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Applications of Aerospace Technology in Industry

A TECHNOLOGY TRANSFER PROFILE

CASE FILE COPY

CONTAMINATION CONTROL

ACKNOWLEDGEMENTS

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Much of the information was gathered with the assistance of NASA in-house and contractor personnel who participated in the development and application of the technology discussed.

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APPLICATIONS OF AEROSPACE TECHNOLOGY IN INDUSTRY

A TECHNOLOGY TRANSFER PROFILE

CONTAMINATION CONTROL

- Prepared for -

The Technology Utilization Office
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PROFILE HIGHLIGHTS

In order to satisfy its mission requirements, NASA developed many specific technical innovations in contamination control for hardware reliability, planetary quarantine and astronaut safety. A wide variety of nonaerospace applications for these inventions has been documented.

Under contract to NASA, Sandia Corporation in Albuquerque, New Mexico produced two volumes, Contamination Control Principles in 1967 and Contamination Control Handbook in 1969, which constituted the first conceptual and methodological integration of the technology. These two references are used extensively by manufacturers and users of contamination control equipment.

NASA and its contractors also provided specifications and one of the first major markets for contamination control equipment manufacturers. This market influence, which extended from 1962 through 1967, promoted standardization and mass production for a wide range of equipment which is now used for contamination control in hospitals and in such industries as television, pharmaceuticals, electronics, computer hardware and food processing.

INTRODUCTION

The last two decades have witnessed the early phases of the birth and growth of an entirely new technical field--Contamination Control. While the driving force behind the rapid development of this field, together with its supporting industry, was directly related to the needs of NASA, the AEC, and DOD, sustained growth in this field is now related to needs in both the private and public sectors of our system. The methods developed to achieve control over troublesome agents, be they microbes, dust, or radiation, are applicable to control of the "open" environment as well as the "closed" environment of the laboratory, the production facility or the spacecraft. The technology of contamination control promises to exert an influence in the solution of environmental problems that is similar to the influence it has demonstrated in the solution of spaceflight problems.

This presentation underscores the strong influence NASA-sponsored research has had on the development of solutions to difficult contamination problems. The specific ways in which space agency programs have affected the emergence and growth of the entire contamination control field also are pinpointed. While the presentation delves deeply into a considerable number and variety of technical innovations, it emphasizes the fact that NASA's work has stimulated significant industrial development in the contamination control field.

The contamination control field is comprised of an industrial base, supplying the tools of control; a user base, adopting control techniques; and a technical base, expanding the concepts of control. Section I presents an overview of the field, while Section II describes significant NASA contributions to the growth of the industry and the technical base. Section III reviews both formal and informal mechanisms used by NASA to communicate a variety of technical advances, and Section IV reviews certain examples of the expansion of the user base through transfer of the technology. Finally, Section V focuses on certain issues related to transfer of NASA-generated contamination control technology.

SECTION I. AN OVERVIEW OF THE CONTAMINATION CONTROL FIELD

The art of contamination control has been practiced in many process-dependent industries for the last 50 years. Examples are found in food processing, pharmaceuticals and photographic products. In each of these industries, quality assurance has been dictated by experience and maintained by good housekeeping practice. Since control of contaminants was largely an art, both standards and practices were evolutionary -- based on technique rather than scientific data.

The need for both quality assurance and reliability in complex equipment caused enormous problems for the manufacturing community after World War II. The breakthrough came during the middle 1950's when the nature of contamination was finally resolved. Instruments were developed that could identify the sources and amounts of contamination present in a manufacturing environment. According to one expert in the field, Philip R. Austin (1970), contamination control has since grown to a $200 million per year industry in the United States.

Airborne dust became the first contaminant to be recognized as the common enemy in the manufacture of small, high-tolerance equipment. In one guidance manufacturing plant where gyroscopes were first built without airborne dust control procedures, for example, every 10 units required 120 reworks on the average. When control for airborne contaminants was instituted, the number of reworks dropped to two.

As important as reliability and quality assurance are in manufacturing, one needs only to consider the high maintenance costs associated with equipment having low reliability to grasp another economic implication of using contamination control technology. Prior to the use of clean room technology, Air Force experience in equipment maintenance over a five year period demonstrated that maintenance costs were ten times the initial cost of the equipment utilized. At any given time from 65 to 75 percent of the equipment was inoperative. With clean room technology utilized in both manufacture and repair, reliability of 92 to 95 percent is commonplace. This achievement not only reduced maintenance costs, but also enabled the equipment to more nearly fulfill the purpose for which it was designed and built (Austin, 1970).

Perhaps the most striking current feature of the contamination control field is the diffusion of the technology into nonaerospace applications. A typical example is provided by the experience of ENVIRCO, a small manufacturing company located in Albuquerque, New Mexico, founded in 1963. Aerospace requirements provided approximately 50 percent of this company's business in its first five years. In the last two years, aerospace has dropped to 10 percent, yet the gross has been maintained at the 1968 level. Hospital requirements now represent from 25 to 30 percent of ENVIRCO's business. The introduction of contamination control principles and requirements into computer facilities, TV stations, and photo studios shows the direction of new market penetration by this company.

In charting the growth of the contamination control field, the development and use of the clean rooms provides a convenient vehicle. Austin estimates that clean room installations costing $75 million have been built during 1970. In his book, Clean Rooms of the World: Case Book of 200 Clean Rooms, published in 1967, some 55 installations are described which utilize the laminar flow principle invented by Willis Whitfield. Whitfield developed the laminar flow principle in 1959 at the Sandia Laboratories in Albuquerque, New Mexico, under contract to the Atomic Energy Commission. (Attachment I presents a historical perspective on the adoption of the laminar flow principle in clean room design.)

Figure 1-1 demonstrates the laminar flow principle in operation. Such installations range in size from 400 square feet to 60,000 square feet and represent an investment approaching $20 million. In 1965, only one hospital in the United States had a clean room facility. By mid-1970, some 25 hospitals were using clean room facilities for one purpose or another: in operating rooms, in intensive care units, and more recently in complete wards.

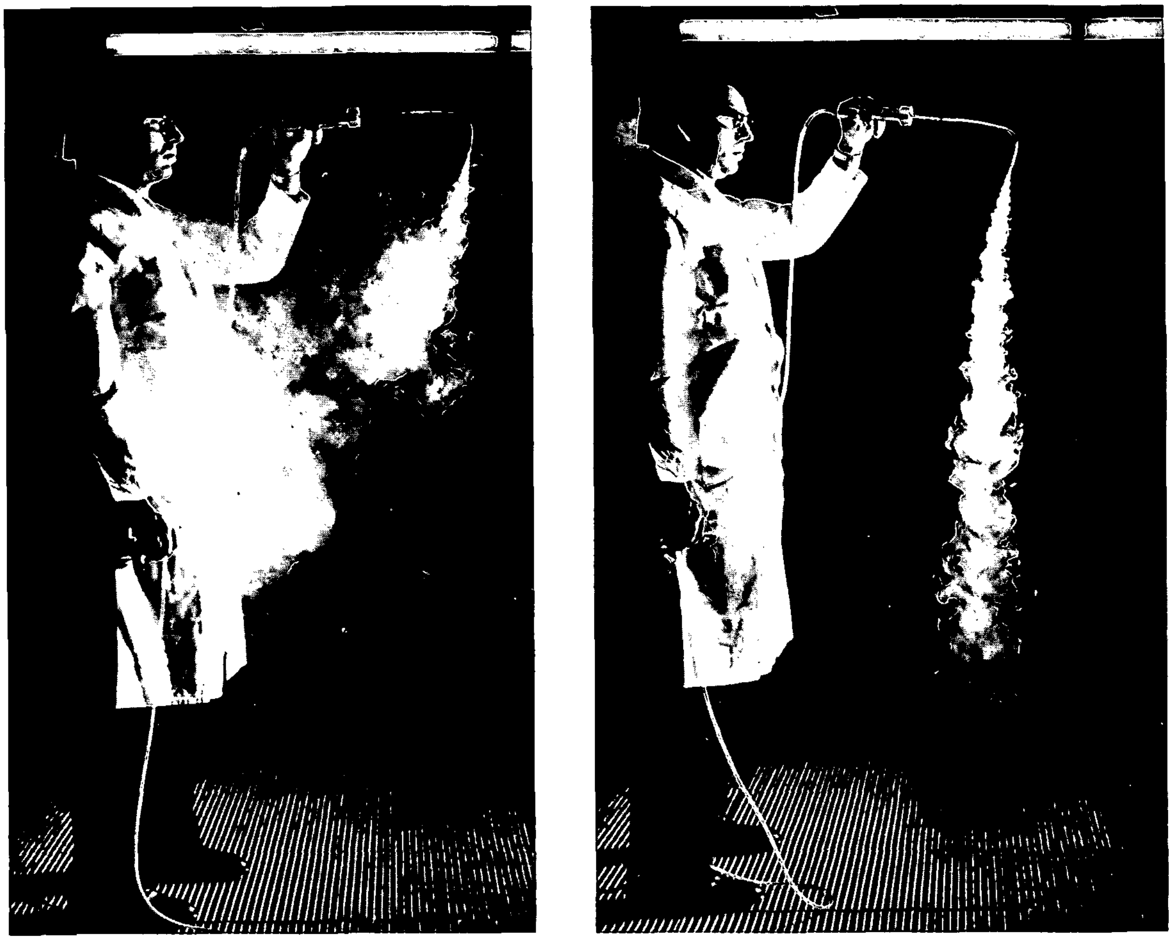

Figure 1-1. Conventional Nonlaminar Air Flow Clean Room at Left; Vertical Laminar Air Flow Clean Room at Right.

A review of the 1970 Contamination Control Directory shows that some 900 companies offered more than 800 technical products and services in support of a ten-year old field. The clean work station provides a major new direction for the contamination control industry that can now be clearly seen. The December 1970 issue of Contamination Control, the Journal of the American Association of Contamination Control, describes 38 companies and their innovative approaches in obtaining control over more limited work areas. The clean work station has found application in diverse fields ranging from biological work to data processing. In his November 1968 state-of-the-art review, Whitfield (1968) estimates that 2,000 clean work stations were in use in the pharmaceutical industry by the beginning of 1969.

The concepts of contamination control obviously extend far beyond the control of airborne particles. The same principles apply to any process where contaminants affect desired product quality or performance. The Falcon East plant of Bioquest, a division of Becton Dickinson and Company, produces millions of sterile, disposable laboratory petri dishes. Contamination control technology is utilized in handling containers for resin preparations and material transfers, as well as in production facilities.

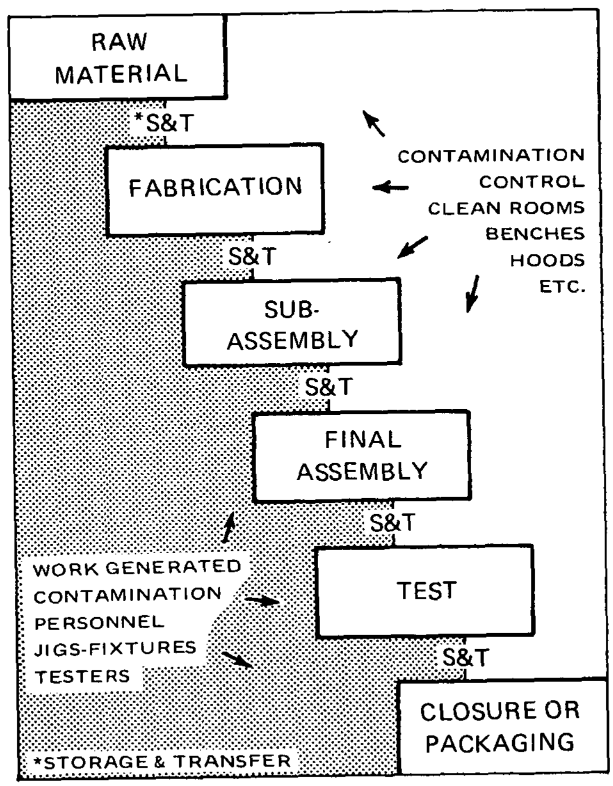

Figure 1-2. Contamination Control Considerations for Design and Manufacture of Product. [From Contamination Control Principles, NASA SP-5045, p. 11.]

The interface between production stages and the sources for contamination are identified in Figure 1-2, together with methods for control. These stages suggest the other facets of the contamination control industry: clothing and special garments, sterilization equipment, interlock facilities and fixtures, filtration and monitoring equipment, humidity and air conditioning, solvent materials and cleaning apparatus, and packaging products. These facets demonstrate the breadth of specialization already characteristic of this new industry.

To sum up, the emergence and growth of the contamination control field may be viewed as a classic example of new needs converting an old art into a new science. In ten short years, government requirements for high reliability in aerospace, defense, and atomic energy have created a substantial new industry in the United States which is now strongly diversifying. Section II examines the economic and technical roles NASA has played in the growth of the contamination control field. NASA requirements for extremely reliable and oftentimes sterile systems provided the first large-scale and continuing market for the young industry. At the same time, the space program created a general technical integration for the field and generated a variety of specific innovations.

SECTION II. NASA CONTRIBUTIONS TO THE CONTAMINATION CONTROL FIELD

To understand the impact NASA has made on the contamination control field, one must examine the role the space agency has played in a number of important, but fundamentally different activities. NASA mission requirements have necessitated the creation of technical innovations specifically related to the control of contamination. The problems of constructing extraordinarily complex systems with a high degree of reliability; the difficulties involved in supporting men in space in a completely closed environmental system in which air and water must be continuously recycled; the necessity of maintaining a planetary quarantine during space missions, so that earth-originated microorganisms do not contaminate neighboring planets and possible extraterrestrial life forms are not introduced into our own biosphere: all of these problems involving contamination control have been solved during the course of NASA mission operations. The solutions are as varied as the problems; some specific examples can be found in Attachment II. Innovations of this type have added to the base of technology that is now being applied in other sectors of the economy.

NASA contributions to the technology of the overall field, however, cannot be gauged in terms of hardware and techniques alone. In part because of the unique nature of its mission and in part because it recognized the need, NASA helped to provide a technical <u>integration</u> of the entire contamination control field. This integration has greatly facilitated the diffusion of contamination control technology into non-aerospace applications.

Finally, by supplying large volume markets for the highly sophisticated technology that was involved, NASA facilitated the rapid growth and consolidation of the industry to the point where it could readily couple into other sectors of the economy, meeting the needs of an ever-growing number of industries. It is useful to examine how these integration and consolidation activities occurred and the ways NASA participated in the overall process.

Technical Integration

The demand for extreme cleanliness in manufacture and assembly quickly led to the establishment of standards describing various levels of cleanliness and how they were to be measured. One of the earliest efforts to establish cleanliness standards involved the Aerospace Industries Association (AIA). In 1960, AIA member firms, many of whom were NASA contractors, cooperated in preparing the "Handbook For Contamination Control of Liquid Propulsion Systems." The primary purpose of the handbook was to provide an authoritative source of information covering all facets of contamination control in liquid rocket propulsion systems.

Soon after the AIA handbook was published, the Air Force prepared Technical Order 00-25-203, entitled "Standard Functional Criteria for the Design and Operation of Clean Rooms and Clean Work Stations." The Tech Order was published in 1961 and, after extensive study and redefinition, was reissued in 1963. Subsequently, a more comprehensive standard, which became the basis for present day clean room operations, was issued. Federal Standard 209, "Clean Room and Work Station Requirements, Controlled Environment," was issued in December 1963 and revised in August 1966. It established three classes of air cleanliness for clean rooms -- class 100, class 10,000 and class 100,000. The numbers refer to the maximum number of particles allowable per cubic foot of air that are larger than 0.5 microns (a speck invisible to the naked eye, and smaller than nearly all microbes and bacteria)

The publication of Federal Standard 209 was important for a number of reasons. By clearly delineating levels of cleanliness and providing guidelines for achieving these levels, the standard permitted production specifications to include contamination control measures necessary to ensure a high level of reliability. In addition, standardization greatly simplified operational procedures for both manufacturers and users of control equipment, particularly clean room equipment. Manufacturers were provided standards by which they could classify the effectiveness of their products and designs. Users, after determining the cleanliness levels necessary for their particular application, could then specify the equipment and techniques necessary to achieve the requisite levels.

By establishing clear standards for the control of airborne contaminants, Federal Standard 209 laid a solid foundation for dealing with contamination problems. It was upon this foundation that a framework was then erected which integrated the entire field. In 1967 the Sandia Corporation, under contract to the Technology Utilization Division of NASA, prepared <u>Contamination Control Principles</u> (NASA SP-5045), a document which conceptualized contamination control in all of its various dimensions. Control was viewed not only with respect to airborne contaminants in the aerospace industry, but was extended to include any contaminant in any situation. Principles were presented that were as applicable to dairy operators as to electronic component manufacturers. Not only solid particles in air, but oxides on the surface of a metal and gases dissolved in a liquid were dealt with. The document relates the control of contamination to all aspects of manufacturing processes, from product design to packaging and storage. It gives a comprehensive, clearly understandable model for contamination control that provides a conceptual integration of the entire field.

Still lacking was a detailed description of how the principles presented in SP-5045 might be implemented in any given situation. This need was met by a document issued in 1969, again written by the Sandia Corporation under contract to NASA. It is entitled Contamination Control Handbook (NASA SP-5076), and is a state-of-the-art description of monitoring, abatement, and control measures available for all aspects of contamination control. These two contamination control documents, SP-5045 and SP-5076, permitted first a conceptual and then a methodological integration of control principles. In this respect they are unique. Together they provide the methodology that permits the principles and the technology of contamination control to be applied to any industry for any contamination problem.

The significance of this technical integration can be seen when absolute cleanliness is compared to absolute vacuum: both conditions can only be approached but never reached. The issue that must be resolved in every control application, therefore, is "How clean is clean enough?" Since the cost of achieving specific levels of control varies exponentially, the importance of being able to determine the correct level of control in a specific application has cost implications as well as performance implications.

The technical integration associated with NASA contamination control work has already had a significant impact outside the space program. For example, in a little over a year the NASA Technology Utilization Program has received over 1,000 requests for the Contamination Control Handbook. In Section IV and Attachment IV of this presentation, 36 transfer cases relating to the handbook are documented. This handbook has played, and will continue to play, an important role in facilitating the utilization of contamination control technology wherever the need arises.

Market Integration

NASA influence has extended beyond that of significantly affecting the technological development of the contamination control field. Through the decade of the 1960's NASA provided a market integration for the contamination control industry through which the hardware and techniques of that industry have found new application in other sectors of the economy.

What is perhaps the greatest tribute to both NASA and the contamination control industry is the fact that the industry itself -- by developing entirely new markets -- no longer depends on aerospace as its main source of revenue. This fact is made strikingly evident in Figure 2-1, where the gross sales of four companies which market a variety of laminar flow equipment have been aggregrated over the last ten years. It can be seen that while sales were increasing at an annual rate of 34 percent between 1964 and 1970, the percentage of sales to nonaerospace industries rose from almost nothing ten years ago to approximately 90 percent in 1970. While NASA's role cannot be clearly separated from the aerospace aggregate, it is estimated to be greater than 50 percent by representatives of these companies. The transition experience of these companies demonstrates the way that needs of one sector can have lasting impact in other sectors through the mechanism of the "first market" generated by aerospace requirements. Three of the four companies were started during the early 1960's in direct response to these requirements.

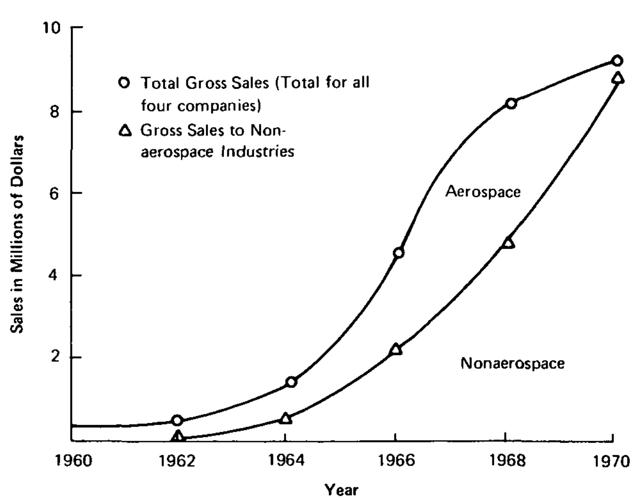

Figure 2-1. Sales of Four Major Producers of Laminar Flow Equipment.

The procurement process not only had the effect of providing "first market"; it also produced the complementary effect of standardizing quality and performance requirements for the technology throughout the industry. The latter benefit was established through NASA's specification activities. As an example, Table 2-1 presents a list of specifications generated by NASA that are related to some aspect of clean packaging requirements. The fact that a supplier can deliver materials, equipment, and services to other markets according to specification is tantamount to the adoption of the specifications by the supplier. This example provides another insight into a market related contribution NASA has made to the contamination control field.

TABLE 2-1. CLEAN PACKAGING SPECIFICATIONS ESTABLISHED BY NASA*

Environmental Control		
	MSFC-STD-246	Design and Operational Criteria of Controlled Environment Areas
	MSC-STD-C-4	Clean Rooms and Work Stations
Materials		
	MSFC-PROC-404	Gases, Drying and Preservation, Cleanliness Level and Inspection Methods
	MSFC-SPEC-234	Nitrogen, Space Vehicle Grade
	MSFC-SPEC-237A	Solvent, Precision Cleaning Agent
	MSFC-SPEC-456	LOX Compatible Film
	MSC-SPEC-C-25	Cleanliness of Precision Packaging Materials
Methods		
	MSC-SPEC-C-11A	Precision Cleaning
	MSC-SPEC-C-12A	Precision Clean Packaging
	MSC-PROC-C-100	Packaging of Precision Clean Parts/Components
	NAS 850	General Packaging Standard
	NAS 853	Field Force, Protection for
	NAS 3447	Precision Cleaned Items, Contamination Barrier for
Systems Cleanliness		
	KSC-C-123D	Cleanliness Levels, Cleaning Protection, and Inspection Procedures for Parts, Field Parts, Assemblies, Subsystems, and Systems for Fluid Use in Support Equipment
	MSFC-SPEC-164	Cleanliness of Components for Use in O_2, Fuel, and Pneumatic Systems
	MSFC-PROC-166C	Hydraulic System Detail Parts, Components, Assemblies, and Hydraulic Fluids for Space Vehicles, Cleaning Testing, and Handling
	MSFC-PROC-195	Cleanliness Level Requirements and Inspection Methods for Determining Cleanliness Level of Gas Bearing, Gas Supply, and Slosh Measuring System
	MSFC-10M01671	Cleanliness Levels, Cleaning, Protection and Inspection Procedures for Parts, Field Parts, Assemblies, Subsystems, and Systems for Pneumatic Use in Support Equipment
Identification		
	MSC-SPEC-C-3A	Decals, Certification of Cleanliness
	MSC-SPEC-M-1A	Marking and Identification

* Source: Contamination Control Handbook, NASA SP-5076, pp. VIII 37-8.

Selected Technical Contributions

In addition to the contributions of technical and market integration, NASA has made significant contributions to the technology of contamination control by meeting specific mission objectives. Certain specific examples of technical developments are presented in Attachment II which coincide with three classes of contamination control technology: prevention, monitoring and abatement. There are, however, two areas of technical concentration that have unusual significance at this time: (1) the development of spacecraft-cabin atmosphere monitors as they relate to air pollution monitoring instrumentation, and (2) microbiological decontamination and sterilization.

Under contract to NASA in 1969, Lieberman and Schipma examined the nature of the relationship between air pollution and spacecraft-cabin monitoring techniques. A spacecraft cabin is a closed ecologic environment; that a nontoxic atmosphere must be maintained within the cabin is a requisite for manned spaceflight. NASA has, therefore, invested a great deal of effort in identifying, measuring, and controlling the components of a sealed-spacecraft-cabin atmosphere. Much of this investment has been channeled by the space agency into the design and production of monitoring equipment, some of which is functionally suited to air pollution monitoring on a broader scale.

Tests with unmanned and manned cabin simulators have shown that nearly 150 vapors are generated in a closed system. These vapors, some of them potentially toxic, are primarily produced by three sources: (1) the metabolic processes of the crew, (2) the supplies and food stored for the use of the crew, and (3) the operation of the spacecraft systems. Additional sources are the materials of which the cabin is constructed and the reactions of products from other sources. The studies that have been conducted to identify and measure these contaminants utilized commercially available analytical instrumentation, such as gas chromatographs, infrared spectrometers, mass spectrometers, and biological sampling devices. This instrumentation has also been used for laboratory analysis in air pollution studies. However, the emphasis in air pollution instrumentation is shifting toward portability, durability, and simplicity of operation (manual or automatic). The development of flight-rated instrumentation by NASA has achieved some of the goals of air pollution investigators.

By way of example, the following NASA-developed instruments and techniques--originally designed for cabin monitoring--are of interest in the field of air pollution: a small general purpose cycloidal-focusing mass spectrometer; a nonmagnetic mass spectrometer; a colorimetric glycol detector; a hot wire detector for chemically active materials; a contaminant sensor; a photoionization source for a mass spectrometer; microwave spectroscopy; and a technique for collecting and analyzing gases.

Another area of NASA's technical concentration in the contamination control field concerns microbiological decontamination and sterilization. Space program interest in this area stems from two concerns: machines and men from earth disturbing the planetary ecological system, and life from other planets causing damage here on earth. The real significance of NASA work in microbiological contamination control lies in its comprehensiveness. It is simple enough to sterilize a surgical instrument in an autoclave; however, it becomes a completely different problem to implement a policy of planetary quarantine that affects all aspects of the design, hardware development, assembly, test, and launch of a spacecraft and capsule.

The nations involved in space exploration have signed an International Planetary Quarantine Agreement which stipulates that extreme precautions will be taken to prevent contamination of other planets. Many inventive solutions have been employed to reduce to a minimum the possibility of such contamination. Special bacteriostatic polymeric coatings were developed for electronic components too delicate to be treated with normal bacteriostats. An instrument for measuring microbial contamination over large areas lightly loaded with microorganisms was devised. Even the fuels used in landing crafts were treated to eliminate bacterial growth.

The decision to send men as well as instruments to the moon resulted in a host of even more complicated contamination control problems. Instruments can be exposed to the cold vacuum of outer space, while men must live in environments that are conducive to the growth of bacteria. Instruments can be made germ free; men cannot. Moreover, men must be supported for days and even weeks in a craft that must be completely self-sustaining, and yet in which no extra weight can be tolerated.

The Apollo Mission has produced such developments as the biological isolation garment, a suit worn by the astronauts that prevented microorganisms from either entering or leaving their immediate environment and yet was comfortable to wear. The garment has been adapted for use in hip surgery. In conjunction with a laminar flow enclosure, it has resulted in a reduction of infections caused by bacteria from surgeons' breath from about 8 percent to less than 1 percent (Wagner, 1970). Bacteriostatic coatings, developed for preventing lunar contamination by earth-originated microorganisms, are now finding application in certain fabrics and plastics used in hospitals (Kadison, 1970).

Conclusion

This brief review of representative NASA contributions to the contamination control field demonstrates the complex and varied effects of aerospace technology and technological requirements. Those contributions range from the general to the specific in terms of the technology, and from the obvious to the subtle in terms of the industry. Section III and its attachment describe the formal and informal communication mechanisms used by NASA and its personnel to facilitate the transfer of its technical contributions.

SECTION III. COMMUNICATIONS OF NASA CONTRIBUTIONS

As NASA-funded technical contributions to the contamination control field occur, they are communicated to persons outside the space program in several ways. Participation in the activities of professional societies, such as the American Association for Contamination Control, has provided opportunities to discuss research results. So, too, have the teaching of special courses and the writing of several hundred publications.

This section focuses primarily on two communication programs NASA uses to disseminate contamination control innovations: formal publications (especially the Tech Brief program), and the work of Technology Application Teams (TATeams). This emphasis on formal publications and TATeams is due primarily to the fact that the most complete transfer data available concern activities associated with these two programs. Attachment III presents a brief description of relevant professional society and teaching activities for which only fragmentary transfer documentation exists.

Formal Publications

Through its extensive formal publications program, NASA has provided contamination control specialists throughout the United States with detailed descriptions of many innovations in the field. To gain some feel for the amount of space program work on contamination control problems, Table 3-1 shows the number of titles appearing in each NASA-funded publication category from January 1963 through October 1970.

TABLE 3-1. NASA PUBLICATIONS PRESENTING SPACE PROGRAM CONTRIBUTIONS TO THE CONTAMINATION CONTROL FIELD: JANUARY 1963 - OCTOBER 1970

	TYPE OF PUBLICATION							
YEAR OF PUBLICATION	Contractor Reports	Tech Briefs*	Technical Memorandums	Technical Reports	Technical Translations	Technical Notes	Other Special Publications	TOTALS
1963	3	2	1	5	0	2	0	13
1964	9	2	0	4	3	0	1	19
1965	23	3	2	3	2	0	0	33
1966	45	18	8	5	0	0	0	76
1967	38	9	4	3	1	1	1	57
1968	43	10	10	3	4	1	1	72
1969	45	16	3	3	0	2	2	71
1970	29	7	4	2	2	1	1	46
TOTALS	235	67	32	28	12	7	6	387

* Tech Brief titles related to contamination control are presented in Attachment III.

The scope of new technology reported in these NASA publications can be grasped partially by examining the contents of Tech Briefs issued during the past seven years. Tech Briefs may be considered representative of the scope of technology involved since they announce many of the innovations resulting from research reported in other NASA publications. Since 1963, 67 Tech Briefs have been prepared and disseminated which describe NASA contamination control work.

The specific relevance of the 67 Tech Briefs to the contamination control field may be demonstrated by dividing them into four categories: prevention of contamination, contamination detection and monitoring, contamination abatement, and publications which present general contamination control principles. Table 3-2 indicates clearly that the vast majority (78 percent) of the Tech Briefs report new techniques for preventing or detecting and monitoring contamination. To provide interested readers with a more specific grasp of the contents of the 67 Tech Briefs, their titles are reproduced in Attachment III.

TABLE 3-2. CONTAMINATION CONTROL TECH BRIEFS

Contamination Control Category	Number Published	Percent
Prevention	30	44.8
Monitoring	22	32.8
Abatement	11	16.4
Principles	4	6.0
TOTALS	67	100.0

Persons outside of the space program have expressed considerable interest in the control technologies reported in Tech Briefs. In all, they have made 1,872 specific requests to NASA for the Technical Support Packages (TSP's) associated with the 67 Tech Briefs. The interest shown, however, has varied for the four classes of Tech Briefs (Figure 3-1).

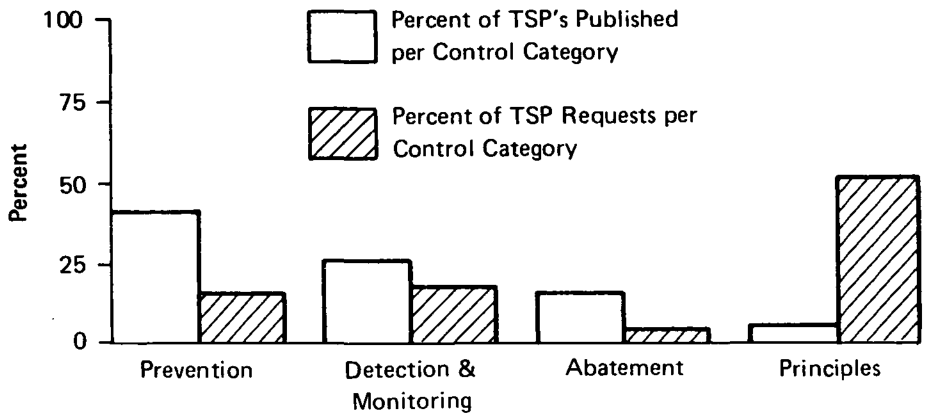

Figure 3-1. TSP Request Frequency Compared With TSP Production for Control Technology Categories.

TSP's in the principles category unquestionably have attracted the greatest interest among persons outside of NASA. Specifically, the Tech Brief announcing the Contamination Control Handbook (SP-5076) generated 1,090 (58.1 percent) of the 1,872 TSP requests recorded. The specific ways contamination control engineers have been able to use these TSP's are examined in Section IV.

Technology Application Teams

In addition to its various publication programs, NASA has disseminated some of its new contamination control technologies through its Technology Application Team (TATeam) program. TATeams, which have been established at four research institutes in the United States* are designed primarily to transfer aerospace technology to applications in such public sector areas as air pollution control, water pollution control, marine sciences and mine safety. Basically, the TATeams consist of multidisciplinary groups of engineers and scientists engaged in problem-solving activities. They represent an interface and information channel between scientists and engineers in the

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* Research Triangle Institute (Research Triangle Park, North Carolina); Illinois Institute of Technology (Chicago, Illinois); Midwest Research Institute (Kansas City, Missouri); Stanford Research Institute (Menlo Park, California).

public sector and the body of scientific and technical information that has resulted from the nation's aerospace research and development effort.

To illustrate the communication functions served by TATeams in the contamination control field, some experiences of the team at the Research Triangle Institute (RTI) may be cited. Since it was founded in June 1966, the RTI TATeam identified 56 air pollution control problems through contacts with the National Air Pollution Control Administration (NAPCA). Sample air pollution control problems explored by RTI include the development of an advanced pollutant sensor for carbon monoxide, the formulation of techniques for measuring airborne particulates, and the design of techniques for analyzing trace metals in combustion effluents from coal and residual fuel oil sources. The team has been able to develop potential solutions to 22 of the 56 problems by using NASA contamination control publications and by working closely with NASA field center personnel with experience in technologies related to pollution control problems.

Conclusion

Communicating NASA contributions in the contamination control field to selected groups of engineers, scientists, and technical managers, represents just one dimension of the technology transfer process. The relative significance of this dimension becomes apparent when viewed in the context of what happens to the communicated information. Applications of that information outside the space program are described in Section IV.

SECTION IV. A TRANSFER PROFILE

The relevance of specific NASA-generated contamination control technology to nonaerospace problems can be demonstrated, in part, by reviewing attempts persons outside the space program have made to use that technology. To develop an appropriate review of such application activities, several hundred persons who showed interest in NASA-developed contamination control technology were contacted. This section presents the results of that survey.

Three Dimensions of the Transfer Process

Before describing the specific details of the application activities identified in the survey, it is important to examine three dimensions of the technology transfer process: the control technology involved, the transfer stages which occur, and the action status of the transfer cases. These dimensions must be understood to put the specific examples of technology transfer into a meaningful frame of reference.

Four types of NASA documents which treat contamination control technology can be distinguished: prevention, monitoring, abatement, and those that relate general control principles. Attachment III identifies specific kinds of innovations associated with these categories (see Tech Brief Exhibit). While the first three types of documents appear to be self-explanatory, the fourth category deserves brief elaboration. Control technology in the first three categories is quite specific (e.g., describing one specific abatement technique), whereas that in the principles category tends to be general (by presenting control theories and principles). The value of making this fundamental distinction between the first three and the fourth control technology categories will become clear in attempting to explain the utility of certain NASA documentation.

Transfer stages may be divided into four categories. Stage One transfers involve the recognition of opportunity and searches for additional information to determine the relevance of innovations to professional activities. Stage Two transfers include laboratory verifications of contamination control theories, designs, or processing ideas. Transfer cases are classified in Stage Three when organizations are market testing prototypes or are using new contamination control techniques in their production activities. Stage Four transfers include those situations in which adopters are selling contamination control machinery or services developed originally under NASA funding. Organizations active in the first three transfer stages are referred to as adapters; their primary goal is to adapt or transform a technology for new applications. Organizations active in the fourth transfer stage are referred to as adopters; they promote the new applications of adapted technology.

The action status of transfer activities refers to the dynamic nature of the transfer process at the time contact is made with organizations. For convenience, two action statuses are distinguished: those which are continuing, and those which have terminated. As will be shown, interest in an innovation may progress through all four transfer stages; or it may continue indefinitely in one or another of the transfer stages, or, finally, interest may terminate in any of the transfer stages. It should be noted that technical, economic, political, and social factors affect decisions to continue or terminate transfer activities.

The Survey

Technology transfer processes are triggered by a variety of communication activities. As indicated in Section III, NASA contributions to the contamination control field have been communicated to other organizations through interpersonal contacts between NASA innovators and non-NASA adopters; through presentations before the American Association of Contamination Control; through such NASA publications as Tech Briefs, Contractor Reports, and Technical Surveys; and through Technology Application Teams such as the one at the Research Triangle Institute.

To generate data which illustrate transfers of NASA-developed contamination control technology, the Tech Brief program was selected for special examination. This is particularly appropriate because the Tech Brief concept mirrors, to a large extent, specific innovations which occur during the conduct of NASA-funded research and development efforts.

As noted in Section III, 67 Tech Briefs have been published since 1963 in which new contamination control technology has been reported. Persons outside the space program have made 1,872 specific requests to NASA for the Technical Support Packages (TSP's) associated with the 67 Tech Briefs. A survey was conducted to generate illustrations of the ways information presented in the TSP's has transferred to nonaerospace uses in the United States. Approximately one-half (935) of the TSP requesters were contacted by mail questionnaire; 382 (40.9 percent) of the requesters contacted responded. Responses are divided into four groups according to the transfer activities involved. Subsequently, telephone interviews were conducted with 89 persons who had indicated on the questionnaire they were engaged in either Stage 3 or 4 transfer activities.

Survey Results

Figure 4-1 presents a profile of the different stages of transfer activities identified in the survey.

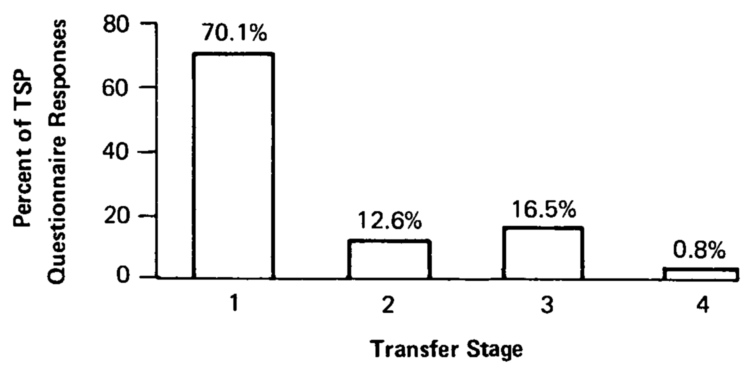

Figure 4-1. Transfer Profile of 382 Persons Using TSP's Related to Contamination Control.

Approximately two-thirds (70.1 percent) of the 382 respondents indicated they either had used the TSP's to keep up-to-date with new developments in the field, or were still trying to determine the relevance of the technology to their organizational needs. For example, the Olin Mathieson Chemical Corporation in New Haven, Connecticut, reported it continues to use a TSP describing the handling of fine powder materials for reference purposes (Tech Brief/TSP 69-10268). By contrast, Wright Industries, a small manufacturing company in Brooklyn, New York, used the same TSP in evaluating its safety standards and concluded its current practices are adequate for employee safety. The Wright Industries' experience provides an example in which the transfer benefit is established in Stage 1, and no further adaptation activity is required. Phrased differently, this experience demonstrates that some transfer activities are stage-limited. (See "Health Hazards of Ultrafine Metal and Metal Oxide Powders" File Summary in Attachment IV.)

Another 48 (12.5 percent) of the respondents stated they were laboratory testing techniques or methods described in TSP's. An example of the transfer cases grouped in this second stage of transfer activities involved a New York consulting firm using TSP 63-10234, "Filter for High-Pressure Gases Has Easy Take-Down Assembly." The firm, Barclay and Associates, is conducting a process feasibility study for a major oil company; a high-pressure gas filter is required as part of the process. (See "Filter for High-Pressure Gases" File Summary in Attachment IV.)

Another case may be cited that illustrates how certain factors interrupt attempts to adopt an entire technical idea, yet at the same time permit interested persons to adopt specific elements of the technology. It involves Steri-tized, Incorporated, a small New York chemical company, which manufactures bacteriostats, fungicides and other bactericides. Until recently, Steri-tized engineers were experimenting with a new bacteriostatic conformal coating described in TSP 67-10599. For economic reasons, they discontinued their tests. Although their adaptation of the conformal coating technology, as described in the TSP, terminated in Stage 2, Steri-tized engineers were able to use elements of the technology. They substituted organic compounds described in the TSP for more costly and less durable inorganic compounds they had been using in other products. An important economic result of that substitution has been an estimated 26 percent reduction in the cost of manufacturing the improved products. (See "Bacteriostatic Conformal Coating" File Summary in Attachment IV.)

Roughly one-sixth (16.5 percent) of the respondents indicated they were market testing prototypes of control machinery or had incorporated new control technology into their manufacturing procedures. One example of such Stage 3 transfer activity involves Scientific Enterprises in Broomfield, Colorado, a firm which produces sophisticated packaging for the aerospace and medical industries. Scientific Enterprises is completing prototype and market feasibility tests of new sterile encapsulation packages reported in TSP 64-10066. (See "Encapsulation of Surgical Instruments" File Summary in Attachment IV.)

Three persons contacted in the survey stated they have adopted and are marketing NASA-developed contamination control technology reported in TSP's. One of these Stage 4 transfer cases involves the bacteriostatic conformal coating technology cited above (TSP 67-10599). The research director of Polyscience, Incorporated indicated his firm favorably evaluated the technology in 1968, and decided to apply for a license to develop it commercially. Since receiving the license from NASA in April of 1969, the firm has been selling the coating. (See "Bacteriostatic Conformal Coating" File Summary in Attachment IV.)

Two other cases of Stage 4 transfer activities may be cited that illustrate the different ways the Contamination Control Handbook, announced in Tech Brief 68-10392, has been used outside of NASA. The first involves Xerox Data Systems in El Segundo, California, a firm which produces computers and such peripheral computer equipment as disc files, disc packs and tape drives. Cleanliness has long been a problem for Xerox as well as for the entire computer industry. To help solve its contamination problems, Xerox hired Ronald R. Hite, an engineer with considerable experience in contamination control. Mr. Hite said he has been able to use the Contamination Control Handbook to produce several improvements at Xerox: faster and more thorough cleaning techniques, cheaper equipment to achieve the same or higher cleanliness standards, and improved monitoring of contamination control equipment.

The operations manager of Dexon, Incorporated described the Contamination Control Handbook as "extremely valuable" in his company's marketing effort. Dexon, which manufactures clean room equipment, used the handbook as a design aid to develop a laminar flow bench with an automatic sensor to control flow differentials about, and efflux velocities from, the blower filter -- guaranteeing specified filtration velocities. On the market less than one month, sales totaled $1,000 with $50,000 in sales anticipated during the next twelve months.

Conclusion

The eight examples cited above illustrate a relatively wide range of activities in which persons using TSP's are applying NASA-developed technologies to solve their contamination control problems. More elaborate descriptions of these and 45 other transfer cases, including several not involving the use of TSP's, are presented in Attachment IV.

What the examples clearly illustrate is the relevance of NASA work to nonaerospace contamination problems. In addition, they clarify the idea that while some transfer efforts proceed through all transfer stages, others may continue or terminate in specific stages for economic as well as technical reasons.

SECTION V. A FOCUS ON ISSUES

This presentation explores, for the first time, the broad nature of NASA contributions to the contamination control field. While the scope of the transfer information presented was limited largely to specific innovations generated under NASA funding, it represents only part of the transfer story. As a "consumer" of contamination control technology, NASA stimulates the growth of a new industry, an industry that no longer depends on aerospace needs for its viability. The creation of contamination control specifications for each of the many facets of NASA procurements generated new technical capability in the industry. The importance of general documents which provided a technical integration for the field has also been clearly established.

The roles of NASA as consumer, specifier, and integrator are more easily recognized in the field of contamination control because the industry is young, the technology is new, and the technology is just beginning to be diffused throughout the private sector. These factors allow the normally indirect nature of NASA contributions to most technical fields to be put into the broader perspective.

ATTACHMENT I

DIFFUSION OF LAMINAR AIR FLOW TECHNOLOGY INTO THE CONTAMINATION CONTROL FIELD: A BRIEF CHRONOLOGY

December 1960	Patent issued to Whitfield for the laminar flow principle.
February 1961	Purchase requisition approved for first laminar flow clean room.
November 1961	Delivery of first laminar flow clean room.
December 1961	Delivery of first laminar down-flow hood.
December 1961	First conclusive tests performed indicating high degree of contamination control.
January 1962	First clean bench constructed at Sandia.
March 1962	Release of first technical report on laminar flow research: A New Approach to Clean Room Design (SC-4673).
April 1962	First clean bench installed in an industrial plant for the Bulova Watch Company.
April 1962	First presentation of laminar flow principle to a technical society, the Institute of Environmental Science, Chicago, Illinois.
April 1962	_Time_ magazine article described Whitfield and laminar flow principle.
August 1962 - January 1963	Survey of governmental agencies and industrial firms by Sandia concerning the need for standardizing clean room facilities.
December 1962	First recirculating laminar down-flow hood delivered to Sandia.
March 1963	Letters through Sandia management to AEC and GSA asking for permission to work on a Federal Standard for clean rooms.
March 1963	Authority granted by GSA through AEC for Sandia to sponsor Federal Standard 209.
March 1963	First curtained down-flow unit built at Sandia.

DIFFUSION OF LAMINAR AIR FLOW TECHNOLOGY INTO THE CONTAMINATION CONTROL FIELD: A BRIEF CHRONOLOGY (Continued)

April 1963	Clean Room Conference at Sandia attended by 175 clean room experts from governmental agencies (including NASA) and industry.
April 1963	Working group established to develop Federal Standard 209, J.G. King, Chairman, and J.A. Paulhamus, Secretary.
June 1963	First ultrasonic cleaner installed in laminar flow clean bench at Sandia.
August 1963	Fully coordinated standard delivered to GSA/ Washington.
December 1963	Federal Standard 209 distributed to governmental agencies and industry.
December 1963	Delivery of first laminar down-flow clean room.
February 1964	First version of movie "Clean Air is a Breeze" released for technical audiences.
April 1964	USPHS performed microbiological test of laminar down-flow room and hospital areas.
May 1964	ASTM acceptance of Sandia filter leak test.
December 1964	Microbiological confirmation study completed by Beckley at the University of New Mexico.
December 1964	Survey revealed the widespread use of laminar flow clean benches. For example, 400 at WE/Allentown, 500 at WE/Laureldale,and 1,200 at IBM/Poughkeepsie.
February 1965	Joint NASA/Sandia spacecraft sterilization study completed.
February 1965	First technical research report released on microbiological contamination control using laminar down-flow facilities.
September 1965	Revision of Federal Standard 209 completed, a portion which describes a standard test method and equipment for identifying pinpoint leaks in laminar flow equipment.

DIFFUSION OF LAMINAR AIR FLOW TECHNOLOGY INTO THE CONTAMINATION CONTROL FIELD: A BRIEF CHRONOLOGY (Concluded)

January 1966	First medical operating laminar flow suite was placed in use at Bataan Memorial Hospital in Albuquerque.
April 1966	Sandia Laboratories contract with NASA to work on Planetary Quarantine problems.
May 1966	A special laminar flow isolation hood for milling diatomaceous earth used in thermal battery processing was designed and procured.
October 1966	Patent issued to Whitfield for a vented laminar flow hood.
November 1966	NASA published <u>Spacecraft Sterilization Technology</u> (SP-108).
January 1967	Third generation dilution system for monitors completed making it possible to use a particle counter in heavy dust environments.
February 1967	Handbook for NASA on Planetary Quarantine work completed.
November 1967	Sandia completed <u>Contamination Control Principles</u> (SP-5045) for NASA.
November 1969	NASA published <u>Clean Room Technology</u> (SP-5074).
November 1969	Sandia prepared the <u>Contamination Control Handbook</u> (SP-5076) for NASA.

ATTACHMENT II

SELECTED TECHNOLOGICAL DEVELOPMENTS RELATING TO CONTAMINATION CONTROL THAT HAVE RESULTED FROM NASA-SPONSORED RESEARCH

Reduced to its simplest elements, contamination control is concerned with how to prevent contamination and how to remove contaminants already present. Associated with both of these aspects of control is the problem of determining how much contamination is present. Hence, developments fall into one of three categories: prevention, abatement, and detection and monitoring. Section II reviewed the significant technical and marketing contributions NASA has made to the contamination control field. This attachment, by contrast, provides some insight into the formidable control problems NASA has successfully addressed. For a more comprehensive listing of specific technical contributions, see the Tech Brief exhibit in Attachment III.

Prevention

The biological isolation garment. NASA's concern with preventing possible contamination of the Earth's atmosphere with extraterrestrial life forms carried by astronauts returning from the moon, resulted in development of the biological isolation garment (BIG).

The BIG is a one-piece, loose-fitting garment fabricated from a special, tightly woven, permeable cotton fabric. Its headpiece, containing a full width visor, incorporates an integral oronasal respirator with 0.3 micron-particle filters, which filter the wearer's inspired and expired breath. All seams are sealed on the inside of the garment to ensure the required biological containment. The garment is provided with a zippered, pressure-sealing closure extending diagonally from the crotch across the left side of the chest and curving over the left ear to the top of the head. It is also provided with medical rubber gloves and sizing adjustments on the legs and torso. A one-piece suit of cotton underwear is worn under the garment. The BIG is easy to don and remove, allows complete freedom of movement, and requires no external support equipment.

The garment is designed to contain 98 percent of viable particles 0.45 micron or larger in diameter and to maintain a habitable environment without the use of an external ventilation system to supply thermally balanced body cooling. Because it is porous, it does not require external ventilation. The garment performs equally well in preventing particles from penetrating into the wearer, and therefore affords protection in contagious areas.

Self-contained clothing system for use in extremely hazardous environments. A protective clothing system has been developed for use in handling the highly toxic and corrosive chemicals that are used as fuels and oxidants for launch vehicles. The clothing system is completely self-contained, and provides protection against red fuming nitric acid, nitrogen tetroxide, hydrazine, monomethyl hydrazine, unsymmetrical dimethyl hydrazine, liquid oxygen and liquid nitrogen. It consists of an outer garment, inner garment, underwear, boots, gloves and helmet. The outer garment, which is a multilayer laminate of tetrafluoroethylene, ethylene propylene, and nylon, provides flexibility with the necessary environmental protection. The outer garment is completely sealed with cuff rings to gloves, boots and helmet. The inner garment of acrylic fiber fur allows freedom and additional insulation.

The helmet is of a double-wall vinyl construction, providing air passages, insulation and impact resistance. It is designed with a communication system and an oral-nasal breathing mask. The visor is constructed of sealed and separated layers of formed plexiglass to reduce fogging and increase insulation.

The environmental control system, contained in a backpack, includes a liquid air storage dewar that provides a comfortable suit environmental level at high temperatures. At low temperatures, a bypass heat exchanger allows air to be supplied directly to the mask, thus giving longer use. Direct breathing for up to 10 minutes can be attained by the evaporation of the liquid air through a direct-breathing heat exchanger and delivered to a demand regulator.

Bacteriostatic plastics. A bacteriostatic coating for electronic components has been developed as a part of NASA's efforts to prevent contamination of other planets by earth-originated microorganisms. Electronic components which could harbor bacteria were a potential source of contamination difficult to deal with because they could be damaged using then-available bacteriostatic coatings, which contained metal ions. The new coating consists of a polymeric epoxy compound, a monomeric epoxy compound, a polyamide resin, and an organic amine curing agent.

The coating technique is accomplished by first preparing a mixture of the polymeric epoxy resin with the polyamide resin and curing agent, and incorporating the monomeric epoxy, such as allyl glycidyl ether, in such proportion that the resultant compound may be applied to the electronic components or assemblies by standard brushing, dipping or spraying techniques. After coating, the items are cured at appropriate consistency.

This coating, besides inhibiting bacterial reproduction, is compatible with electronic components used in space applications in that it exhibits a low outgassing rate in a vacuum and possesses high electrical resistivity.

A polymeric coating that can be used for encapsulation and sterilization of such things as surgical instruments has been developed by NASA personnel. Ethylene oxide, in the gaseous or liquid state, is mixed with an appropriate plasticizer and an uncuring polymeric material that do not chemically react with the ethylene oxide. The instruments are dipped into a thin solution of the mixture to encapsulate them and then removed for vacuum degassing and subsequent curing of the adherent film. Sterilization of the instruments occurs during the degassing and curing process. In this process, most of the ethylene oxide and other residual gases are liberated from the mixture, and all the surfaces of the instruments are exposed to the sterilizing action of the released ethylene oxide. A residual quantity of this sterilizing gas remains diffused within the tightly adherent solid polymer film that encapsulates the instruments.

The encapsulating polymer preserves the instruments in a sterile condition for indefinite periods but is readily removable when they are needed for use.

Abatement

Reduction of contamination during tube welding. In order to insure leakproof tubular joints and fittings, it is absolutely essential that the surfaces to be connected are completely free of contaminating materials. In addition, care must be taken during the welding or soldering operation to insure that contamination of the internal tube surface does not occur. A number of measures have been devised for dealing with contamination in these situations.

A tool has been developed for tubular welding that provides a constant purge of inert gas in the weld area, preventing contamination and oxidation. The tool is so designed that purge gas is constantly in contact with the hot interior of the tube as well as the sleeve that is being welded. Hence, after the operation the remaining half of the sleeve is free from contamination and oxidation and ready to be welded to another tube.

Contamination of internal tube surfaces by solder compound during soldering operations has been prevented by using a Teflon sleeve insert. Teflon, which is relatively inert and has a melting temperature above that reached during soldering, is machined into a sleeve configuration and forced into the two ends of the tubes to be connected before the soldering operation begins. In this way, contamination by either the flux or the solder itself is eliminated.

A portable tool that permits the outside surface of a tube or pipe to be abrasion-cleaned prior to joining has been devised. The tool consists of an abrading cylindrical unit that fits down over the end of the tube to be cleaned and can be rotated by an electric drill. A conduit which extends into the rotating head is connected to a vacuum source. All debris and contaminants generated by the cleaning and polishing action of the head are thus removed by vacuum. The tool provides a convenient method to clean and polish tubing in confined areas without introducing contamination.

Detection and Monitoring

Devices for measuring surface contamination. A technique devised at the Sandia Laboratories (and announced in an AEC/NASA Tech Brief) uses indium adhesion to provide a quantitative measure of surface cleanliness. Indium, a very soft metal that does not work harden, is placed on the tip of a probe which is then contacted with the surface under a force of 10g. The degree of adhesion between the indium and the surface is directly proportional to the cleanliness of the surface. The force needed to pull the indium tip away from the surface will then be a quantitative measure of cleanliness. This method of quantitatively measuring cleanliness works with hydrophobic as well as hydrophilic contaminants, and can be used on rough as well as smooth surfaces.

A way has also been devised to monitor the amount of contaminant being deposited on a surface using the optical absorbance characteristics of the surface. Light from a tungsten lamp is projected through a collimating lens onto the test surface and the resultant reflected image passes through a second (focusing) lens that focuses the image to illuminate a restricted area (two millimeters in diameter) of a silicon sensor cell. The output signal from the sensor cell is proportional to the output signal from the light source. An additional silicon sensor cell is located in the tungsten lamp housing to continually sample the lamp output for the purpose of calibration. Any change in the monitor output signal is proportional to change in the optical absorption characteristics of the test surface.

An instrument for measuring microbial contamination over large areas that are lightly loaded with microorganisms has been developed under NASA sponsorship. Conventional measurement techniques, such as the agar contact method and the swab-rinse method, are limited to relatively large populations of microorganisms on small to moderately sized surfaces. The planetary quarantine requirement that space vehicles landing on planets be sterile has necessitated sampling of large surface areas containing low levels of microbial contamination.

The instrument used is a vacuum probe that utilizes air flow through an orifice to remove particles from surfaces and a membrane filter to capture these particles, which are then assayed using conventional microbiological procedures. The design of the probe takes into account the fact an ordinary vacuum device would be ineffective because air movement in the immediate vicinity of micron-sized particles would not be enough to overcome the adhesion between the particles and the surface. Instead, the instrument makes use of a shock wave generated by having air drawn through two orifices at the tip of the probe at a critical flow rate. The air at the shock wave is very turbulent and tends to dislodge small particles, which then enter the moving air stream and are caught by the membrane filter. This probe has been operated with particle removal efficiencies consistently in excess of 80 percent using a variety of surfaces, even when surface roughness height far exceeds particle size.

ATTACHMENT III

NASA COMMUNICATION ACTIVITIES AND TECH BRIEF EXHIBIT

While documentary channels for the communication of NASA contributions have been described in Section III, a more balanced picture of transfer communication results when other channels also are examined. NASA in-house and contractor personnel have participated in dozens of professional association activities concerned with contamination control. In addition, they have organized and taught several contamination control courses and have prepared hundreds of publications in the field. Although the impact of these activities must still be measured, the identification of such communication efforts provides a perspective for viewing their transfer value.

Professional Associations and Conferences

Less than three years after NASA came into being, the American Association of Contamination Control (AACC) was born. Since that time in 1961, NASA contamination control contractor personnel have figured prominently in managing AACC:

- In 1964-1965, Harry A. Hamilton became AACC president. Mr. Hamilton had responsibilities in the contamination control area for the General Electric Company in St. Petersburg, Florida.

- Milton W. McKenzie served as AACC president in 1965-1966. At the time, Mr. McKenzie managed a contamination control program for the Martin Marietta Corporation in Denver, Colorado.

- The secretary of AACC in 1969-1970 was C. Thomas Williamsen. Mr. Williamsen dealt with contamination problems for several years as an employee of Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York.

- G. Briggs Phillips, whom NASA has consulted as an expert in biological contamination control, became AACC president in 1971.

To promote cooperation with AACC, NASA management and contractor personnel often have presented invited papers before AACC national and regional meetings. At the annual AACC meeting on May 27, 1965, for example, John E. Condon, Director of NASA's Office of Reliability and Quality Assurance, identified major communication problems confronting the space agency in its contamination control work and recommended specific steps to solve those problems. Similarly, J. G. Hagard, Director of Contamination Management in North American Rockwell's Space Division, described a useful management approach to contamination control before members of the Rio Grande Chapter of the AACC on March 3, 1969.

NASA has cooperated with other Federal agencies in facilitating the transfer of new contamination control technology. Thus, for example, on September 12-14, 1967, NASA and the Atomic Energy Commission co-sponsored the "AEC/NASA Symposium on Contamination Control: Current and Advanced Concepts in Instrumentation and Automation." More than 500 engineers, scientists, and technical managers attended the symposium in Albuquerque, New Mexico.

The space agency also has sponsored a series of "Spacecraft Sterilization" Conferences designed to update interested engineers in state-of-the-art advances growing out of space research. Interest in these conferences has been substantial. For example, 700 biologists, engineers, and technicians attended the National Conference on Spacecraft Sterilization Technology held on November 16-18, 1965 at the California Institute of Technology in Pasadena.

Additional examples of presentations before professional and industrial groups by NASA in-house and contractor personnel are shown in Table III-1.

Training Courses

Since the contamination control field is a relatively new interdisciplinary specialty, many engineers have found it useful to take special courses reviewing recent advances in the state-of-the-art. NASA in-house and contractor personnel participated in arranging and conducting at least five such formal training courses in the last two years (see Table III-2).

TABLE III-1. EXAMPLES OF PROFESSIONAL ASSOCIATION PRESENTATIONS BY NASA IN-HOUSE AND CONTRACTOR PERSONNEL

Speaker	Organization	Topic	Conference	Date	City
Vincent J. DeLaria	NASA-Electronics Research Center	"Space Research and Contamination Control"	Fifth Annual Technical Meeting of the AACC	April 1, 1966	Houston, Texas
Willis J. Whitfield	Sandia Laboratories	"Development of an Increased Sampling Rate Monitoring System"	Sixth Annual Technical Meeting of the AACC	May 15-18, 1967	Washington, D. C.
M. G. Koesterer	General Electric Company	"NASA Handbook of Biological Aspects of Spacecraft Sterilization"	Seventh Annual Technical Meeting of the AACC	May 13-16, 1968	Chicago, Illinois
Don W. Stanfill and James C. Little	Goddard Space Flight Center; Union Carbide Company	"High Bay Laminar Flow Clean Rooms"	Seventh Annual Technical Meeting of the AACC	May 13-16, 1968	Chicago, Illinois
George Ervin	Jet Propulsion Laboratory	"Immediate and Future Challenges to Contamination Control Technology"	Eighth Annual Technical Meeting of the AACC	May 19-22, 1969	New York, N.Y.

Tech Briefs

Section III of this presentation identified several different types of documents NASA in-house and contractor personnel have used to report the results of their contamination control work. Among other things, the description of publications in Section III emphasized that the technology reported in Tech Briefs may be considered representative of the broad scope of technology presented in other NASA publications. In fact, Tech Briefs often are used to announce the availability of other documents. Tech Briefs also serve as a mechanism for documenting the development of very specific contamination control techniques which are not documented anywhere else in the NASA system.

The following exhibit presents a detailed listing of 67 contamination control Tech Briefs divided into four categories: those dealing with specific contamination prevention, monitoring, or abatement techniques, and those reporting general control principles.

TABLE III-2. ILLUSTRATIONS OF CONTAMINATION CONTROL TRAINING COURSES IN WHICH NASA IN-HOUSE AND CONTRACTOR PERSONNEL HAVE PARTICIPATED: 1969 - 1970

Title	Sponsor	Date	City
"Principles and Practices of Contamination Control"	NASA, AACC, and the University of Alabama	August 18-22, 1969	Huntsville, Alabama
"Industrial Clean Room Contamination Control"	Rochester Institute of Technology (RIT) and AACC	October 13-15, 1969	Rochester, New York
"Industrial Clean Room Contamination Control"	RIT and AACC	March 4-6, 1970	Rochester, New York
"Technical Lecture Series on Contamination Control for Science and Industry"	AACC	April 20-21, 1970	Anaheim, California
"Systems Approach to Contamination Control for Engineers, Scientists, and Managers"	University of Colorado and AACC	August 12-14, 1970	Boulder, Colorado

TECH BRIEF EXHIBIT (Continued)

Technical Category	Tech Brief Number	Tech Brief Title
Contamination Prevention (Continued)	67-10473	Tool Samples Subsurface Soil Free of Surface Contaminants
	67-10599	Bacteriostatic Conformal Coating for Electronic Components
	68-10271	Preparation of Silver-Activated Zinc Sulfide Thin Films
	68-10302	Effects of Surface Preparation of Quality of Aluminum Alloy Weldments
	68-10500	Biological Isolation Garment
	69-10123	Production of Metals and Compounds by Radiation Chemistry
	69-10127	Battery Case Shear
	69-10273	Technique for Highly Efficient Recovery of Microbiological Contaminants
	69-10310	Precision Mounting for Instrument Optical Elements Provided by Polyimide Bonding
	69-10450	Improved Fire Resistant Radio Frequency Anechoic Materials
	69-10485	Freon, T-B1 Cutting Fluid
	69-10495	Heat-Shrinkable Jacket Holds Fluid in Contact With Tensile Test Specimen
	69-10788	Gas Chromatograph Injection Port Protection Device
	70-10248	Self-Sealing Propellant-Actuated Device Eliminates Atmosphere Contamination
Contamination Detection and Monitoring	66-10068	Sensor Detects Hydrocarbon Oil Contaminants in Fluid Lines
	66-10090	Radioactive Tracer System Detects Oil Contaminants in Fluid Lines
	66-10131	Surfactant for Dye-Penetrant Inspection is Insensitive to Liquid Oxygen
	66-10320	Solvent Residue Content Measured by Light Scattering Technique
	67-10076	Cleanroom Air Sampler Counts, Categorizes, and Records Particle Data
	67-10205	Quartz Crystals Detect Gas Contaminants During Vacuum Chamber Evacuation

TECH BRIEF EXHIBIT

Technical Category	Tech Brief Number	Tech Brief Title
Contamination Prevention	63-10141	Vented Piston Seal Prevents Fluid Leakage Between Two Chambers
	64-10066	Encapsulation Process Sterilizes and Preserves Surgical Instruments
	65-10117	Double Gloves Reduce Contamination of Dry Box Atmosphere
	66-10093	Tool Provides Constant Purge During Tube Welding
	66-10166	Dispenser Leak-Tests and Sterilizes Rubber Gloves
	66-10201	Self-Contained Clothing System Provides Protection Against Hazardous Environments
	66-10217	Fiberglass Container Shells Form Contamination-Free Storage Units
	66-10238	Insert Sleeve Prevents Tube Soldering Contamination
	66-10241	Brazing Process Using AL-SI Filler Alloy Reliably Bonds Aluminum Parts
	66-10258	Critical Parts Are Stored and Shipped in Environmentally Controlled Reuseable Container
	66-10311	Union Would Facilitate Joining of Tubing, Minimize Braze Contamination
	66-10371	Brazing Retort Manifold Design Concept May Minimize Air Contamination and Enhance Uniform Gas Flow
	66-10538	Tungsten Insulated Susceptor Cup for High Temperature Induction Furnace Eliminates Contamination
	66-10678	Improved Rolling Element Bearings Provide Low Torque and Small Temperature Rise in Ultrahigh Vacuum Environment
	66-10683	Valve Effectively Controls Amount of Contaminant in Flow Stream
	67-10408	Improved Sample Capsule for Determination of Oxygen in Hemolyzed Blood

TECH BRIEF EXHIBIT (Continued)

Technical Category	Tech Brief Number	Tech Brief Title
Contamination Detection and Monitoring (Continued)	67-10231	Improved Atmospheric Particle Analyzer
	67-10243	Analytical Technique Characterizes All Trace Contaminants in Water
	67-10358	Steel Test Panel Helps Control Additives in Pyrophosphate Copper Plating
	67-10661	Air Sampler Collects and Protects Minute Particles
	68-10024	Locating and Sealing Air Leaks in Multi-roomed Buildings
	68-10089	Monitor Senses Amount of Contamination Deposited on Surfaces
	68-10231	Vacuum Probe Sampler Removes Micron-Sized Particles from Surfaces
	68-10342	Indium Adhesion Provides Quantitative Measures of Surface Cleanliness
	68-10413	UV Detector Monitors Organic Contamination of Optical Surfaces
	69-10223	Automated Microorganism Sample Collection Module
	69-10292	Apparatus Automatically Measures Soluble Residue Content of Volatile Solvents
	69-10520	A New Method for the Determination of Particulate Contamination Levels for Surface Cleanliness of Fluid Systems
	69-10691	Conditioning of Pulses from Aerosol-Particle Detectors
	69-10816	Fluid Sample Collection and Storage Device
	70-10187	New Microwave Spectrometer/Imager Has Possible Applications for Pollution Monitoring
	70-10201	Prediction of Gas Leakage of Environmental Control Systems
Contamination Abatement	63-10234	Filter for High-Pressure Gases Has Easy Takedown, Assembly
	64-10319	Gas Diffusion Cell Removes Carbon Dioxide from Occupied Airtight Enclosures

TECH BRIEF EXHIBIT (Concluded)

Technical Category	Tech Brief Number	Tech Brief Title
Contamination Abatement (Continued)	65-10280	Electron Bombardment Improves Vacuum Chamber Efficiency
	65-10375	Portable Tool Cleans Pipes and Tubing
	66-10242	Portable Sandblaster Cleans Small Areas
	66-10298	Ultrasonic Cleaning Restores Depth-Type Filters
	68-10555	Electrolytic Silver Ion Cell Sterilizes Water Supply
	70-10208	Effects of Decontamination, Sterilization, and Thermal Vacuum on Polymeric Products
	70-10294	Design Method for Absorption Beds
	70-10424	Molecular Sieves Control Contamination and Insulate in Thermal Regenerators: A Concept
	70-10456	Elimination of Gases and Contamination from Water
Contamination Control Principles	68-10392	Contamination Control Handbook
	69-10268	Health Hazards of Ultrafine Metal and Metal Oxide Powders
	69-10277	Sterilization Training Manual
	69-10593	Microbiological Aspects of Sterilization Development Laboratories

ATTACHMENT IV

SUMMARY OF TECHNOLOGY TRANSFER REPORTS INVOLVING
NASA-GENERATED CONTAMINATION CONTROL TECHNOLOGY

CONTAMINATION CONTROL TECHNOLOGIES INVOLVED	TRANSFER STAGES							
	1		2		3		4	
	Cont.*	Term.	Cont.	Term.	Cont.	Term.	Cont.	Term.
PREVENTION								
• Aircraft Galley and Cargo Refrigeration System					430**			
• Bacteriostatic Conformal Coating				27782			44974	
• Encapsulation of Surgical Instruments					44955			
• Gas Chromatograph Protective Device					35190			
• Medical Application of Clean Room Technology							35907	
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• Polyurethane Filter for Burn Treatment					38611			
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DETECTION AND MONITORING								
• Microbiological Vacuum Probe					44301			
• Photo-Cell Inspection Meter					23829			
ABATEMENT								
• Filter Eliminates Gases and Contamination From Water			44964					
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EDUCATION								
• Contamination Control Handbook	23044 23944 27506 28147 32236		26258 26614 27847 27857 27862 28008 29226 29236 30506 31286		23188 24098 25330 26764 27830 27837 27850 27858 28149 28246 29174 29250 29742 30612 31324 31368 31762 34100 38142 39662		27878 33050	
• Health Hazards of Ultrafine Metal and Metal Oxide Powders	32560 33328							

* The action status, continuing or terminated, of transfer cases at the time DRI-PATT contacted users. Cases are classed as terminated when (a) no further adaptation or adoption is contemplated, (b) a better technical alternative has been found, or (c) continued transfer activity is not economically feasible.

** Numbers in columns refer to PATT case numbers.

AIRCRAFT GALLEY AND CARGO REFRIGERATION SYSTEM TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The AiResearch Manufacturing Division of the Garrett Corporation (430) has on the market a refrigeration system for aircraft galleys and cargo containers. The basic technology was developed under contracts with the Air Force and NASA. The Air Force work resulted in a cooling and ventilating system for suited personnel handling toxic materials at missile sites. Later, under contract with the Manned Spacecraft Center, Garrett applied the technology in suits worn by Gemini astronauts during extra-vehicular activity. Finally, the technology was adapted by Garrett to an aircraft refrigeration system which was first marketed in mid-1968.

The technology is simple and reliable. Liquid nitrogen is vaporized in a heat exchanger and vented into the enclosure (food compartment or space suit) by a jet pump ejector. The vaporized nitrogen mixes with compartment air and the mixture is cooled as it flows across the heat exchanger. The cooled air recirculates through the compartment, providing continuous forced low-velocity circulation capable of maintaining temperatures within a two-degree range.

The aircraft systems are self-contained, use no batteries or external power, need no mechanical maintenance, and the nitrogen atmosphere retards food spoilage. Operating costs are low: liquid nitrogen for 24 hours' operation costs only 27¢.

The cargo refrigeration unit is containerized, providing capability for many uses from the field to the supermarket. Since the unit is entirely self-contained and requires no external power, it is remarkably adaptable for shipping all kinds of perishables. Evaluation by a major airline has been completed with excellent results. Vine-ripened Hawaiian pineapples were flown to California and immediately displayed in a supermarket. Despite a price increase of 5¢ per pound, pineapple sales rose 40 percent within a few weeks. Meat and papayas have also been shipped successfully.

During the first year of sales of the galley refrigeration unit, 55 planes were equipped. The unit price was $4, 000 for each of the

25 units installed in Boeing 737's, and $9,000 for each of the 30 systems placed in Boeing 707's and 727's. The Royal Canadian Air Force has made a recent purchase: four units are now in operation on RCAF planes.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Number: 430
TEF Number: 228
Date of Latest Information Used: July 10, 1970

BACTERIOSTATIC CONFORMAL COATING
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In a thorough effort to minimize the number of viable, earth-originated bacteria carried by spacecraft to other planets, NASA has had to develop the technology for a planetary quarantine. Since many of the standard techniques for obtaining and maintaining a bacteria-free surface would be damaging to the delicate parts of a spacecraft, alternative methods have been developed.

One of these new methods was invented by Messrs. LeDoux and Bland at Goddard Space Flight Center. It was originally designed for the electronic components in a spacecraft and consists of ether sterilization of a component followed by the application of a bacteriostatic, epoxy-based coating using standard brushing, dipping or spraying techniques. The coating is then cured at an appropriate temperature and additional coats may be applied with alternative curing cycles. The finished product should have a coating thickness of from 0.005 to 0.010 inch.

Chemically, the coating is comprised of a polymeric epoxy compound, a monomeric epoxy compound, a polyamide resin, and an organic amine curing agent. Physically, it exhibits high electrical resistivity, a low outgassing rate, and is capable of restraining electronic components when subjected to mechanical vibration. This technology has several potential applications outside the space program and Tech Brief 67-10599 was issued to describe it.

Mr. D. McGonigal, director of R & D for Polyscience, Inc. (44974), read this Tech Brief and he thought a market could probably be developed for the technology. The company received a NASA license in April of 1969 for commercial use of the invention and a few sales have been made. McGonigal said the present market is small because the company has not yet conducted research to determine additional applications of the coating. They plan to develop new uses in the near future and there will be a sales push for the coating when this research is done.

Steri-tized, Inc., a small chemical company in New York (27782), manufactures bacteriostats, fungicides, and other bactericides for industry. In conjunction with its line of bactericides, the company is constantly looking for new product lines and for new areas of potential sales application. Company president M. Kadison stated that his firm was working on a new bacteriostatic coating when he read the Tech Brief.

The company is not marketing the bacteriostatic coating as described in TB 67-10599, but the technology has been incorporated into improved versions of two coating products the company had been making for some time. The improved products are made at a cost reduction of 26 percent, which Kadison attributed directly to the Tech Brief. Due to the improvement, additional markets for the two coatings have developed which include textiles (canvas for tenting, boat covers, and shoe liners and cotton for sheets and pillow cases) and vinyl extrusions (shower curtains and swimming pool liners). These items were previously coated with bactericides and fungicides which contained mercury, tin or lead. Public outrage and government regulations have severely restricted the use of such metals. Kadison said their own coating products contained phenyl mercury which was replaced by the organic compounds described in the Tech Brief.

Control Numbers

Tech Brief Number: 67-10599
NASA Center: Goddard Space Flight Center
PATT Case Numbers: 27782, 44974
TEF Number: 299
Date of Latest Information Used: November 11, 1970

ENCAPSULATION OF SURGICAL INSTRUMENTS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Under the terms of the International Planetary Quarantine Agreement, the number of viable, earth-originated microorganisms transferred to other planets must be minimized. NASA has generated a broad area of technology to meet this requirement. Many special techniques have been devised because a sterilizing process or agent must be compatible with the rigidly specified component it sterilizes.

In particular, the fuel must be sterile but still provide the specified thrust per pound. Scientists at the Jet Propulsion Laboratory have developed a process for sterilizing propellants of lunar landing vehicles. This was done by adding ethylene oxide (a sterilizing agent) to the polyurethane propellant which produced a sterilized but still effective fuel. In the process of this investigation, they observed that ethylene oxide could also be added to other polymeric materials without affecting their material properties and proposed this method for encapsulating surgical instruments.

After reading a 1964 Tech Brief on this proposed use, the president of Scientific Enterprises (44955) in Broomfield, Colorado applied, in 1965, for a license to use the technology commercially. His company does sophisticated packaging for aerospace and medical industries. Scientific Enterprises has found several organic polymers suitable for use with ethylene oxide to form a sterile encapsulation. Since these polymers do not form a bond with the instrument metal, the coatings are easily removed so the instrument may be used. The process gives very satisfactory results as shown by the company's prototype testing, and they offer to apply this sterile coating for customers. The company is attempting to reduce costs for external commercial market use.

Control Numbers

Tech Brief Number: 64-10066
NASA Center: Jet Propulsion Laboratory
PATT Case Number: 44955
TEF Number: 342
Date of Latest Information Used: October 30, 1970

GAS CHROMATOGRAPH PROTECTIVE DEVICE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Gas chromatographic chemical analysis is applicable to solid/ liquid propellants, pollution and contamination surveillance, polymers, oils, low-boiling impurities, etc. Samples containing nonvolatile substances are not usually analyzed by gas chromatographic procedures because nonvolatiles and other deleterious foreign materials "poison" the columns. This condition invalidates results and necessitates reworking lengthy column preparations, installations, and calibrations. However, hydrazine fuels used in rockets and turbine engines must be frequently tested for quality control by this method; when they include hydrazine nitrate, which is a nonvolatile, the testing is inaccurate and quite difficult. The rapid "poisoning" in this case is caused by the deposition of hydrazine nitrates and the buildup of acidic salts. Messrs. E. A. Welz and M. D. Robertson of North American Rockwell Corporation, under contract to Marshall Space Flight Center, developed a procedure and a device to eliminate these problems.

The first problem was solved by reacting a small portion of the sample with sodium methoxide to liberate hydrazines from any free radicals present. The acidic salt buildup is eliminated by installing an on-column inlet modified to hold an exchangeable insert, which was packed with Polyethyleneimine (PEI) on a standard filler material. PEI is known to be an efficient trap for acidic and highly polar material. These techniques have increased the lifetime of the chromatographic column to three months of continuous service. The protection is ensured simply and inexpensively, and selective retention of undesirable materials is easily accomplished.

Sundstrand Aviation, an Illinois division of Sundstrand Corporation (35190), produces various hydrazine fuels, and one of them includes hydrazine nitrate (Sundstrand 70-20-10). Sundstrand's quality control monitoring had been costly and inefficient. After reading TB 69-10788. which described the protective device, the project chemist tried it out in his laboratory. He plans to use it for any future fuel analysis and regrets it was not available a year ago.

Control Numbers

Tech Brief Number:	69-10788
NASA Center:	Marshall Space Flight Center
PATT Case Number:	35190
TEF Number:	343

Date of Latest Information Used: October 27, 1970

MEDICAL APPLICATIONS OF CLEAN ROOM TECHNOLOGY

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Hospital environments are subject to strict controls to minimize possibilities of infection; nonetheless, it is quite difficult to eliminate inflection entirely. Airborne bacteria are especially troublesome in operating rooms. As many as five percent of surgical patients become infected despite thorough scrubbing of the operating room with disinfectant detergents, use of sterile clothing, prevention of air currents by keeping doors closed, use of ultraviolet lights, and administration of prophylactic antibiotics. Significant advancement in operating room sterility has been achieved by a transfer of technology from NASA's body of contamination control techniques.

The transfer was accomplished by an engineer who had worked on the development of dust covers for spacecraft assembly operations under a NASA subcontract. The engineer now works for Contamination Reduction Systems (35907) in Conshohocken, Pennsylvania. The NASA artifact incorporated a high efficiency particulate air filter (HEPA filter) developed originally by the Atomic Energy Commission. Other components of a vertical flow air circulation system were added by the engineer to develop the patented air filtration system for CRS which is used in hospitals and other medical facilities. Sales of the system are presently about $800, 000 annually.

The combination of 99.97 percent efficient HEPA filters, a vertical flow system, and a clean room enclosure constitutes the patented medical system, which virtually eliminates airborne bacteria from the enclosure within a few minutes. Among the hospital applications are operation room sterility, reverse isolation of patients with depressed immunological defenses (e.g., transplant recipients, patients undergoing irradiation, cancer chemotherapy, and those with blood dyscrasia), protection of premature infants and patients with respiratory diseases such as emphysema and bronchial asthma, and protection of patients undergoing open treatment of burns. The system also performs valuable functions in rooms for preparing intravenous medications, infant formulas, culture media, and sterile supplies. Research laboratories in the pharmaceutical industry, microbiological studies, and other scientific applications are now a major market for the CRS product.

An article in the Journal of the American Medical Association (March 18, 1968) reported the results of using the system in operating rooms: the principal sources of operating room infections (staphylococcal and psendomonas particles) were reduced ten to eighteen fold within two to three minutes of turning on the filter. A research clean room located in a room in which small animals were housed was equipped with the system for an experiment reported in the American Journal of Public Health (October 1967). In combination with conventional floor scrubbing techniques, the "washing" of the room with sterile filtered air created an essentially sterile environment under very adverse conditions. In the August 1969 issue of Applied Microbiology, similar success was described for an animal care laboratory; the system reduced the volume of airborne contaminants stirred up during cage cleaning and changing activities to the level observed when no personnel activity occurred. Airborne infection of the animals was greatly reduced, and for the first time experimenters were able to quantify the various factors contributing to the spread of airborne infection.

Control Numbers

Tech Brief Number:	None
NASA Center:	Marshall Space Flight Center
PATT Case Number:	35907
TEF Number:	308

Date of Latest Information Used: March 31, 1970

NONCONTAMINATING SWABS PRODUCED BY HANDICAPPED WORKERS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

While assembling rockets, North American Rockwell, under contract to Marshall Space Flight Center, established clean room operations involving a dust free, temperature-controlled environment. Grease marks, filings, and all other contaminants had to be removed in order to avoid potential explosion hazards when the rocket components were eventually exposed to propellants. Attempts were made to remove small bits of contaminants with cotton swabs, but sharp corners and surface irregularities tended to snag the cotton and produce a small lint deposit contamination. Also, fragments of wood from the swab handle contributed contamination.

A North American Rockwell technician devised a modification involving placement of a nylon cover over the cotton, and heat-shrinkable rubber tubing over the wooden handle. The modified swab performed well and could be reused.

Technology utilization engineers at North American Rockwell perceived a transfer potential early in 1968, and conveyed the idea to Build-Rehabilitation Industries (37429). The nonprofit firm employs and rehabilitates handicapped workers in North Hollywood, California. Since May 1968, the firm has produced more than 20,000 swabs and sold about $3,000 worth. Efforts are being made to find new markets for the swabs.

Control Numbers

Tech Brief Number: None
NASA Center: Marshall Space Flight Center
PATT Case Number: 37429
TEF Number: 212
Date of Latest Information Used: May 6, 1970

POLYURETHANE FILTER FOR BURN TREATMENT

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

NASA's program to land an unmanned craft on Mars included a project in which balloons were sent 100, 000 feet above the earth to test for microbiological contamination. The testing device included a special polyurethane filter. Edward Rich, Jr., a NASA employee for nine years, conceived the idea of adapting the filter to medical uses, specifically for burn treatment.

After taking a job with the National Institutes of Health (NIH), Rich performed additional research to develop a new burn bandage known as Burn Aid (38611). Burn Aid is inexpensive and can be used at home as well as in a hospital. A portable unit provides a supply of air or specific gases, which flow through the filter to the burn. The filter itself is sandwiched between two sheets of vinyl that are sealed on all edges. The bottom sheet is coated with an adhesive and covered with paper. The physician cuts a hole in the bottom sheet, large enough to avoid contact between the bandage and the injured area, then peels off the remaining paper to expose the adhesive for application to unburned skin around the injury. The flow of gas is then started through the filter. Only the filtered air contacts the wound, preventing infection and hastening the healing process. NIH has filed a patent application for the medical use of the filter.

Control Numbers

Tech Brief Number:	None
NASA Center:	Goddard Space Flight Center
PATT Case Number:	38611
TEF Number:	84

Date of Latest Information Used: April 24, 1970

SPECIAL-SUIT TECHNOLOGIES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Garrett Corporation (44073), a Los Angeles, California firm with a broad background in providing special suits for aerospace uses, is using its expertise to design and fabricate new garments for several unique nonspace applications. Several years ago the company's experience in developing a protective suit for handlers of toxic materials led to its developing a new aircraft galley refrigeration system which incorporates a novel nitrogen-coolant system similar to that used to cool the wearer of the protective suit. (See "Aircraft Galley and Cargo Refrigeration System" above.)

In recent months the firm has drawn on other special-suit technology developed initially for NASA, to design a unique surgical garment. Under contract to Langley Research Center, the firm developed a suit for use in research into metabolic rate variations under lunar-gravity conditions and a variety of physical activities. This background provided conceptual inputs to development of a positive-pressure suit for surgeons, of which prototypes are in use. The surgeon's suit involves a hood through which a forced air flow is introduced to circulate past the face and downward to be expelled into a laminar air flow below the operating table. The idea of using a laminar flow enclosure and a means of transporting the surgeon's exhaled breath away from the operating area originated in England. A noted British hip surgeon observed that dust from clothing, carrying bacteria from the surgeon's breath, easily settled in on the large tissue area exposed in hip surgery, causing an unacceptably high rate of infection. His solution to the problem was to set up a portable laminar flow enclosure about the operating table, and draw the surgeon's breath away from the area by a flexible suction hose. A California hip surgeon visited England to observe the advanced techniques developed by the British surgeon, and decided that the breath-removal problem would be better handled with a positive-pressure suit. He collaborated with the developers of the Langley metabolism-measuring suit in designing the new surgical suit. He has performed 240 hip operations using the suit and a laminar flow enclosure, and has not had a single instance of infection. In his judgment, these surgical arrangements mark a new definition of competent hip surgery, and the hospitals without the technology -- still experiencing an infection rate of 7-8 percent -- must soon adopt it.

Control Numbers

Tech Brief Number: None
NASA Center: Langley Research Center
PATT Case Number: 44073
TEF Number: 334
Date of Latest Information Used: September 3, 1970

MICROBIOLOGICAL VACUUM PROBE

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The recovery of microorganisms from surfaces has been studied by microbiologists since the early part of the century. During this period five basic methods have evolved for the microbiological examination of surfaces: the agar overlay method, the agar contact method, the swab-rinse method, the rinse method, and the agar-dip method. Each method has individual advantages and disadvantages, but all were designed for sampling relatively large populations of microorganisms on small to moderately sized surfaces.

The planetary quarantine requirement that space vehicles landing on planets designated as biological preserves be sterilized, has imposed a requirement for the sampling of large surface areas with small amounts of microbial contamination.

The settling strip method has been developed and used for estimating the viable contamination deposited on surfaces. With this method, sterile stainless steel strips are placed in the same environment as the surface, and after a determined period of environmental exposure, the strips are assayed for microbial contamination. The criticisms of this method are that it is indirect and inaccurate when the amount of microbial contamination is small.

The need for a microbiological surface sampling device, with the capability for sampling large areas that are lightly loaded with microorganisms, has been met by the invention of a vacuum probe sampler at Sandia Corporation under contract from NASA's Office of Space Science Applications. The results of this development by the Planetary Quarantine Group at Sandia were published by Sandia Corporation in the following reports: SC-RR-67-688, SC-RR-68-592, SC-RR-68-593. The group also published an article on the vacuum probe in Applied Microbiology, January 1969, pp. 164-168 (Journal for the American Society for Microbiology).

The vacuum probe is an instrument that utilizes airflow through an orifice to remove particles from surfaces and a membrane filter to capture these particles. This device has demonstrated the ability to repeatably remove in excess of 90 percent of the settled microbiological foci, which are in the micron size range or larger, from a smooth surface without harming the surface.

Becton, Dickinson Research Center (44301), in Raleigh, North Carolina, received a contract from Langley Research Center to convert the metal probe invented at Sandia to a plastic version and, later, another contract from Langley to improve the design of the plastic probe. The two contracts included the purchase, by NASA, of 1,000 plastic probes. Center director Dr. Briggs Phillips stated Becton, Dickinson has patents pending on the most advanced models. The company's marketing component anticipates that the food and drug industry will become a substantial market for the probe.

Control Numbers

Tech Brief Number: None
NASA Center: Langley Research Center
PATT Case Number: 44301
TEF Number: 346
Date of Latest Information Used: October 29, 1970

PHOTO-CELL INSPECTION METER

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In April 1966 a contamination monitor was proposed to detect possible contamination deposits on spacecraft surfaces during launch and booster-stage separations. The need for the instrument was indicated by the thermal design engineer of the AIMP-D satellite, when his analysis of an overheating battery failure suggested that contamination of the satellite may have occurred from the fourth-stage rocket. Contamination would alter the optical properties of the satellite's surface coating, causing increased effective solar absorptance and thermal emittance of the thermal control surfaces. The successor satellite AIMP-E was redesigned to compensate for the problem, and a monitoring instrument was attached for the flight of AIMP-E.

Robert Sheehy and Albert Bush of Goddard Space Flight Center developed the monitor using light bulb performance data from a manufacturer's catalog, and a continuous intensive testing program. The monitor, described in Tech Brief 68-10089, projects light from a tungsten lamp through a collimating lens onto the sample surface. The light is reflected from the sample surface through a second lens that focuses the image on a two-millimeter silicon sensor cell. The sensor cell output is proportional to the output signal from the light source, and is compared with the signal from another sensor mounted in the lamp housing to provide an internal calibration standard. Changes in the monitor output signal are proportional to changes in the optical absorption characteristics of the sample surface.

Hermaseal Company (23829), a mercury switch manufacturer in Elkhart, Indiana, has used the basic ideas underlying the NASA monitor to construct a monitor for determining cleanliness standards for production quality control. The firm's test machine was built at a cost of $75 and has reduced inspection time by 60 percent, accounting for annual savings of about $1,000.

<u>Control Numbers</u>

Tech Brief Number:	68-10089
NASA Center:	Goddard Space Flight Center
PATT Case Number:	23829
TEF Number:	25

Date of Latest Information Used: September 16, 1969

FILTER ELIMINATES GASES AND CONTAMINATION FROM WATER

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The stringent weight requirements for manned spacecraft have forced the development of recycling technology. A typical recycling problem occurred with fuel cells used in spacecraft. The "waste" from fuel cell operation is water containing hydrogen gas. The water and hydrogen must be reused separately and this requires a separation process from which both parts are recoverable.

Trans World Airlines, Inc., under contract to Kennedy Space Center, has designed a simple and inexpensive filter that solves this problem. The device will handle pressures up to 100 $lb/in.^2$ at temperatures up to 121°C; depends in no way on gravity; gives absolute filtration, with automatic venting of freed gases; and prevents backward transmission of contamination. Other gas/fluid combinations may be separated by modifying the filter material. It will also filter bacterial contamination from water and prevent bacterial growth through the filter. Even viruses could be filtered.

Product manager J. M. Brammer of Health Science Industries, Inc. (44964) in Bellevue, Washington learned about this development in a Tech Brief from NASA. He believes that it will solve a problem of long standing for manufacturers of hemodialysis fluid delivery systems (including artificial kidneys), namely: deaeration of the fluid flowing to the patient.

The fluid, a dialysate solution, becomes aerated in the mixing processes and it will contain from one to four cc's of air per liter afterward. The air must be removed before the fluid enters the patient, and this has been done in the past by allowing it to stand still for a time under low pressure,which is inefficient and inadequate. The company is currently testing the filtration device and preliminary results are favorable.

Control Numbers

Tech Brief Number: 70-10456
NASA Center: Kennedy Space Center
PATT Case Number: 44964
TEF Number: 345
Date of Latest Information Used: November 5, 1970

FILTER FOR HIGH-PRESSURE GASES

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

During NASA's development of the Ranger, one of the contamination control problems that was solved concerned the filtration of high temperature, high-pressure (12, 500 psi) sterilizing gases. A small, simple filter was designed by W. F. MacGlashan at the Jet Propulsion Laboratory which could be placed on the gas supply tubing and yet be easily assembled and disassembled for cleaning. The filter cartridge is also suitable for chemical sterilizing gases. The design is such that the device would be suitable for use in other high-pressure tubing systems requiring a filter that can be readily taken apart.

Barclay and Associates (44956) in Port Chester, New York is conducting a process feasibility study for a major oil company,and a high-pressure gas filter will be required in the process. The filter developed at JPL is being considered for this use along with several other filters.

The Rogg Corporation (44957) in New Milford, Connecticut is a small manufacturer of precision components and actively seeks new products. The company applied to NASA for a commercial license to produce the filter after receiving a Tech Brief describing the technology. A license was granted in June of 1964. Since that time 50 filters have been produced, most of which have been sold or given away on a trial basis.

Mr. Rogg, owner of the company, said there has been no market for the filter. He has found this is due to its being an isolated item in their line of products. Rogg is presently expanding their line to include items related to the filter's use which should improve its marketability.

Control Numbers

Tech Brief Number:	63-10234
NASA Center:	Jet Propulsion Laboratory
PATT Case Numbers:	44956, 44957
TEF Number:	341

Date of Latest Information Used: October 30, 1970

PORTABLE TUBE CLEANING TOOL
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

In the design of any type of transportation system, safety and reliability are important considerations. In the design of manned space vehicles, these considerations are paramount. Long hours are spent engineering reliability into that equipment which is absolutely essential to the safety of the crew. This essential equipment includes the familiar retro-rockets which provide the deceleration thrust, and the reaction control system which enables the spacecraft to maintain the proper attitude during the firing of the retro-rockets. To insure that the reaction control system would function properly after the Gemini spacecraft has orbited around the earth for up to two weeks, not only were dual systems provided, but, in addition, all screw fittings in the reaction control system were eliminated and replaced by brazed connections to insure against leakage of the very corrosive hypergolic propellants used in the system. To prepare the tubing for a brazing operation which would produce a leakproof connection, special tools had to be devised because of the limited access and restricted working conditions. One of the implements created to perform this task is a portable cleaning tool

The portable cleaning tool comprises a hand-held device for cleaning or polishing the exterior of a tube or pipe end. The work engaging portion of the tool has an opening with a rotating abrasive member provided within, adapted to be positioned over the end of the member to be cleaned. Because the diameter of the rotating abrasive member is larger than the tubes which it will clean, the cleaning operation is accomplished by working the tool about so that the entire outside surface of the tube to be cleaned is brought into contact with the abrasive member. A vacuum suction arrangement removes the residue from the cleaning operation and also insures that none of the residue enters the tube being cleaned.

Upon receiving a waiver from NASA, McDonnell licensed the invention to the Aeroquip Corporation (44965) of Jackson, Michigan. Aeroquip produces auxiliary equipment for aerospace use, including a line of hardware to be used for induction brazing of metal tubing which now incorporates the cleaning tool. Although the brazing method costs twice as much as ordinary threading, the result is much safer and longer lasting. These factors are important in such applications as cryogenics, chemical refining, water desalinization, and nuclear reactor plumbing. The company is actively seeking a wider market for its system of brazing hardware in these areas of application. About 35 of the systems have been sold and brochures showing the system's advantages are currently being distributed to industry.

Control Numbers

Tech Brief Number: None
NASA Center: Manned Spacecraft Center
PATT Case Number: 44965
TEF Number: 344
Date of Latest Information Used: November 9, 1970

CONTAMINATION CONTROL HANDBOOK
TECHNOLOGY TRANSFER EXAMPLE SUMMARY

The reliability and precision demanded for manned space flight require extreme cleanliness in all stages of manufacture and assembly of components. Throughout industry, aerospace components are fabricated in "clean rooms" that are more sterile and clean than were hospital operating rooms of a few decades ago. In order to facilitate use of advanced contamination control methods in the many industries in which cleanliness is important, NASA's Office of Technology Utilization has issued three Special Publications dealing with the technology.

A widespread need for guideline information was met by the 1967 publication of Contamination Control Principles (SP-5045). A series of lectures for a Lewis Research Center course for clean room technicians and supervisors was published in Clean Room Technology (SP-5074). Finally, Contamination Control Handbook (SP-5076) was published in 1969, and publicized in Tech Brief 68-10392. Prepared for NASA by Sandia Laboratories, the handbook contains in one volume the information and data most likely to be useful to persons with industrial and other contamination control duties.

Among the topics treated in the handbook are an introductory description of different kinds of contamination and environments, followed by intensive examination of contamination control in product design, clean packaging, maintaining product cleanliness, and control of contamination of surfaces, gases, and liquids. Airborne contamination, microbial contamination, and radiation also receive thorough treatment. A glossary and abundant bibliographical citations complete the volume.

The handbook has stimulated a great deal of interest among electronics manufacturing firms, who have used it variously to improve production standards, establish clean room specifications and aid in designing new facilities, identify substitutes for contaminating solvents, and train clean room personnel. Specific, documented savings by the fourteen electronics firms interviewed have exceeded $60,000. Six chemical manufacturers report having used the document for similar purposes, and two have been able to develop new products through establishment of capabilities and techniques described in the book. An Air Force installation saves $20,000 annually through improved quality control methods; and a manufacturer of aerospace hydraulic mechanisms used the book to improve precision parts cleaning techniques and saved $20,000 per year.

Other organizations have used the handbook to improve quality control and production controls in bearing manufacturing; to establish industrial hygiene standards in copper refining which so far have led to savings of 100 man-hours per year; to devise effluent measures for producing pollution control equipment which produced savings totaling $2,500; to develop a new ceramics product by acquiring sophisticated quality control capabilities; to design, build, and increase sales by $50,000 of new clean room equipment; to develop photographic processing facilities at a state university; to improve contamination control in manufacturing computer hardware which has allowed the production rate to double; and to modify production technology in the manufacture of special-purpose dry cleaning equipment, which increased sales by $150,000 per year.

A standards handbook was formulated for the hydraulic power equipment industry, largely with information from the handbook. Service industries also are benefitting from use of the manual. A pathologist uses it to prepare articles and lectures for hospital personnel. He estimates that hospitals throughout the nation have saved $100,000 and 1,000 man-hours per year, in addition to enhancing patient care through use of the information. An insurance company uses the handbook to assist in evaluating claims, and has prepared an accident prevention booklet with some of the handbook information. The U.S. Department of Agriculture established several clean rooms to prevent microbiological contamination of materials in research to develop new protein-rich foods from cottonseed. A public health agency uses the handbook as a reference source in its supervision and certification of medical equipment manufacturers. A NASA Biomedical Applications Team used the handbook and other sources to assist a surgeon in preparing a proposal for installation of laminar flow ventilation and clean room techniques in a major university hospital's operating rooms. Open heart operations demand the most rigid observance of sterile techniques, and the clean room conditions are expected to contribute significantly to reduction of infection.

Control Numbers

Tech Brief Number:	68-10392
NASA Center:	Marshall Space Flight Center
PATT Case Numbers:	23044, 23188, 23944, 24098, 25330, 26258, 26614, 26764, 27506, 27830, 27837, 27847, 27850, 27857, 27858, 27862, 27878, 28008, 28147, 28149, 28246, 29174, 29226, 29236, 29250, 29742, 30506, 30612, 31286, 31324, 31368, 31762, 32236, 33050, 34100, 38142, 39662
TEF Number:	262

Date of Latest Information Used: October 27, 1970

HEALTH HAZARDS OF ULTRAFINE METAL AND METAL OXIDE POWDERS

TECHNOLOGY TRANSFER EXAMPLE SUMMARY

Special studies conducted for Lewis Research Center by a Massachusetts contractor facilitated establishment of guidelines for operations and handling fine powder materials. After several years' experience with the guidelines, no clinical signs of chemical toxicity have been found in any Lewis operating personnel. Because of this success and the belief that the studies would have value in many operations that generate potentially toxic fine dusts, a 1969 Tech Brief was published to announce availability of the information to the general public.

The documentation is based on a review of toxicological data in the literature; experimental studies dealing with electron microscopy, particle size, aerosol generation and sampling, and related matters; and an industrial hygiene survey of laboratory work areas. The results of these studies included specification of threshold limit values for exposure to ultrafine dusts, identification of the necessity of air monitoring for controlling dust levels, recommendations for control measures for all operations, an outline for a continuing industrial hygiene and surveillance program, and recommendations for future toxicological research.

Wright Industries (32560), a small manufacturing company in Brooklyn, New York, used the NASA document to evaluate its safety standards and concluded that its current practices were adequate for employee safety. Olin Mathieson Chemical Corporation (33328) in New Haven, Connecticut, has found the information useful for reference purposes.

Control Numbers

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NASA Center: Lewis Research Center
PATT Case Numbers: 32560, 33328
TEF Number: 323
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