated for more environmentally advantaged process technologies. In Phase IV, alternative process technologies were evaluated for compatibility, cleaning effectiveness, and waste minimization/pollution prevention viability. The most promising candidates were then selected for demonstration. Le provided an overview of the project and technologies, with emphasis on the manufacturing processes waste streams, and existing or projected reports were referenced for actual test results.

Chairs:

Dr. Ben Goldberg, Lead, NOET Propulsion and Prediction Technology Team, NASA/MSFC

Ron McIntosh, Chief, Nonmetallic Materials Division, NASA/MSFC

Speakers:

A1.1 *Eliminating the Use of Ozone Depleting Substances in SRM Manufacturing*, G. Sheaffer, The Aerospace Corporation

A1.2 *Environmentally Benign Cleaning and Degreasing Methods for the SRM Industry*, J.E. Cocchiaro, Johns Hopkins University

A1.3 *Solid Propellant Environmental Issues*, M.D. Le, Phillips Laboratory

A1.4 *Green Missile Program*, D.B. Hagler, U.S. Army Missile Command

Green Missile Program was presented by D.B. Hagler of the U.S. Army Missile Command at Redstone Arsenal. This paper identified a cooperative effort to identify and eliminate major sources of toxic and hazardous materials used in solid rocket propulsion systems, as undertaken by the Tri-Services, DOE, and EPA, with limited involvement by NASA, as interfaced through the JANNAF committee. This interagency team prioritized environmental research needs for solid propulsion systems, based upon their perceptions of current and potential regulatory impacts. They identified three high-priority research tasks: 1) eliminating lead in minimum smoke propellants, 2) eliminating HCl as a combustion product, and 3) minimizing solvents used in energetic oxidizer processing. These tasks were then approved for FY-97 funding under SERDP.

SESSION A2

ENVIRONMENTAL POLICY

During this session, three papers were presented on environmental policy. Although they may create a spike in costs early in the cycle, reduced environmental costs will pay off over the life of a product. NASA is currently educating its buyers to consider environmentally preferred products, as well as developing metrics to track such purchases.

Halons As Hazardous Wastes, Policy Implications of the Montreal Protocol Decision VII/12 were discussed by D.P. Verdonick of Hughes Associates, Inc. The Montreal Protocol is intended to protect the stratospheric ozone layer from CFC's, HCFC's, and halons. Initially, it concentrated on the production of such chemicals. However, in November 1995, this focus changed at a meeting of the Parties to the Montreal Protocol, held in Vienna. One result of this meeting was Decision VII/12 which, for the first time, moves towards controls on the *use* of such chemicals by recommending "limiting the use of halons in new installations to critical applications" and "promoting the environmentally safe destruction of halons, when they are not needed in halon banks." Decision VII/12 also incorporates other environmental considerations besides ozone depletion. Since replacements have yet to be identified for halons used in many aviation fire fighting applications, the aerospace community must closely monitor and contribute to the discussions surrounding the international phase-out of halons.

National Performance Review and Its Effects on How NASA Develops Policy was addressed by O. Dominguez of NASA Headquarters. The NPR challenged the Federal Government to reengineer the way it does business, as well as ensuring that these changes are reflected in Federal policies, directives, procedures, and guidelines. NPR requirements include a 50% reduction in the number of policy documents, as well as reducing each document's page count by 50%. Status was provided on the implementation of NPR requirements into policy initiatives undertaken by NASA, which has established its baseline number of Agency policies, directives, procedures, and guideline documents.

NAS-411 - Does It Fit into DoD Acquisition Reform? was discussed by C. DiGiandomenico of Pollution Prevention Planning, Inc. NAS 411 was created by an industry/DoD/services task group to address concerns about the acquisition of hazardous materials in military contracts and issued by the AIA in 1993. The standard has had some success, but full acceptance is being hindered by a lack of guidance on its implementation. In addition, the standard does not address other environmental concerns (such as encouragement for pollution prevention activities and the relationship of NAS-411 to ISO 14000). DoD and AIA have begun discussions which may lead to a revision of NAS-411 to enhance the usefulness of this standard to the acquisition process.

Chairs:

Olga Dominguez, Deputy Director, Environmental Management Division, NASA Headquarters

Glynn Rountree, Director of Environment and Health, AIA

Speakers:

A2.1 *Halons As Hazardous Wastes, Policy Implications of the Montreal Protocol Decision VII/12,* D.P. Verdonick, Hughes Associates, Inc.

A2.2 *National Performance Review and Its Effects on How NASA Develops Policy,* O. Dominguez, NASA HQ

A2.3 *NAS-411 - Does It Fit into DoD Acquisition Reform?* C. DiGiandomenico, Pollution Prevention Planning, Inc.

SESSION A3

CLEANING: OXYGEN SYSTEMS ISSUES AND APPROACHES

During this session, four papers provided an overview of the problems faced by the aerospace community in seeking viable alternative cleaning agents.

Oxygen Systems Cleaners for Aerospace Applications, as presented by S.E. Davis of NASA/MSFC, reviewed problems facing the aerospace community in seeking viable replacements for CFC cleaning agents. This discussion focused on the process that NASA uses to select cleaning agents for oxygen systems, as well as the necessity of using oxygen compatible materials in such systems, with references to specifications and regulations related to oxygen system cleaning. Test methods were presented for the approval of cleaning agents in oxygen systems, as well as a listing of materials tested at NASA/MSFC. Information was also provided for submitting proposed CFC replacement cleaners to MSFC for testing and approval.

Elimination of Chlorinated Solvents and Other Hazardous Materials in the Manufacture of High Pressure Liquid Oxygen SSME Turbopumps was discussed by M. Privett of Pratt & Whitney, who presented that company's alternatives to trichloroethylene in precision cleaning and verification operations in manufacturing of SSME high-pressure turbopumps. Regulatory reporting and costs are encouraging the use of trichloroethylene to be discontinued. Pratt & Whitney is studying both aqueous and high-pressure liquid carbon dioxide precision cleaning operations to replace the degreasing operation now in use. Pratt & Whitney is also eliminating all hexavalent chromium materials used on the turbopumps, as well as pursuing alternatives to the present chlorinated solvent verification methods.

Supercritical Fluid Cleaning of Oxygen Service Instrumentation was presented by J.A. Peters of The Applied Research Laboratory at Pennsylvania State University, who discussed the laboratory investigations into supercritical fluid cleaning of simulated pressure gauges, as well as this method's applicability to oxygen system components (such as pressure gauges, transducers, and flowmeters). These items present a major challenge in oxygen systems cleaning, due to their complex surface geometries, blind holes, narrow passages, and small interstices. In the past, such components were cleaned using CFC-113 and methylchloroform, which are now banned by ODC regulations. Moreover, many alternative cleaners either present toxicological problems or have physical properties which make them poorly suited for such applications. However, work conducted by the Applied Research Laboratory indicates that supercritical fluid

Chairs:

Freida Lowery, Materials Engineer, NASA/MSFC

Jon Sharpe, Manager, Non-Metallic Materials Processes Development and Production, Lockheed Martin

Speakers:

A3.1 *Oxygen Systems Cleaners for Aerospace Applications*, S.E. Davis and F.S. Lowery, NASA/MSFC

A3.2 *Elimination of Chlorinated Solvents and Other Hazardous Materials in the Manufacture of High Pressure Liquid Oxygen SSME Turbopumps*, M. Privett, Pratt & Whitney

A3.3 *Supercritical Fluid Cleaning of Oxygen Service Instrumentation*, J.A. Peters, Applied Research Laboratory, Pennsylvania State University

A3.4 *Investigation of Aqueous Cleaning Systems and Various Solvent Systems As Alternatives to CFC-113,* Dr. H. Beeson, White Sands Test Facility, NASA/JSC cleaning is an effective, safe, and environmentally sound method for cleaning instruments used in oxygen service.

Investigation of Aqueous Cleaning Systems and Various Solvent Systems As Alternatives to CFC-113 was addressed by Dr. Harold Beeson of White Sands Test Facility at NASA/JSC. During the investigation of the aqueous cleaning and verification system, known contaminants (such as hydraulic fluid and commonly used oils) were used and the nonvolatile residues compared to those left by CFC-113. In addition, oxygen compatibility and cleaning effectiveness were investigated for each replacement solvent (which included ethanol, tetrachloroethylene, HCFC-141b, HCFC-225, HFE-7100, and Vertrel® MCA) and compared to those of CFC-113.

SESSION B1

REPLACEMENT MATERIALS AND PROCESSES - I

During this session, seven papers discussed the development of alternatives for CFC-113, 1,1,1-trichloroethane (methyl chloroform), and CFC-11 for such uses as solvents and foam-blowing agents.

Update on Hydrofluoroether Alternatives to Ozone Depleting Substances was presented by Dr. R.M. Minday of 3M Specialty Chemicals Division Laboratory. For many solvent applications, the alternative must be nonflammable, thermally and chemically stable, non-corrosive, compatible with key materials, low in surface tension, and low in toxicity. Dr. Minday discussed a line of HFE's that his company has introduced to the market to meet these more demanding requirements. He described several HFE products which are non-ozone depleting, have short atmospheric lifetimes, and low global warming potentials. These products have proven effective as replacements for ODS cleaning applications and are expected to be on the new SNAP list within the month.

Ozone Friendly HFC Formulations to Replace CFC-113 and Methyl Chloroform in Cleaning Applications were addressed by A.N. Merchant of the DuPont Company, who discussed the use of HFC's as a replacement for the same types of solvents. DuPont has developed a consortium of HFC products that contain varying concentrations of HFC-43-10. Light residues are effectively removed by HFC-43-10 neat. When mixed with co-solvents (such as hydrocarbons and esters), it can remove tougher contaminants like oils and greases. The cleanliness of the tested components were determined by ionic, visual, microscopic, and particulate count examinations.

HFC-245fa: A Nonflammable, Liquid Blowing Agent was presented by M. Bogdan of Allied Signal, Inc., who encouraged the audience to consider HFC-245fa as a long term replacement for the blowing agent HFC-141b. HFC-245fa has similar physical properties but is nonflammable and nontoxic to humans or the environment. This similarity has allowed the alternative blowing agent to slide in as a replacement in the manufacture of rigid polyurethane and polyisocyanurate insulating foams.

Cleaning Performance and New Technologies Based on Volatile Methyl Siloxane Solvents were discussed by R. Cull of Dow Corning Corporation. He noted the favorable characteristics of VMS materials, which are VOC-exempt, SNAP-approved, and ozone safe. They are not global warmers or hazardous air pollutants. Straight VMS materials are being used in precision cleaning applications to

Chairs:

Marlene Price, Materials Engineer, Rocketdyne Division, Rockwell International

Beth Cook, Deputy, NOET Replacement Technology Team, NASA/MSFC

Speakers:

B1.1 *Update on Hydrofluoroether Alternatives to Ozone Depleting Substances,* Dr. R.M. Minday, 3M Specialty Chemicals Division Laboratory

B1.2 *Ozone Friendly HFC Formulations to Replace CFC-113 and Methyl Chloroform in Cleaning Applications,* A.N. Merchant, DuPont Company

B1.3 *HFC-245fa: A Nonflammable, Liquid Blowing Agent,* M. Bogdan, Allied Signal, Inc.

B1.4 *Cleaning Performance and New Technologies Based on VMS Solvents,* R. Cull, Dow Corning Corporation

B1.5 *Development of a Low Density Polyisocyanurate Foam Insulation with HCFC-141b Blowing Agent,* E. Blevins, Lockheed Martin Manned Space Systems remove silicone residue, fingerprints, and light oils. These materials can soften silicones to allow effective removal of conformal coatings, and USAF has found them to be more effective than PFC's for particulate removal in ultrasonics operations. However, these products range from flammable to combustible.

Development of a Low Density Polyisocyanurate Foam Insulation with HCFC-141b Blowing Agent was presented by E. Blevins of Lockheed Martin Manned Space Systems. At NASA/MSFC, the Materials Research Laboratory used a design of experiments approach to develop an insulation that meets the requirements for use on the Space Shuttle's external tank. This insulation (which has an average density of 2.15 lbs per cubic foot) is foamed with the environmentally friendly blowing agent HCFC-141b, as opposed to an earlier formulation that used CFC-11. Statistically based experiments were designed to optimize the formulation for maximum mechanical strength at cryogenic temperatures with a minimum foam density. HCFC-141b (which has approximately one-tenth the ozone-depleting potential of CFC-11) is an outstanding substitute while still available prior to production phase-out.

B1.6 *Evaluation of Polyurethane Foam Insulation Blowing Agents with Zero Ozone Depletion Potential,* J. Sharpe, Lockheed Martin Manned Space Systems

B1.7 *A Tooling Foam with Zero Ozone Depletion Potential for Composites Fabrication,* D.E. MacArthur, Lockheed Martin Manned Space Systems

Evaluation of Polyurethane Foam Insulation Blowing Agents with Zero Ozone Depletion Potential was discussed by J. Sharpe of Lockheed Martin Manned Space Systems, who discussed research efforts underway to identify and develop alternatives to HCFC-141b, which is being used as an interim blowing agent. These alternatives must meet cryogenic requirements for ET insulation, with zero ozone-depleting potential. Several candidates were reviewed (including hydrocarbons, fluorocarbons, hydrofluoroethers, and hydrofluorocarbons) and HFC-245fa is considered particularly promising.

A Tooling Foam with Zero Ozone Depletion Potential for Composites Fabrication was addressed by D.E. MacArthur of Lockheed Martin Manned Space Systems. Lockheed teamed with UAH to develop a tooling foam for use in composites processing. Marcore is a urethane modified polyisocyanurate foam system, blown with an environmentally friendly blowing agent. This patented material has mechanical and thermal properties superior to those of commercially available materials. The tooling form is compatible with typical preimpregnated composite resins and associated cure cycles, and it can be used in rapid prototyping situations. Marcore has been demonstrated to be effective in the construction of feedlines, as well as prosthetic fitting molds.

SESSION B2

APPROACHES TO ENVIRONMENTAL MANAGEMENT

During this session, six papers presented environmental management practices and pollution prevention through hazard reduction and the development of less hazardous or nontoxic replacements.

Management Strategies for Multi-Use Government Facilities were presented by M.G. Hale of SAIC Support Operations. When supervision of Moffett Field's runways and infrastructure was turned over to NASA/ARC, environmental affairs management was consolidated for both facilities, using one management structure, one contractor, and a "charge back" system for payment of services. Advantages included a central point of contact for regulatory authorities, reduced management, and common standards. The only disadvantage encountered by the lead facility was delayed payment of services from the subordinate facility.

Environmental Technology Program at Aerojet Azusa was addressed by G. Robertson of Aerojet Electronic Systems, who discussed Aerojet's management strategy for reducing pollution in a cost-effective manner. The company assessed its compliance needs, developing a vision and values statement for all employees. Pollution prevention was found to be preferable to dependency on pollution control techniques. A "green team" surveyed the company to determine priority of pollution reduction, prepared and implemented a pollution prevention plan, and provided follow-up using continuous improvement techniques. Aerojet includes life cycle environmental costs in all projects and designs for the environment, from process selection to energy consumption.

Environmental Technology Innovation for the Food Manufacturing Industry was discussed by R.J. Phillips of R.J. Phillips and Associates, Inc. This discussion focused on water conservation. In the food processing industry, large volumes of water become contaminated with dissolved solids, suspended solids, and microbes, which must be removed in order to recycle the water. State of the art systems were described in microfiltration, ultrafiltration, and reverse osmosis, including their capabilities and limitations.

Hazard Potential of ODS and HAZMAT Alternatives was presented by G. Sheaffer of The Aerospace Corporation. This talk addressed the hazard potential of ODS and HAZMAT alternatives. In 1993, USAF defined its pollution prevention program and established the following strategic goal: "Prevent future pollution by reducing hazardous material use and releases of pollutants into the environment to as near zero as feasible." A data matrix was prepared for alternative solvents, in order to implement the

Chairs:

Dr. Rebecca McCaleb, Director, Environmental Engineering and Management Office, NASA/MSFC

Gail Sheaffer, Project Engineer Environmental Programs, The Aerospace Corporation

Speakers:

B2.1 *Management Strategies for Multi-Use Government Facilities,* M.G. Hale, SAIC Support Operations

B2.2 *Environmental Technology Program at Aerojet Azusa,* G. Robertson, Aerojet Electronic Systems

B2.3 *Environmental Technology Innovation for the Food Manufacturing Industry,* R.J. Phillips, R.J. Phillips and Associates, Inc.

B2.4 *Hazard Potential of ODS and HAZMAT Alternatives,* G. Sheaffer, The Aerospace Corporation

B2.5 *TRW's Approach to Solar Cell Assembly Defluxing Using Ozone Depleting Chemical Replacements,* L. McIntyre, TRW

ODS replacement/substitution area. Key information included hazard potential assessment (flammability, volatility, etc.), complexity (lot-to-lot consistency, materials compatibility, etc.), shelf life, worker acceptance, process flow changes, and schedule/cost impacts. Conclusions stated that (1) alternative solvents aren't drop-in replacements, (2) work needs to continue to avoid impacts to hardware performance, reliability, and schedules, and (3) detailed long-term studies are needed for critical applications.

B2.6 *The Use of IVD Aluminum Coating to Replace Cadmium Platings,* V.L. Holmes, McDonnell Douglas Corporation

TRW's Approach to Solar Cell Assembly Defluxing Using Ozone Depleting Chemical Replacements was addressed by L. McIntyre of TRW. This presentation discussed solvent cleaner replacements for trichlorofluoroethane in solar cell defluxing applications. No aqueous or semi-aqueous cleaning agents were found to be acceptable. HCFC (AK-225) and HFC (Vertrel® SMT, an azeotrope of Vertrel® XF HFC and dichloroethylene) cleaned as well as trichlorofluoroethane, but both materials more aggressively attacked the substrate's silicone solar cell-to-coverglass bond region. Warm isopropyl alcohol cleaned as well as trichlorofluoroethane without degrading the silicone bond region as much as other solvents. Flammability concerns were addressed in regard to isopropyl alcohol and the equipment needed to ensure safe replacement.

The Use of IVD Aluminum Coating to Replace Cadmium Platings was presented by V.L. Holmes of McDonnell Douglas Corporation. Cadmium plate is being replaced by a nontoxic IVD aluminum coating, which was developed and characterized several years ago and is now being implemented in a limited number of areas. This process offers significant reductions in toxicity and should be scrutinized for substitution in a wide variety of cadmium coating applications.

SESSION B3

CLEANING: DEVELOPMENTS IN AQUEOUS MEDIA

During this session, six papers discussed new developments in aqueous media for cleaning.

Program Development for An Aqueous Cleaning System was presented by N. Sagers of Thiokol Corporation. Thiokol evaluated seven process parameters for Brulin 815GD aqueous cleaner, including effects on different metals and contaminating agents. The Conaco grease proved to be the toughest contaminating agent to remove. The cleaner temperature was set at 150 °F, due to equipment requirements. Performance criteria included bath life, degreasing ability, and ability to remove inspection fluids. Surfactant level variability did not affect cleaning. Bath life could be determined by observation during black light inspection. The phosphates (used in the Brulin to sequester calcium and magnesium) were the first ingredients to be depleted. Bond failures were observed when the tripolyphosphate dropped to 47 ppm.

Aqueous Tube Cleaning Advances at McDonnell Douglas Aerospace was discussed by S.J. Adams of McDonnell Douglas Aerospace. The Space Division has implemented an aqueous tube cleaning system. A manifold/cabinet system is used to remove "honey oil" from long tubes with multiple bends. Four chemical solutions can be plumbed through the cabinet's lines, which reduces space and cost for tube processing. Precleaning is performed using water at 170 °F. Then a washing solution (5% Rebound detergent) is performed at 130 °F. Two water rinses (one at 170 °F and another at 180 °F) are performed prior to an oven dry at 130 °F.

Aqueous Precision Cleaning of Engine Components was addressed by S.M. Stern of Rocketdyne Division, Rockwell International. This division has also implemented an aqueous cleaning system. A wide variety of hardware can be precision cleaned in a series of large ultrasonic tanks. Both Turco 3878 and Turco 4215 are used as detergents. The amount of particulate on cleaned hardware was greatly affected by certain variables, including the amount of hand rinsing performed and the bath temperatures. The aqueous precision cleaning process is working as well as the solvent process it replaced at Rocketdyne. Tightening the garment policy has helped control fibers in the new facility. No problems have been observed on anodized aluminum, but ultrasonics have caused some cavitation of 6061-T6 aluminum. Concerns remain over the use of ultrasonics on plated parts and low alloy steels.

Chairs:

Eric Eichinger, Lead, Environmental Team, Rockwell

Darrell DeWeese, Materials Engineer, NASA/MSFC

Speakers:

B3.1 *Program Development for An Aqueous Cleaning System,* N. Sagers, Thiokol Corporation

B3.2 *Aqueous Tube Cleaning Advances at McDonnell Douglas Aerospace,* S.J. Adams, McDonnell Douglas Aerospace

B3.3 *Aqueous Precision Cleaning of Engine Components,* S.M. Stern, Rocketdyne Division, Rockwell International

B3.4 *Substitution of Spray-In-Air Aqueous Cleaning for TCA Degreasing of Space Shuttle RSRM Hardware,* R. Wynn, Thiokol Corporation

B3.5 *Development of Statistical Process Control Methodology for An Environmentally Compliant Surface Cleaning Process in A Bonding Laboratory,* D.E. Hutchens, Thiokol Corporation

Substitution of Spray-In-Air Aqueous Cleaning for TCA Degreasing of Space Shuttle RSRM Hardware was presented by R. Wynn of Thiokol Corporation. Thiokol has been testing an aqueous spray in air process, which is already in use for small hardware components. In phase 1, a high-pressure water blast was evaluated. Test specimens were grit-blasted and precleaned with TCA, and the aluminum was primed with standard RSRM primer. Tensile testing of RTV bonded specimens indicates that the spray in air process is a very effective cleaning process. The 70-psi wash uses a 10% detergent solution at 150 °F. This process proved effective on NBR and EPDM non-metallic surfaces. It can be evaluated for epoxy bond surfaces by measuring fracture energy. Fracture energy data were used to establish a 1-megaohm purity requirement for rinse water. A wet/dry vacuum is the best way to quickly remove water, which is an important concern, given the flash oxidation of steel.

Development of Statistical Process Control Methodology for An Environmentally Compliant Surface Cleaning Process in A Bonding Laboratory was discussed by D.E. Hutchens of Thiokol Corporation. To further evaluate the spray in air process, Thiokol performed a statistical process review. An EA-913NA adhesive was used to bond steel specimens. After data analysis was complete, no difference could be observed between the spray air and TCA.

Replacement Technologies for Precision Cleaning of Aerospace Hardware for Propellant Service were addressed by P. Biesinger of Allied Signal Team. Thiokol also reviewed a high-pressure WaterJet process. A 30,000-psi water spray eliminated metal erosion due to grit blasting (98% reduction). In 1995, this process was installed to clean case segments and domes. The labor and time required for these cleaning process has been reduced, and a material cost savings has been realized. The system can also be used to remove paint and grease. A boron nitrate corrosion inhibitor was added to avoid the problem of corrosion resulting from steam condensation.

B3.6 *Replacement Technologies for Precision Cleaning of Aerospace Hardware for Propellant Service,* P. Biesinger, Allied Signal Team

SESSION B4

AEROSPACE CLEAN AIR REGULATIONS - THE FINAL STAGE (PANEL)

In September 1995, EPA promulgated the NESHAP for aerospace manufacturing and rework facilities, applicable to owners or operators of original equipment manufacturing and reworking for commercial, military, or civil aerospace operations. A major source is defined as having potential emissions of 10 tons per year of one HAP or 25 tons per year of aggregated HAP's. A NESHAP supplement and the Aerospace CTG await final approval by EPA.

Regulation rulemaking uses a roundtable process, discussed by B. Jordan, EPA Director of Air Emissions Standards. It includes representation from organizations such as DoD, NASA, manufacturers, regulators, industry members, and environmental groups. All are encouraged to provide sound technical justifications for their positions. Here, the rule development process began in 1991 and resulted in a technically feasible rule that reduces emissions.

Sections 741, 742, and 748 (applicability, definitions, general standards, and handling/storage of waste) were addressed by J. Copeland of McDonnell Douglas Aerospace. The aerospace NESHAP and its supplement apply to aerospace manufacturing/rework (i.e.: cleaning operations, primer/topcoat applications, depainting, chemical milling maskants, and waste handling that involves a major source). Discussions included general standards and potential changes in the NESHAP supplement. Space vehicles may be exempt from all requirements, except depainting. The Space Shuttle SRM manufacturer will be allowed to clean with methyl chloroform.

Sections 744 (cleaning) and 745 (primer/topcoat application operations) were discussed by K. Kurucz of Lockheed Martin. Section 744 affects such operations as handwipe, spray gun, and flush cleaning, as well as identifying exempt cleaning operations. Compliance of cleaning solvents is achieved via adherence to requirements for vapor pressure or composition. Section 745 sets the VOC limit at 2.9 lb/gal and the organic HAP limit at 3.5 lb/gal for primers and topcoats. (These limits do not factor in water and exempt solvents.) Options for controlling emissions for coatings that contain VOC's and organic HAP's include emissions averaging, control devices, and coating application techniques. All spray application apparatuses should achieve emission reductions equivalent to HVLP or electrostatic spray application methods. Inorganic HAP emissions are controlled through the use of waterwash systems or dry particulate filters.

Chairs:

Joe Copeland, Principal Staff Consultant for Health, Safety, and Environmental Affairs, McDonnell Douglas Aerospace

Marceia Clark-Ingram, Lead NOET Regulations and Specifications and Standards, NASA/MSFC

Panelists:

B4.1 *Roundtable Process Used In Rulemaking, NESHAP for Aerospace Manufacturing and Rework Facilities, NESHAP for Aerospace Manufacturing and Rework Facilities (Supplement), and Aerospace Control Techniques Guidelines (CTG),* B. Jordan, Office of Air Quality Planning and Standards, EPA

B4.2 *Sections 741, 742, and 748 (Applicability, Definitions, General Standards, Handling/Storage of Waste),* J. Copeland, McDonnell Douglas Aerospace

B4.3 *Sections 744 (Cleaning) and 745 (Primer/Topcoat Application Operations),* K. Kurucz, Lockheed Martin

B4.4 *Section 746 (Depainting),* W. Stevens, Delta Airlines

Section 746 (depainting) was addressed by W. Stevens of Delta Airlines. It prohibits the use of methylene chloride for coating removal, except in small quantities for spot stripping and decal removal. Instead, non-HAP chemicals or other depainting methods must be used. Dry media coating removal processes must control inorganic HAP emissions via waterwash systems or dry particulate filters and organic HAP emissions via carbon adsorbers or incinerators.

B4.5 *Chemical Milling Maskant Application Operations,* J. Copeland, McDonnell Douglas Aerospace

Chemical milling maskant application operations were discussed by J. Copeland of McDonnell Douglas Aerospace. The aerospace NESHAP only applies to Type II chemical milling maskants, with HAP and VOC limits of 1.3 lb/gal (less water and exempt solvents). The NESHAP supplement will address limits on Type I maskants. Control devices include carbon adsorbers and incinerators, which should reduce organic HAP and VOC emissions by 81%. He also discussed CTG, which provides guidance on reducing HAP and VOC emissions from aerospace manufacturing and rework operations for SIP's that must be developed in non-attainment areas. It addresses specialty coatings with performance criteria that exceed those of primers and topcoats for specific applications. Approximately 60 categories exist (e.g., cryogenic flexible primers and conformal coatings), most used in very small quantities.

B4.6 *Section 750 (Demonstration of Compliance Status),* W. Stevens, Delta Airlines

Section 750 (compliance status) was addressed by W. Stevens of Delta Airlines. It describes test methods and procedures to derive data demonstrating the compliance status of operations affected by the aerospace NESHAP. They range from determining composite vapor pressure of a cleaner to determining overall control efficiency of a carbon adsorber. Method 24 will be used to determine VOC content of solvent-based coatings and maskants.

B4.7 *Sections 752 (Recordkeeping) and 753 (Reporting),* M. Clark-Ingram, NASA/MSFC

Sections 752 (recordkeeping) and 753 (reporting) were discussed by M. Clark-Ingram of NASA/MSFC. The owner or operator of an impacted facility must report compliance status to EPA or the state annually or semiannually. Recordkeeping and reporting requirements vary among operations, but become more burdensome for non-compliant materials emissions controlled via control devices or averaging options.

B4.8 *NASA/USAF/EPA InterAgency Depainting Project,* P. Goozh, NASA HQ

An interagency depainting project is being conducted by NASA/USAF/EPA to evaluate paint removal techniques that do not use methylene chloride, as discussed by P. Goozh of NASA HQ. Nine techniques are being evaluated on approximately 400 substrates of clad and non-clad 2024-T3 aluminum in four thicknesses. This study includes robust aging (800 thermal cycles from -65 to 160 °F). Five processing/aging/depainting cycles are planned.

SESSION C1

ROCKET MOTOR MANUFACTURE AND USE: REPLACEMENT AND PREDICATIONS TECHNOLOGIES

During this session, six technical papers dealt with the subject of SRM environmental issues. As a heavy user of chemicals and products that require special attention and disposal procedures, the SRM industry is actively pursuing technology to bring their operations in compliance with Federal law and EPA policies.

Disposal Process for Propellant from Air Force ICBM's was presented by J.A. Hurley of Tyndall Air Force Base. This paper discussed USAF efforts to safely dispose of surplus solid rocket propellants. They have identified a bacteria which attacks AP and reduces it to chlorine, which can be safely disposed of through public sewage systems. Plans call for construction of a pilot plant to demonstrate this capability in the area of Salt Lake City, UT.

Recovery and Reuse of Rocket Propellants were discussed by Dr. W.S. Melvin of the U.S. Army Missile Command. This paper summarized U.S. Army efforts to reclaim and reuse AP from SRM propellants by extracting it with an ammonia reaction process. The AP can then be reused in many applications. This approach has become increasingly economical as the process is refined and AP costs continue to rise.

Replacement of Dichromate Catalyst Polysulfide Sealant was addressed by C.M. Conway of USBI. This paper synopsized USBI's work on sealants used extensively to prevent corrosion on faying surfaces, fastener heads, and nuts on the SRB aft skirt, forward skirt, and frustum. Historically, such sealants have contained chromium and other hazardous metals. Attempts are being made to find a direct replacement, using environmentally advantaged sealants that are free of these elements and show promise for SRB use.

Updated Assessment of the Environmental Impacts of Rocket Effluents was presented by Dr. R.R. Bennett of Thiokol Corporation. This paper discussed the impacts of chlorine and aluminum particulates found in SRM exhaust. It cited studies which indicate that SRM exhaust has an extremely small impact on the ozone layer, acid rain, and aluminum in the atmosphere, while far greater effects result from natural phenomena (such as volcanic eruptions).

Chairs:

Ron Nichols, Chief, Propulsion Technology Office, NASA/MSFC

Scott Schutzenhofer, Propulsion Engineer, NASA/MSFC

Speakers:

C1.1 *Disposal Process for Propellant from Air Force ICBM's,* J.A. Hurley, AL/EQS, Tyndall Air Force Base

C1.2 *Recovery and Reuse of Rocket Propellants,* Dr. W.S. Melvin, U.S. Army Missile Command

C1.3 *Replacement of Dichromate Catalyst Polysulfide Sealant,* C.M. Conway, USBI

C1.4 *Updated Assessment of the Environmental Impacts of Rocket Effluents,* Dr. R.R. Bennett, Thiokol Corporation

C1.5 *Solid Rocket Exhaust Cloud Modeling and Verification Measurements,* Dr. R.R. Bennett, Thiokol Corporation

C1.6 *Advances in Clean Burning Hybrid Rocket Fuels,* Dr. D. Dean, McDonnell Douglas Aerospace

Solid Rocket Exhaust Cloud Modeling and Verification Measurements were discussed by Dr. R.R. Bennett of Thiokol Corporation, who has collected extensive amounts of data on clouds formed by SRM firings. These data have been compared to predictions from models currently accepted by Government and industry as most representative of the cloud behavior. The paper compared these predictions to empirical data, discussing discrepancies where some error has been noted in the model.

Advances in Clean Burning Hybrid Rocket Fuels were addressed by Dr. D. Dean of McDonnell Douglas Aerospace. This paper presented test results for hybrid fuels with chemical additives. Small hybrid motor tests indicated that the additives significantly improve the regression burn rate of hybrid fuels. Burn rate control is an important issue in the development of hybrid motors for applications where specific impulse is critical to achieve certain performance characteristics.

SESSION C2

APPROACHES TO POLLUTION PREVENTION IMPLEMENTATION

During this session, six papers provided an overview of approaches to pollution prevention taken by various organizations.

Pratt & Whitney's Consolidated Pollution Prevention Team was discussed by M. Falco of Pratt & Whitney, which approaches the challenge of integrating pollution prevention into its everyday business using a consolidated pollution prevention team. This team provides overall company pollution direction, interfaces with management, and provides guidance to sub-teams (including those which represent Pratt & Whitney facilities), fostering pollution prevention in the design of products and identifying, developing, and validating alternative processes and materials. This approach has been very successful, resulting in significant reductions in hazardous waste generation, toxic air emissions, and ODC usage.

Space Shuttle Main Engine (SSME) Component Processing Review was addressed by M. Price of Rocketdyne Division, Rockwell International. Rocketdyne also used a team concept to comply with environmental regulations while maximizing effectiveness and efficiency of production operations for SSME component processing. The team identified all production operations using hazardous materials in component processing and then applied unit flow analysis to each operation. This analysis contributed to the development of new cleaning processes (which have had a significant impact on the role that cleaning now plays in the production process) to replace those which use ozone-depleting materials.

V-22 Aircraft Environmental Program was presented by C. Kim of the U.S. Naval Air Warfare Center. The V-22 Osprey Aircraft Program innovatively integrated DoD-mandated environmental considerations into the acquisition process. A multi-disciplinary team (consisting of program management, environmental and materials engineers, legal counsel, and USMC aircraft maintenance personnel) was established to coordinate and implement environmental requirements. The team developed an environmental strategy by analyzing the aircraft system and identifying specific technical and environmental issues. These efforts enabled the V-22 program to establish and implement an effective environmental program.

Reusable Solid Rocket Motors (RSRM) ODC Elimination Program Overview was presented by R.P. Golde of Thiokol Corporation, which worked with NASA/MSFC to establish a multi-phase plan to eliminate the use of TCA in the RSRM production process. This plan

Chairs:

M. Jo Kines, Environmental Specialist, NASA/JSC

Ron Mize, 2nd AETC Vice-Chairman, NASA/MSFC

Speakers:

C2.1 *Pratt & Whitney's Consolidated Pollution Prevention Team,* M.J. Falco, Pratt & Whitney

C2.2 *SSME Component Processing Review,* M. Price, Rocketdyne Division, Rockwell International

C2.3 *V-22 Aircraft Environmental Program,* C. Kim, U.S. Naval Warfare Center

C2.4 *RSRM ODC Environmental Program,* R.P. Golde, Thiokol Corporation

C2.5 *Event Helps Incorporate Environment, Health, and Safety Concerns into Pratt & Whitney Production Operations,* J. Zavodjancik, Pratt & Whitney

C2.6 *Space Shuttle RSRM Hand Cleaning Solvent Replacement at Kennedy Space Center,* J.M. Keen, Thiokol Corporation and C.D. DeWeese and L.W. Key, NASA/MSFC targeted a 90% elimination of TCA usage by January 1, 1996. It included the elimination of two large vapor degreasers, grease diluent processes, and propellant tooling hand cleaning using TCA. The overall ODC elimination program was outlined from initial phases through the final testing and implementation phases (including facility and equipment development).

Event Helps Incorporate Environment, Health, and Safety Concerns into Pratt and Whitney Production Operations was explained by J. Zavodjancik of Pratt & Whitney, which sponsored a pollution and hazard prevention initiative at one of its facilities, focusing on environmental, health, and safety issues. Over a 4-day period, 33 members of a multi-disciplinary team addressed environment, health, and safety issues associated with 6 processes. Their objectives included developing a method to incorporate such issues into production decisions, developing an evaluation process that can be used at other facilities, minimizing the amount of hazardous waste generated, reducing concerns related to health and safety, reducing processing costs, and improving production capabilities. All objectives were realized, with numerous benefits achieved.

Space Shuttle RSRM Hand Cleaning Solvent Replacement at Kennedy Space Center was addressed by J.M. Keen of Thiokol Corporation, who summarized the approach used to eliminate all RSRM hand-wipe operations using TCA at NASA/KSC. Initially, all uses of TCA were identified for the RSRM program. Since related operations are performed by USBI (the SRB prime contractor), the SRB and RSRM programs both committed to jointly implement common replacement cleaners to the maximum extent possible. The most promising candidates for USBI/SRB screening were then tested with RSRM-unique materials and bondlines for adhesion, compatibility, corrosion, and dry time. An organic cleaner (Reveille) met or exceeded the applicable engineering requirements for all substrates and bondlines. Reveille was then selected as the primary cleaner of choice for all RSRM surfaces (except cork).

SESSION C3

CLEANING: VERIFICATION AND INSTRUMENTATION - I

During this session, five papers focused on replacements for ODC solvents that are suitable for processing critical surfaces, as well as subsequent monitoring techniques to verify cleanliness. Topics included replacement cleaning systems and methodology for real-time analysis of chemical contaminants which may interfere with bonding operations on critical surfaces. This session mentioned both liquid fuel and solid rocket motor propulsion systems, as each provides a different set of problems within the manufacturing environment.

Elimination of Ozone Depleting Chemicals - Cleanliness Verification Alternatives was presented by V. Douglas of Rocketdyne Division, Rockwell International, while *Replacement of ODC Cleaning Agents in Orbiter Processes* was presented by E. Eichinger of Rockwell Space Systems Division. NVR analysis using CFC's has provided a good indicator of surface contamination in near real time prior to the ban on CFC's. Attempts to find other solvents which can provide similar indications on critical surfaces has been a major undertaking by every aerospace manufacturer. These speakers showed the results of their work with a series of alternative cleaning reagents. Several aqueous cleaners showed good results for most contaminating organics, but no single cleaning agent was able to perform well for all contaminants. Several practical cleaning agents appear to represent good replacements for CFC-113 and 1,1,1-trichloroethane on many contaminants.

Cleanliness Validation and Use of HFC (CFC-Free) Processes at NASA/Stennis Space Center were discussed by H.R. Ross of NASA/SSC. Evaluations are being conducted on new cleaning and verification processes to replace the CFC-113 processes now in use. Although many aqueous processes have been evaluated, a need still exists for nonaqueous solvents in areas for which no aqueous alternatives exist (such as the cleaning and verification of precision instruments). Several solvent properties must be considered when cleaning instrumentation, including contaminant removal efficiency, oxygen systems compatibility, toxicity, and the ability to be used as a verification fluid. Aerospace hardware was used to evaluate the cleaning performance of CFC-113 versus HFC solvent blends.

Evaluation of AD-225™ and Vertrel® as Alternative Solvents for Precision Cleaning and Verification of Small Components was presented by O. Melendez of NASA/KSC, who has successfully applied AD-225™ and Vertrel® to remove surface contamination. The air/water impingement

Chairs:

Dr. Gary L. Workman, Senior Research Scientist, UAH

Dr. Michael Meltzer, Pollution Prevention Engineer, Lawrence Livermore

Speakers:

C3.1 *Elimination of Ozone Depleting Chemicals - Cleanliness Verification Alternatives,* V. Douglas, Rocketdyne Division, Rockwell International

C3.2 *Replacement of ODC Cleaning Agents in Orbiter Processes,* E. Eichinger, Space Systems Division, Rockwell International

C3.3 *Cleanliness Validation and Use of HFC (CFC-Free) Processes at NASA/Stennis Space Center,* H.R. Ross, NASA/SSC

C3.4 *Evaluation of AD-225™ and Vertrel® as Alternative Solvents for Precision Cleaning and Verification of Small Components,* O. Melendez, NASA/KSC

C3.5 *Use of Variable Angle Spectroscopic Ellipsometry in Order to Determine Contaminant Optical Properties,* C. Hughes, UAH process is being compared to CFC-113 in terms of how effectively each removes contamination from small parts.

Use of Variable Angle Spectroscopic Ellipsometry in Order to Determine Contaminant Optical Properties was discussed by C. Hughes of UAH, who presented data on spectrometric ellipsometry to show the sensitivity of the technique to organic residual surface films. The data (acquired with the assistance of J. Reynolds of NASA/MSFC) shows that ellipsometry technique provides a useful tool to identify film optical constants and/or film thicknesses. Much study has focused on how critical bonding surfaces can be affected by HD2 grease and silicone oils (which are extensively used in the RSRM manufacturing environment), since such surfaces can be easily contaminated on SRM cases and nozzles. In addition to NVR approaches, other real-time techniques of interest are under development, including FTIR and NIR spectrometry, IR reflectance, and variable wavelength ellipsometry.

SESSION C4

DEVELOPING NOET METRICS: PRIORITIZING REPLACEMENT TECHNOLOGIES THROUGH MEASUREMENTS OF GLOBAL/LOCAL CHANGE (WORKSHOP)

This workshop was held to discuss how to enhance communications among participants (including regulators, scientists, computer model makers, environment measurers, and the aerospace industry) to the level that interested communities may make consistent, informed, proactive technical decisions in the areas affected by environmental policy. Nine participants were invited, including Government representatives from EPA, NASA (LaRC and MSFC), and DoD, as well as U.S. industry (AIA, Thiokol, and PAL), academics (UAH), and the international community (SEP). In addition, observers were present from NASA/JSC, Lockheed Martin, and Thiokol Corporation.

Proceedings began with a presentation that set the meeting agenda, outlined guidelines, and offered strawman outcomes, as well as providing background information on NOET. Considerable discussion followed among the participants. Communication appeared to be a key issue, as did the validity of models and modeling techniques still used within the regulatory community. Three invited presentations were then made, as follows.

- Some recent additions to our understanding of launch system effluents and their environmental implications were delineated by A.J. McDonald of Thiokol Corporation, resulting in considerable discussion about long-range prospects for regulation and how those prospects were perceived by EPA, NASA, and USAF.
- The charter and composition of the AIAA Atmospheric Environment Technical Committee (identified as a potential contributor to enhanced communications) were presented on a viewgraph by Dr. P.C. Vaughn of NASA/JSC. No EPA personnel were identified as current members of the committee, but it was noted that EPA has been represented in the past.
- NASA's Mission to Planet Earth program was discussed by Dr. V. Connors of NASA/LaRC, who identified some issues which might add to or address concerns raised about communications and modeling. EPA is not represented on the formal partnership list for Mission to Planet Earth. Recently, the program has evaluated 18 new proposals, which address areas such as impact assessment modeling and whether the environment is getting better or worse.

Chairs:

Dr. Ben Goldberg, Lead, NOET Propulsion and Prediction Technology Team, NASA/MSFC

Dr. Clark Hawk, Director of the Propulsion Research Center, UAH

Speakers:

C4.1 *Some Recent Additions to Our Understanding of Launch System Effluents and Their Environmental Implications,* A.J. McDonald, Thiokol Corporation

C4.2 *Charter and Composition of the AIAA Atmospheric Environment Technical Committee,* Dr. P.C. Vaughn, NASA/JSC

C4.3 *NASA's Mission to Planet Earth,* Dr. V. Connors, NASA/LaRC

Group discussion then centered on two major themes:

1. How can non-regulatory Government agencies and private industry become more involved with the regulatory agencies (specifically EPA) in a two-way dialog to the benefit of both communities?

2. How can value added technology transfer be maximized from the aerospace community to the environmental regulations and measurement community?

It was evident that a forum involving the above communities has value and that communication enhancements are appropriate. The group agreed upon seven specific actions and decided to reconvene by telecon in approximately 1 month.

SESSION D1

REPLACEMENT MATERIALS AND PROCESSES - II

During this session, seven papers focused on various material and process replacement issues, including adhesive joining technology, chrome-free conversion coating processes, the use of supercritical carbon dioxide to process pyrotechnics, and environmentally compatible solid film lubricants for high stress/load applications.

Environmentally Compliant Adhesive Joining Technology was discussed by J.S. Tira of Allied Signal, Inc. Many ODC-free adhesive options are already available to general industry. Adhesive suppliers are being challenged to narrow the field in their recommendations for specific applications and requirements. Adhesive joining technology has "four M's" (materials, methods, machinery, and manpower) that should be used to help identify critical areas of concern (e.g., which soils need to be removed from substrates prior to adhesive application).

Iron Strike to Replace Nickel Strike was addressed by M.J. Nelson of Boeing Defense and Space Group. Nickel strike bath processing (which promotes electroplating adhesion on certain alloys) releases harmful nickel mist, targeted for regulation by the EPA. Processing and end item criteria (e.g., appearance, corrosion, and plating adhesion) were evaluated during efforts to identify a new nickel-free strike bath. A full factorial design of experiments indicated that iron strike solutions can be used to prepare stainless steel and nickel alloys for tin/zinc or nickel/zinc plating without sacrificing the plating's corrosion or adhesion properties. A hull cell was used to optimize the application parameters, and results were validated on bushings.

Chrome-Free Conversion Coating Process Evaluation was presented by P.J. Brezovec of Concurrent Technologies Corporation. An EPA project used 6061-T6 aluminum to evaluate a commercially available chrome-free chemical conversion coating (using the variable screening portion of a sequential experimental design and analysis strategy, then applying analysis of variance and T-test techniques to the results). Test panels were conversion coated, then powder coated or cathodic electroplated, under realistic manufacturing conditions. This process test used a fluoacid-modified organic coating, based on results from the NCMS Chrome Alternatives Project. The new material offered much less restrictive threshold limit values and permissible exposure levels.

Rapid Quantitative Measurement of the Level of Crosslink Density Based On A Variation of the Solvent Swell Principle was explained by J.L. Anderson of The MESARAN Company. Evaporative rate analysis is a

Chairs:

Rick Golde, Manager, RSRM ODC Elimination Program, Thiokol

Mal Privett, Senior Materials Engineering, Pratt & Whitney

Speakers:

D1.1 *Environmentally Compliant Adhesive Joining Technology,* J.S. Tira, Allied Signal, Inc.

D1.2 *Iron Strike to Replace Nickel Strike,* M.J. Nelson, Boeing Defense and Space Group

D1.3 *Chrome-Free Conversion Coating Process Evaluation,* P.J. Brezovec, Concurrent Technologies Corporation

D1.4 *Rapid Quantitative Measurement of the Level of Crosslink Density Based On A Variation of the Solvent Swell Principle,* J.L. Anderson, The MESARAN Company

D1.5 *Processing A Pyrotechnic Using Supercritical Carbon Dioxide,* R.E. Farncomb, U.S. Naval Surface Warfare Center

D1.6 *Comparison of Environmentally Friendly Space-Compatible Grease to Its Predecessor in A Space Mechanism Bearing Test Rig,* T.R. Jett, NASA/MSFC

D1.7 *Development and Implementation of Environmentally Compatible Solid Film Lubricants,* H.L. Novack, USBI

microcomputer-based technique that uses a variant of the classic solvent swell method to measure crosslink density in polymers by monitoring radiochemical retention. A GM detector is positioned directly above a polymer surface treated with a 18-microliter layer of a low-boiling solvent. Metered air flows between the detector and surface, sweeping away vapor phase solvent and radioactive molecules. After initial solvent evaporation, the radiochemical evaporation rate is measured as a function of crosslink density level. The solvent/radiochemical formation is based on a four-stage cure ladder (low cure, low specification, high specification, and overcure).

Processing A Pyrotechnic Using Supercritical Carbon Dioxide was discussed by R.E. Farncomb of the U.S. Naval Surface Warfare Center. This discussion outlined the processing of MTV (a pyrotechnic material) using a hexane replacement (supercritical carbon dioxide) in small batches (super shock process). Previously, hexane was used to dissolve Viton and mix with Teflon® and magnesium, as well as to wash the subsequent MTV crumb, resulting in 10 pounds of decanted liquid waste for every pound of product. Now, super critical carbon dioxide is used to obtain acetone extraction at much lower pressures (2000 - 4000 psi) and temperatures (40 - 70 °C), creating reusable liquid carbon dioxide and acetone without further processing.

Comparison of Environmentally Friendly Space-Compatible Grease to Its Predecessor in A Space Mechanism Bearing Test Rig was presented by T.R. Jett, NASA/MSFC. In the past, CFC-based solvents were used to produce specialty greases for use in orbital space environments. A 1-year study used 20 small electrical motors to compare CFC-based versus CFC-free lubricants. Both were used on two 440C bearings per motor, operated continuously in a high vacuum environment at 90 °C. Mass loss was carefully measured for the bearings and lubricants (pre- and post-test), and profilometer traces were used to measure bearing surface finishes after testing. Failure was defined as motor failure before 1 year of continuous operation. The CFC-free lubricants delivered acceptable performance, and infrared analysis did not detect any lubricant breakdown.

Development and Implementation of Environmentally Compatible Solid Film Lubricants were discussed by H.L. Novack of USBI. SFL's are used at several critical attach points on the Space Shuttle launch vehicle (e.g., SRB/ET attach ball assembly), which require unrestricted relative motion when highly loaded. High-temperature dual-coat SFL's that contained environmentally restricted materials (e.g., lead and antimony) have been replaced by a new family of single-coat SFL's, which employ a unique mixture of non-hazardous pigments in a resin system that can be cured at relatively low temperatures (450 °F) and used in continuous operational environments up to 650 °F.

SESSION D2

HAZARDOUS MATERIALS TRACKING AND WASTE MINIMIZATION

During this session, five papers provided an overview of the engineering challenge of developing replacement materials and processes to ensure safety and compatibility with the environment in aerospace operations, as well as effectively monitoring those efforts.

LFWC Implements Computerized System to Monitor Water Quality was explained by S.V. Obert of Lockheed Martin Corporation, who spoke on an integrated remote monitoring and notification system (IRMNS) that was conceptualized, pilot tested, and installed at Lockheed Martin's 650-acre site and plant in Fort Worth, TX. The IRMNS system performs three major activities (monitoring wastewater quality parameters associated with the site's nine NPDES discharge outfalls, notifying personnel in the event of an alarm condition, and fulfilling various other sampling requirements). Radio frequency communication is used to link field sites to the office-based network monitoring station. IRMNS is constructed primarily from off-the-shelf items, allowing easy integration of proven reliable components at low cost, with minimal design and engineering efforts.

Development of An Electrochemical Waste Treatment Facility was discussed by G.W. Nauflett of the U.S. Naval Surface Warfare Center, who spoke on an innovative low-cost alternative means to dispose of Otto II fuel (a mono-propellant used for torpedo propulsion). The current practice is to collect and dispose of the fuel, which is generally contaminated with seawater. This initiative was mounted to determine an alternative that would regenerate the fuel for reuse, using currently available equipment. Results led to a focus on a mediated/catalyzed electrochemical oxidation process, which is a low-temperature low-pressure technique that uses a metal ion in a mineral acid electrolyte (the agents required for subsequent oxidation of organic materials). This presentation described the use of regenerative Oxidant Cerium IV (Ce^{3+}/Ce^{4+}) for the treatment of waste fuels. Demonstrations have confirmed that this technology can be effectively used to treat Otto II fuel that is contaminated with seawater. A standard for commercializing the process is about 18 months away, and plans call for a pilot plant test to be constructed in Key Port, WA (where the fuel is collected). This collection point was receiving about 2 million pounds per year of Otto II fuel for disposal at the inception of this initiative, although the quantities of fuel being collected have been on a general downward trend.

Chairs:

Thomas Staab, Environmental Quality Engineer, Allied Signal Aerospace

George Nauflett, Research Chemist, U.S. Naval Surface Warfare Center

Speakers:

D2.1 *LFWC Implements Computerized System to Monitor Water Quality,* S.V. Obert, Lockheed Martin Corporation

D2.2 *Development of An Electrochemical Waste Treatment Facility,* G.W. Nauflett, U.S. Naval Surface Warfare Center

D2.3 *Minimization of Cyanide Waste-Rejuvenation of Silver Cyanide Plating Bath,* Dr. T.M. Tam, Lockheed Martin Missiles and Space

D2.4 *Demonstration of Nonchromate Conversion Coating for Use with IVD Aluminum,* Lt. R.A. Smith, Tyndall Air Force Base

D2.5 *Low-Cost Heavy-Metal-Bearing Wastewater Pollution Prevention Treatment: Demonstration of A Sodium-Sulfide/ Ferrous Sulfate-Based Batch Treatment System for the USAF,* Dr. W.L. Johnson, BDM Engineering Services Company

Minimization of Cyanide Waste-Rejuvenation of Silver Cyanide Plating Bath was addressed by Dr. T.M. Tam of Lockheed Martin Missiles and Space. Due to the buildup of carbonate ions in the solution, Lockheed Martin routinely had to replace a conventional silver cyanide bath used to produce molybdenum solar cell interconnects in Sunnyvale, CA. A new method was developed to rejuvenate the baths without generating a large quantity of hazardous waste. After barium hydroxide was added to the plating bath, the carbonate was removed as barium carbonate. This process alleviated three concerns: the impact of increased hydroxide ions to quality of the plated silver, the effectiveness of the barium hydroxide in removing carbonates, and impact to the plated silver if barium ions remained in the solution after treatment. Its implementation minimized cyanide waste generation, improved process control, and significantly reduced the amount of silver needed for plating.

Demonstration of Nonchromate Conversion Coating for Use with IVD Aluminum was presented by Lt. R.A. Smith of Tyndall Air Force Base. This ongoing project will demonstrate a nonchromate alternative to chromate conversion coating for IVD aluminum-coated parts. In 1993, USAF's Armstrong Laboratory (Environics Directorate) entered into a contract with McDonnell Douglas Aerospace-East to identify a nonchromated alternative to the traditional chromate conversion coating for IVD Aluminum. Several conversion coatings were tested for adhesion and corrosion, as well as being subjected to a number of performance tests (e.g., electrical, humidity, fluid resistance). Results were compared with a chromate conversion coated panel used as a baseline. The chosen alternative is now being demonstrated at Warner Robins Air Logistics Center. Successful implementation would improve the work environment at USAF Air Logistics Centers, reducing hazardous waste and virtually eliminating the need for costly pollution control equipment. This study is expected to publish a final report in June 1997.

Low-Cost Heavy-Metal-Bearing Wastewater Pollution Prevention Treatment: Demonstration of A Sodium-Sulfide/Ferrous Sulfate-Based Batch Treatment System for the USAF was discussed by Dr. W.L. Johnson of BDM Engineering Services Company. USAF's Armstrong Laboratory sponsored this project, which produced a low-cost sodium sulfide/ferrous sulfate-based chemical batch treatment process for aqueous heavy metal bearing waste. In this process, heavy metal ions are precipitated as insoluble sulfide salts or hydroxides from the aqueous stream. It was successfully used to treat metal-bearing wastewater (generated by the USAF Corrosion Control Facility in Columbus, MS) at an experimental batch processing station. This process was preferred over many alternatives because it uses simple procedures and readily available low-cost commercial components.

SESSION D3

CLEANING: VERIFICATION AND INSTRUMENTATION - II

During this session, five papers discussed a wide range of cleanliness verification instruments. The ability to monitor contamination levels can make part cleaning operations more efficient, as well as providing feedback for reducing waste generation and air emissions caused by over- or undercleaning.

An Optically Stimulated Electron Emission (OSEE) Based Portable Surface Contamination Monitor was addressed by D.F. Perey of NASA/LaRC. Also known as photoelectron emission, OSEE is non-contacting, requires little operator training, and has very high contamination sensitivity. A portable OSEE-based surface contamination monitor was developed to incorporate several improvements in resolution, reproducibility, and sensitivity. This instrument can be operated manually or automatically, making it suitable for hand-held or robotic inspections. Output data is visually displayed and may be sent to an external computer for archiving or analysis.

Study of SRM Critical Surfaces Using Near Infrared Optical Fiber Spectrometry was presented by Dr. G.L. Workman of UAH. This paper addressed NIR fiber optic spectroscopy as applied to RSRM bonding surfaces. It discussed the use of optical fiber spectrometry for process monitoring of materials used in aerospace propulsion systems and how this technique can be used to clarify surface chemistry issues. An integrating sphere was used to improve signal-to-noise ratios and allow inspection of rough surfaces. Chemometric techniques included PCA and PLA to enhance data analysis, which appear very promising for application of this equipment to in-process surface inspection.

Multi-Band Identification and Discrimination Imaging Spectroradiometer (MIDIS): An Imaging Spectroradiometer for Real-Time Non-Destructive Test, Inspection, and Material Identification was discussed by M. Dombrowski of Surface Optics Corporation. MIDIS has great potential for cleanliness inspections. Discussions included on-going spectral imager research and development, processing algorithms, and non-contact remote sensing applications. At a full-spectrum update rate of 80 Hz, MIDIS can simultaneously collect 80-point spectra at 1,000 frames per second from three imaging heads (the first operating from 400 to 950 nm, the second from 1.5 to 5.5 μm, and the third from 5 to 12 μm). Compact processing electronics radiometrically calibrate data and apply spectral-matched filtering algorithms to identify pixels with a specific

Chairs:

Ralph Carruth, Chief of Engineering Physics Division, NASA/MSFC

DeWitt Burns, Contamination Engineer, NASA/MSFC

Speakers:

D3.1 *An OSEE-Based Portable Surface Contamination Monitor,* D.F. Perey, NASA/LaRC

D3.2 *Study of SRM Critical Surfaces Using Near Infrared Optical Fiber Spectrometry,* Dr. G.L. Workman, UAH

D3.3 *MIDIS: An Imaging Spectroradiometer for Real-Time Non-Destructive Test, Inspection, and Material Identification,* M. Dombrowski, Surface Optics Corporation

D3.4 *Diffuse Reflectance Mid-Infrared Spectroscopy As A Tool for the Identification of Surface Contamination on Sandblasted Metals,* G.L. Powell, Lockheed Martin Energy Systems

D3.5 *In-Process Cleaning Analysis,* Dr. M. Meltzer, Lawrence Livermore National Laboratory spectral radiance. Remote passive identification of materials will aid in pollution monitoring, process control, and surface cleanliness and physical condition assessment.

D3.6 *Quantitative Measurement of Oily and Greasy Residues from 1 to 100,000 Nanograms,* J.L. Anderson, The MESARAN Company

Diffuse Reflectance Mid-Infrared Spectroscopy As A Tool for the Identification of Surface Contamination on Sandblasted Metals was addressed by G.L. Powell of Lockheed Martin Energy Systems, who described a new portable diffuse reflectance FTIR spectrometer. Reflectance mid-infrared spectroscopy can be used to determine surface contamination, and diffuse reflectance is particularly useful for obtaining spectral data from many materials. Lockheed Martin collaborated with NASA/MSFC to develop an FTIR spectrometer which uses diffuse reflectance optics to interrogate surfaces. Designed to be hand-held or remotely positioned, it weighs less than 8 kg and can be manipulated into any orientation during operation. Rapid in-field analyses can be made with sensitivity comparable to sample compartment accessories in laboratory instruments. The unit permits dedicated scanning, collection, and analysis routines.

In-Process Cleaning Analysis was discussed by Dr. M. Meltzer of Lawrence Livermore National Laboratory. A portable residual gas analyzer was developed to provide cleaning verification in a production-line environment. It uses off-the-shelf technology to interface with surfaces, desorbing trace amounts of contamination with a combination of vacuum and heat. It can detect and identify contamination thicknesses of only a few monolayers. This mass spectrometer system offers data processing capabilities, a library for identifying and quantifying surface contamination, and read-outs in standard metrics (e.g., micrograms per square centimeter of surface area).

Quantitative Measurement of Oily and Greasy Residues from 1 to 100,000 Nanograms was explained by J.L. Anderson of The MESARAN Company. Direct quantitative measurements can be made of microorganic residues to nanogram levels (two orders of magnitude below current technology and three orders below the 1-mg-per-square-foot equivalent) at ambient temperature and pressure. Calibration is based on a series of volumetric dilutions of typical residues, with depositions of a 10-microliter aliquot onto each clean reference surface. A high-boiling-but-volatile Carbon 14-labeled compound is added to form a chemical solution with the residue, and residue is measured as the solution evaporates. Log count versus time is monitored by observing beta particle levels emitted by molecules retained at the interface. The evaporation curve slope is an inverse measure of the amount of residue (higher slopes indicate less residue and vice-versa), increasing the method's sensitivity.

SESSION D4

AIR EMISSION REDUCTION AND CONTROL

During this session, seven papers addressed various efforts to reduce and control air contaminant emissions.

Capture, Containment, and Concentration of Surface Coating Emissions were discussed by C. Smith of Mobile Zone Associates. This paper describes a device that localizes supply air in a coating booth, reducing the volume of air sent to control systems (and thus controlling costs). Required flow rates are maintained in the booth, while a cab is created to provide a supply of fresh air for the operator. Exhaust air flow rates are reduced by 65 to 95%. This booth can also accommodate the new multiple stage dry filters.

The Design of A Small Transportable Solid Rocket Motor Exhaust Scrubber was presented by R. Carns of the U.S. Naval Surface Warfare Center. Each year, emissions must be controlled during the test firing of several hundred small solid rocket motors. A scrubber with a basic scrubbing solution is being designed to remove 98% of the HCl and particulate contaminants (25% of allowable limits) without affecting test data collection or cycle time. The phase 1 scrubber has a footprint of 8 by 20 feet and is designed for a 7-lb motor. If successful, this prototype will be scaled up in two phases to a system that will scrub exhaust from a 1500-lb solid rocket motor.

Photocatalytic Oxidation of VOC and HAP at Ambient Temperature and Pressure was addressed by C. Smith of Mobile Zone Associates and A. Raissi of the Florida Solar Energy Center. This paper discussed the future of photocatalytic oxidation, a developing technology that uses a UV light source and a catalyst (such as titanium dioxide) to completely oxidize solvent vapors at ambient temperatures and pressures. When solvent vapors were introduced through a laboratory prototype, results indicated that annualized capital and operating cost could be as low as 10% of incineration or thermocatalytic oxidation. Control efficiencies apparently approached 100% for VOC concentrations between 10 and 200 ppm.

Treatment of VOC-Laden Air Using a Pilot Scale Hybrid System was discussed by J.M. Schneider of the Applied Research Laboratory at Pennsylvania State University. This paper discussed the optimization of a pilot scale (2,000-scfm) hybrid VOC and HAP treatment system to control organic constituents in a specific exhaust stream for a spray paint booth. This system includes photolytic degradation (i.e.: use of UV light without catalyst), two counter-current packed bed aqua-scrubbers, and carbon adsorption, all operating at ambient temperature. A low-volume stream of ozone is used to regenerate the carbon.

Chairs:

Janice M. Schneider, Research Assistant for Environmental Programs, Pennsylvania State University

Kraig L. Kurucz, Senior Environmental Engineer, Lockheed Martin Missiles and Space

Speakers:

D4.1 *Capture, Containment, and Concentration of Surface Coating Emissions*, C. Smith, Mobile Zone Associates

D4.2 *The Design of A Small Transportable Solid Rocket Motor Exhaust Scrubber*, R. Carns, U.S. Naval Surface Warfare Center

D4.3 *Photocatalytic Oxidation of VOC and HAP at Ambient Temperature and Pressure*, C. Smith, Mobile Zone Associates and A. Raissi, Florida Solar Energy Center

D4.4 *Treatment of VOC-Laden Air Using A Pilot Scale Hybrid System*, J.M. Schneider, Applied Research Laboratory, Pennsylvania State University

The ozone regeneration reduces waste, chlorinated solvents are oxidized in the photocatalytic cell, and polar organics dissolve into the water. Research focused on chemical agent resistant coatings, but is applicable to other types of coatings. Removal efficiencies of 90 to 95% were achieved for various organics.

Elimination of ODC's in the I-136 Igniter was discussed by L.M. Suarez of the U.S. Army Research, Development, and Engineering Center at Picatinny Arsenal. At present, trichloroethane and ethanol are involved in the pyrotechnic blending process of the I-136 igniter, used in ammunition up to 50-caliber. Significant challenges must be overcome to eliminate VOC and ODC from this production process, as well as reducing emissions of lead, barium, and antimony (which contribute to contamination at target ranges and expose personnel firing the weapons to these metallic contaminants).

D4.5 *Elimination of ODC's in the I-136 Igniter*, L.M. Suarez, U.S. Army Research, Development, and Engineering Center, Picatinny Arsenal

Environmentally Friendly Cleaning Improvements During Overhaul Operations were presented by P.H. Johnson and R.M. Melnik of Sikorsky Aircraft. This paper presented a case study that quantifies reduced emissions achieved at the Sikorsky Operations and Repair Center. Chemicals were used to decrease the use of perchloroethane, trichloroethane, and machine coolant, reducing processing costs and floor space requirements. These replacement operations were well accepted by operators.

D4.6 *Environmentally Friendly Cleaning Improvements During Overhaul Operations*, P.H. Johnson and R.M. Melnik, Sikorsky Aircraft

Environmental Technology at Boeing Defense and Space Group, Helicopters Division was presented by J.M. Finn of the Boeing Defense and Space Group. In this case study, Boeing Defense and Space Group Helicopters Division achieved, documented, and quantified emission reductions. The use of aqueous cleaning allowed a reduction from 12 to 2 TCA and TCE degreasers, reducing TCA emissions by 100% and TCE emissions by 80%. Coating substitutions reduced VOC emissions by 50%. A chromated FPL etch was replaced by phosphoric acid anodizing, and machine coolant was recovered.

D4.7 *Environmental Technology at Boeing Defense and Space Group, Helicopters Division*, J.M. Finn, Boeing Defense and Space Group

SESSION E1

ENVIRONMENTALLY COMPLIANT COATING TECHNOLOGIES

During this session, eight papers focused on coatings and processes that restrict VOC and HAP contents in primers and topcoats, limit use of paint strippers containing methylene chloride, and require topcoats and primers to be applied with HTE methods.

Flashjet™ Coatings Removal Process: Production Plans and Experiences was presented by T.L. Nied of McDonnell Douglas Aerospace Support. Flashjet™ strips coatings by simultaneously applying pulsed light energy and CO_2 particles. The FAA and USAF approved this process for unrestricted use on metallic and composite surfaces. Nied indicated that Flashjet™ produces a strip rate twice as fast as media blasting at one-third the cost.

Environmental Impact and Treatment of Reformulated Chemical Agent Resistant Coatings was discussed by B.A. Streibig of Pennsylvania State University. CARC coatings were reformulated to replace VOC's with water and NMP (which is preferable to other organic solvents in that vapor pressure is very low, molecular weight is relatively high, and toxicity is less). Streibig discussed chemistries required to remove NMP from an exhaust air stream. This research was conducted concurrently with reformulation of the coatings, optimizing effectiveness for both processes. It produced a hybrid air pollution control system that may allow increased use of NMP in coatings, cleaning, and depainting operations.

An Interagency Study of Depainting Techniques was presented by B. Cook of NASA/MSFC. EPA, NASA, and USAF are conducting this assessment of nine technologies for stripping paint in aerospace operations, representing abrasive, impact, cryogenic, thermal, and molecular bonding dissociation removal techniques. (The last includes ~40 chemical stripping products.) During processing, four thicknesses of clad and non-clad aluminum substrates were cleaned, painted, and environmentally aged. After test specimens are processed and stripped five times, metallurgical impacts will be assessed on fatigue, tensile strength, crack initiation, and crack propagation. Progress reports may be requested from NASA/MSFC.

Testing of Solvents for Removal of Urethanes/ Epoxies was addressed by L.M. Thompson of Lockheed Martin Energy Systems. Oak Ridge Laboratory is researching alternative chemical strippers, in response to EPA and OSHA limitations on methylene chloride. Candidates are selected using the Hansel Solubility Parameter Theory, which states that solvents with similar

Chairs:

Brenda Fukai-Allison, Specialist Engineer, The Boeing Commercial Airplane Company

Gail Murphree, Environmental Materials Engineer, USBI

Speakers:

E1.1 *Flashjet™ Coatings Removal Process: Production Plans and Experiences,* T.L. Nied, W. Schmitz, McDonnell Douglas Aerospace Support

E1.2 *Environmental Impact and Treatment of Reformulated Chemical Agent Resistant Coatings,* B.A. Streibig, J.M. Schneider, and L. Watt, Pennsylvania State University, Ron Vargo, Marine Corps Logistics Base

E1.3 *An Interagency Study of Depainting Techniques,* B. Cook, NASA/MSFC

E1.4 *Testing of Solvents for Removal of Urethanes/ Epoxies,* L.M. Thompson, Lockheed Martin Energy Systems parameters will have similar dissolution properties. Work to date has included a weight gain test using standard polyurethane and epoxy pieces, lap shear testing of solvent effects on thin coating bondlines, paste versus liquid media effectiveness, and hand-pulled adhesion tests.

Alternative Coating Removal Methods for Radome Materials were presented by C.H. Cundiff of Battelle. Candidates include light energy ablation (high-intensity pulsed UV light with CO_2 pellet blast, pulsed CO_2 laser blast), aqueous removal (medium pressure water blast), and dry media (Type VI synthetic media, biodegradable starch acrylic graft media, wheat starch, dry sodium bicarbonate). Only off-the-shelf products were considered. The minimum removal rate was 0.75 ft^2/min. No more than a trace of primer could remain, with maximum surface roughness of 200 microinches. Acceptable results were produced by high-intensity UV/CO_2 pellet blasting and unacceptable results by water blasting, as well as Type VI and starch/acrylic graft polymer media.

E1.5 *Alternative Coating Removal Methods for Radome Materials,* C.H. Cundiff, Battelle, R.I. Slife, WR-ALC/TIEDM, Warner Robins Air Force Base

The Effect of Long Term Cure on Offgassed Products of Coatings was discussed by S. Whitfield of NASA/MSFC, who presented a long-term cure study on coatings for use in habitable environments on the International Space Station. Coatings include Chemglaze Z352 (polyurethane), Conathane CE-1155 (polyurethane), 512X 310/910 X533 Primer Amine with 821 X 817 Toccata (polyisocyanate over epoxy). Green Primer (zinc chromate), and 03-W-182 White Semi-Gloss (polyurethane with aliphatic isocyanate). Even cured to manufacturers' specifications, some coatings apparently continue to offgas solvents, which could prove deadly in a closed environment. Tests are planned to determine the effects of elevated temperatures on offgassing.

E1.6 *The Effect of Long Term Cure on Offgassed Products of Coatings,* S. Whitfield, G. Engle, NASA/MSFC

E1.7 *Convergent Spray Process for Environmentally Friendly Coatings,* J. Scarpa, USBI

E1.8 *Accelerated Corrosion Test Methods on Non-Chromated Coatings,* R.R. Johnson, McDonnell Douglas Aerospace

Convergent Spray Process for Environmentally Friendly Coatings was presented by J. Scarpa of USBI. Lower VOC coatings must be applied using HTE methods, HVLP spray, and electrostatic spray. Many coatings must be sprayed to maximize uniformity and integrity. However, reducing VOC often means increasing the percentage of solids in a coating, making it difficult to spray. The Convergent Spray process is a novel HTE spray method developed to apply a thick 100% solids material to SRB's, which can be used to apply solventless high-solids materials. A variety of finishes are possible. Cure times can vary with the type of coating, and chemical accelerators can be added.

Accelerated Corrosion Test Methods on Non-Chromated Coatings were discussed by R.R. Johnson of McDonnell Douglas Aerospace. This project compared several corrosion test methods against the ASTM B117 neutral salt spray method, which is the industry standard for evaluating corrosion resistance for primers and conversion coatings. After ten primers were applied over three aluminum pretreatments, test panels were subjected to five corrosion test methods. (Other panels were placed in outdoor exposure, still in progress.) Then coating degradation was measured. ASTM B117 is an excellent indicator of leachability of chromate corrosion inhibitors, but may not accurately assess the effectiveness of non-chromate corrosion inhibitors during outdoor exposure.

SESSION E2

ENVIRONMENTAL INFORMATION TECHNOLOGY

During this session, four papers highlighted information resources available to the technological community, including systems maintained by USAF, the Defense Logistics Agency, Delta Air Lines, and Pratt & Whitney.

Linking Material, Process and Product Change Decisions for a Better Environment was discussed by J. Folck of the USAF Materials Laboratory at Wright Patterson Air Force Base. This discussion highlighted the Hazardous Materials Alternatives Guide, an Internet site maintained by the Aeronautical Systems Center which can record and link the results of shopping, qualification activities, and product application decisions. This resource was created to facilitate the sharing of pollution prevention information, both within the ASC community and the aerospace industry community at large. Due to regulatory and economic pressures, many process sites are trying to identify substitutes and alternatives for chemical substances whose use is now restricted or prohibited. As candidates are found, they must be qualified for use on one or more customers' products. Many qualification decisions require the approval of individual customers, who base their decisions upon the results of inspections, demonstrations, tests, and analyses. This database provides a link between the process site and product application decisions, enabling multiple customers and process site owners and operators to benefit from precedent decisions. Following qualification of a substitute or alternative for first product application, subsequent product approval applications may be made by following the less costly method of qualification by analysis (i.e.: qualification by similarity).

Defense Supply Center Richmond - Changing for the Future was presented by S. Perez of the Defense Supply Center Richmond, the Defense Logistics Agency's center of excellence in environmental programs (including the DLA Environmental Products catalog), managing chemicals, pesticides, industrial gases, and packaged petroleum products in the Federal supply system. DSCR is also home to DoD's HAZMAT telephone helpline, ODS Reserve, and the Hazardous Materials Information System (HMIS). The presentation essentially covered all of the environmentally-oriented products, technical information, and publications available to military and Federal civilian agency customers of DSCR. Such information should be useful to environmental, logistics, maintenance, engineering and management personnel at all DoD and civilian agency locations that use

Chairs:

Arthur Henderson, Lead, R&D, NOET Replacement Technology Team, NASA/MSFC

Ernie Renner, Director, Best Manufacturing Practices, Department of the Navy

Speakers:

E2.1 *Linking Material, Process and Product Change Decisions for A Better Environment,* J. Folck, USAF Materials Laboratory, Wright Patterson Air Force Base

E2.2 *Defense Supply Center Richmond - Changing for the Future,* S. Perez, Defense Supply Center Richmond, Defense Logistics Agency

E2.3 *Implementation of Delta Air Lines' Environmental Management Information System,* M.R. Craig, Delta Air Lines

E2.4 *Elimination/Reduction of Ozone Depleting Substances and "EPA 17" Materials in F100 Worldwide Maintenance Manuals,* M. Privett, Pratt & Whitney hazardous and/or toxic materials. This presentation also provided a home page address on the World Wide Web (http://www.dscr.dla.mil).

Implementation of Delta Air Lines' Environmental Management Information System was explained by M.R. Craig of Delta Air Lines. At present, Delta Air Lines and MTC use LINDEN™ environmental management software in their aircraft maintenance centers as a proactive environmental compliance tool for hazardous materials and waste management. Regulatory and technology considerations were vital in shaping system requirements, which were determined over a 2-year period before network distribution of LINDEN™ was implemented. Benefits include enhanced employee safety, cost-efficient access to MSDS information, and strict regulatory compliance.

Elimination/Reduction of Ozone Depleting Substances and "EPA 17" Materials in F100 Worldwide Maintenance Manuals was addressed by M. Privett of Pratt & Whitney. Significant pressures exist (in the form of regulatory reporting and costs, as well as corporate environmental goals) to eliminate the use of trichloroethylene. Pratt & Whitney is pursuing both an aqueous precision cleaning operation and a high-pressure liquid CO_2 precision cleaning method to totally replace the degreasing operation now in use. The liquid CO_2 unit is being evaluated to permit an integral NVR analyzer with the unit. Alternative verification methods are being investigated to replace the present chlorinated solvents. Pratt & Whitney is also eliminating all hexavalent chromium materials used on SSME turbopumps in applications such as sealing anodized surfaces, as well as working to implement a low-VOC water-based maskant for plating and chemical milling operations. F100 engine maintenance manuals and repair operations are being revised to reflect the "EPA 17" list and to reduce and/or eliminate the use of ODS's worldwide.

SESSION E3

CLEANING: METHODS AND MECHANICAL SYSTEMS

During this session, eight papers focused on cleaning methods and mechanical systems.

Testing and Qualification of HFE/Co-Solvent Cleaning Agents in Vapor Degreasing Operations were discussed by B.C. Smiley of Petrofirm, Inc. This paper describes an environmentally friendly co-solvent/ fluorocarbon vapor degreasing process that can be used to permanently replace CFC-113 and TCA in various cleaning applications. This process operated very satisfactorily in modern vapor degreasing equipment, as well as in older equipment that was well-maintained and slightly modified. From the operator's perspective, the co-solvent process is identical to a conventional vapor degreasing process in which the parts are immersed in a boil sump. This new alternative may offer the possibility of an eleventh-hour rescue for many organizations unable to identify or afford the equipment required to use non-ODS alternatives.

Non-ODS Handwipe Cleaner for Precision Cleaned SSME Hardware was presented by Marlene Price of Rocketdyne Division, Rockwell International. Various aqueous and solvent cleaners were evaluated to identify acceptable substitutes for CFC-113 and TCA in handwipe operations for precision-cleaned SSME hardware.

Replacement of Hazardous Solvents for Handwiping Operations in Gas Turbine Engine Manufacturing was addressed by M. Privett of Pratt & Whitney. This program eliminated the need to use MEK and IPA solvents during the manufacture of stator airfoil assemblies. An aqueous and a nonhazardous hydrocarbon solvent were identified for operations involving braze surface preparation, surface preparation before bonding rubber materials, removal of excess uncured rubber, and cleaning. These substitutions did not impact material properties or performance, added no additional costs to the process, and substantially reduced hazardous wastes.

The Elimination of Methyl Chloroform Solvent Used for the Cleaning of Propellant Contaminated Tooling During the Production of Space Shuttle SRM's was discussed by B.A. Burgon of Thiokol Corporation. In the past, Thiokol Corporation's Space Operations Mix and Cast Work Center has used methyl chloroform as a cleaning solvent throughout the propellant production process for the RSRM. This operation plans to change over to two solvents (Ionox BC® and PF Degreaser®) based on data which indicates that their propellant properties and bond strengths equal or exceed those of methyl chloroform.

Chairs:

Sheldon Toepke, Manager Environmental Technology, McDonnell Douglas Aerospace

Bill Jones, Research Manager, NASA/LeRC

Speakers:

E3.1 *Testing and Qualification of HFE/ Co-Solvent Cleaning Agents in Vapor Degreasing Operations,* B.C. Smiley, Petrofirm, Inc.

E3.2 *Non-ODS Handwipe Cleaner for Precision Cleaned SSME Hardware,* Marlene Price, Rocketdyne Division, Rockwell International

E3.3 *Replacement of Hazardous Solvents for Handwiping Operations in Gas Turbine Engine Manufacturing,* M. Privett, Pratt & Whitney

E3.4 *The Elimination of Methyl Chloroform Solvent Used for the Cleaning of Propellant Contaminated Tooling During the Production of Space Shuttle SRM's,* B.A. Burgon, Thiokol Corporation

The GSFC Combined Approach of ODC Stockpiling and Tribological Testing to Mitigate the Risks of ODC Elimination was presented by R. Predmore of NASA/GSFC. This paper discusses an overall philosophy of risk mitigation for flight hardware while confidence is being established in ODC-free cleaning procedures. Over the next few years, a multi-step testing program will deliver increasing amounts of data in this area, starting with surface analysis comparisons between ODC and various non-ODC technologies. Meanwhile, NASA/GSFC has stockpiled sufficient ODC solvents to support all short-term mission requirements, if necessary.

E3.5 *The GSFC Combined Approach of ODC Stockpiling and Tribological Testing to Mitigate the Risks of ODC Elimination,* R. Predmore, NASA/GSFC

Adhesion Performance of Solid Film Lubricants on Substrates Cleaned with Environmentally Compliant Cleaners was discussed by P.B. Hall of NASA/MSFC. Various environmentally compliant cleaners were tested to determine their effects on the adhesion properties of SFL's used by several NASA programs. These tests were conducted per ASTM D2510-83, "Standard Test Method for Adhesion of Solid Film Lubricants," with two lubricants (Inlox 88 and Boosterlube) that NASA uses on flight-critical components.

E3.6 *Adhesion Performance of Solid Film Lubricants on Substrates Cleaned with Environmentally Compliant Cleaners,* P.B. Hall, NASA/MSFC

The Effect of ODC-Free Cleaning Techniques on Bearing Lifetimes in the Parched Elastohydrodynamic Regime was explained by W.R. Jones, Jr. of NASA/LeRC. A parched elastohydrodynamic rig was used to determine relative bearing lifetimes as a function of cleaning procedures in a series of accelerated tests. These tests ran 52100 steel bearings in the counter-rotating mode (4600 rpm) with a full complement and a single load of lubricant. Service life was reduced by approximately 50% for bearings cleaned with UV/ozone and 70% for bearings cleaned with supercritical CO_2 (as compared to control bearings cleaned with Freon).

E3.7 *The Effect of ODC-Free Cleaning Techniques on Bearing Lifetimes in the Parched Elastohydrodynamic Regime,* W.R. Jones, Jr., NASA/LeRC

Dry-Ice Ultraviolet Light Cleaning of Metal Parts was discussed by S. Toepke of McDonnell Douglas Aerospace. An environmentally friendly process for metal cleaning has been successfully demonstrated. The process involves a pre-clean step using dry ice pellet blasting followed by a final cleaning by exposure to ultraviolet light. The investigators were able to achieve a water-break-free surface, excellent adhesion of IVD aluminum, and good corrosion resistance of conversion coat, sulfuric acid anodize, and chromic acid anodize.

E3.8 *Dry-Ice Ultraviolet Light Cleaning of Metal Parts,* S. Toepke, McDonnell Douglas Aerospace

SESSION E4

FEDERAL INTERPRETATION: THE WORLD WITH ISO 14000 IN IT (AIA PANEL)

Four panelists discussed a draft of the ISO 14001 International Environmental Management Systems (EMS) voluntary standards, which will be finalized in 1996. These standards have received widespread attention, and many organizations will devote significant effort to determine whether they are applicable and, if so, how they should be best implemented. ISO 14001 has the potential to replace existing EMS standards (e.g., differing national standards). It may work well with Government EMS standards (e.g., NAS 411) or may be supplanted by other organizational standards or policies (e.g., corporate EMS standards).

An Overview of the ISO 14000 Series was presented by S. Evanoff of Lockheed Martin, who summarized some of industry's concerns and perceived benefits about the standards. Major concerns include the high degree of variability in certification/registration to the standard (which raises questions about the value of the standard), problems associated with the disclosure requirements, the difficulty of determining cost benefits of certification/registration, and conflicting messages from Federal and state regulatory agencies regarding the standards. Industry is taking a "wait and see" attitude before deciding whether to pursue ISO 14000 registration.

A Federal Agency Perspective on EMS was given by Colonel R. Drawbaugh, USAF, who presented the results of an EMS survey conducted among the military sectors of 51 countries. (One impetus for this effort was a Canadian mandate that the Ottowan Province's military sector have an EMS in place by the end of the year.) The survey was conducted under the auspices of a NATO project conducted to determine international plans and experiences with EMS. Specific questions included: "How are nations implementing EMS?" and "How are they training to EMS?" In July 1995, the team held an initial meeting to discuss results of the survey. Preliminary results indicate that Canada, Denmark, and Sweden were the most advanced in this area and that significant concern was voiced about the difficulty of justifying an EMS based on cost. In the past, military analysis efforts focused on policies and budgets, but EMS is beginning to be considered for implementation. In the U.S., the EPA is moving towards advocating EMS implementation, especially as budgets are curtailed.

Chairs:

Steve Evanoff, Corporate Environmental Safety and Health, Lockheed Martin

Nick Shufro, Manager of Regulatory Affairs and Policy Planning for Environmental Health and Safety, United Technologies Corporation

Speakers:

E4.1 *An Overview of the ISO 14000 Series,* S. Evanoff, Lockheed Martin

E.4.2 *A Federal Agency Perspective on EMS,* Colonel R. Drawbaugh, USAF

E4.3 *Trade Issues Related to ISO 14000,* G. Hale, *International Environment Systems Update*

E4.4 *A Corporate Perspective on ISO 14000*, N. Shufro, United Technologies Corporation

E4.5 *Implementation of A Corporate EHS Management System,* D. Ufford, Texas Instruments

Trade Issues Related to ISO 14000 were discussed by G. Hale, editor of *International Environment Systems Update*, who provided a history of international environmental trade negotiations, environmental labeling programs, and development of the ISO 14000 series. This panelist noted several drivers for EMS development internationally, including the dramatic increase in corporate environmental standards, a tendency towards harmonization of international standards, growing awareness of environmental problems, shrinking political boundaries, "greening" trade rules, and the evolution of environmental requirements as trade barriers. Some key decisions and concerns were reviewed in the development of the NAFTA environmental side agreements, multilateral trade regulations under the Uruguay Round Protocol to GATT, and the Maestricht Treaty of the European Union. A brief discussion was presented on ISO 14000 perspectives held by U.S. Federal agencies, U.S. state agencies, Canada, the United Kingdom, the Netherlands, Malaysia, and Japan.

A Corporate Perspective on ISO 14000 was given by N. Shufro of United Technologies Corporation. This panelist reviewed United Technologies Corporation's strategy on these standards and the reasons for their position, including a gap analysis conducted between ISO 14000 and mandatory internal standards, corporate objectives, and market drivers for ISO 14000. Discussions also included division of corporate labor to implement ISO 14000, as well as United Technologies Corporation's role in the development and drafting of the ISO 14000 series standards.

Implementation of A Corporate EHS Management System was presented by D. Ufford of Texas Instruments. This panelist discussed vision and principles, strategies for adopting an EHS system, the paradigm shift required to develop such a system, and cost considerations. Texas Instruments is conducting a pilot program for analyzing and planning the implementation of a corporate EHS management system.

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The mandated elimination of CFC's, Halons, TCA, and other ozone depleting chemicals and specific hazardous materials has required changes and new developments in aerospace materials and processes. The aerospace industry has been involved for several years in providing product substitutions, redesigning entire production processes, and developing new materials that minimize or eliminate damage to the environment. These activities emphasize replacement cleaning solvents and their application verifications, compliant coatings including corrosion protection systems, and removal techniques, chemical propulsion effects on the environment, and the initiation of modifications to relevant processing and manufacturing specifications and standards.

The papers from this conference are being published in a separate volume as NASA CP-3349.

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