(NASA-CR-152659) A STUDY OF NASA OCCUPATIONAL INJURIES AND PROPERTY DAMAGE AT GODDARD SPACE FLIGHT CENTER, LANGLEY RESEARCH CENTER AND HEADQUARTERS Technical (Weiner Associates, Inc., Lutherville, Md.)

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"A Study of NASA Occupational Injuries and Property Damage at Goddard Space Flight Center, Langley Research Center and Headquarters"

1971 - 1976

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EXECUTIVE SUMMARY, CONCLUSIONS & RECOMMENDATIONS

Background

The National Aeronautics and Space Administration under a continuous management improvement program for loss control directed Weiner Associates, Inc., under Contract NASW-2903, to examine the overall spectrum of safety and health accident/injury data presently in existence from three of its centers, GSFC, LRC and Headquarters, which were thought to be representative of the agency as a whole.

Objectives

The overall objective of this work was to analyze NASA's accident and injury history at these centers and to advise NASA on ways and means to upgrade its current loss control program to reduce, if possible, its personnel injury, accident rates and associated losses of equipment or facilities.

Conclusions

This study indicates that at Goddard Space Flight Center, Langley Research Center and Headquarters, safety programs are working well and that while the severity of lost-time injuries has increased at these centers, it has dropped over 50% for all of NASA in the last four years. GSFC and LRC severity levels are now of the same magnitude as that for all of NASA. In addition, non-aircraft/mission property damage of the type A & B class at these centers is well under control and those accidents of this type that do occur are the result of failure of supervisors to recognize significant hazardous situations. Type "I" incidents are not a major loss factor but are a major function of the level of prototype R&D carried out at each center. The rise in accident frequency seen at these centers during the last several years is not indicative of a failure of safety programs or a real increase in accidents, but rather the result of a change in the manner of evaluating and reporting accidents imposed by a change over from Z16.1 to OSHA formats. NASA administration of safety programs at the centers studied is in full compliance with the requirements of the 1970 Occupational Safety and Health Act and Executive Order 11807.

NASA, in comparison to other large R&D oriented government and non-government facilities, shows similar trends in accident frequency and severity. In addition, the absolute value of the histograms of these parameters is directly comparable to similar government and non-government organizations over the last five years. NASA in comparison to all government and industry has significantly lower frequency and severity rates and the trends of increase in occupation injury frequency are the result of the general momentum of government increases due to reporting format changes.

The major controllable NASA losses are tied to occupational injury lost-time and property damage due to fire. Although losses due to personal injury are declining, the Continuation of Pay program at NASA is a significant source of loss due to employee abuse and must be remodled and administered by each center to discourage such abuse. NASA employees average about two times as much lost-time per accident over the five most prevalent categories of injury as NASA support contractor personnel, although contractor personnel are exposed to the same or greater work environment risks. For those categories of injury which have the largest frequency of occurrence (back/legs/foot/ankle) and, hence, the highest statistical base, NASA employees average from 62% to 210% more lost-time per similar body part injured. These same categories of injury are associated with the type of body damage that depends a great deal on the patient's personal judgment rather than a strict medical judgment as to the time the patient is well enough to return to work.

All non-aircraft and non-mission failure fires of the type A & B at the NASA centers studied in this work, showed the same basic cause profile. They were fires involving large pieces of equipment or buildings that had no fire detection alarms or protection systems or if they did, these systems were inoperable at the time of the fire. This type of fire is caused by non-NASA workmen involved in minor repair work without the benefit of effective portable standby firefighting equipment, no fire prevention training and apparently ignorant of the potential disaster their work could cause.

Type "I" fires represent an extremely small element of NASA's total loss picture. Most of the type "I" fires at the facilities studied are by-products of the nature of the NASA center's basic business. Many of them are electrical in nature based on short circuits in facility lighting fixtures or in experimental bread-board type equipment that has not reached final design stages where fault-protection systems are naturally added. A second category of small fires is induced by equipment that has been overloaded or is aging. This is also a natural event in an R&D environment where equipment is exposed to unusual conditions that may tax design or to advanced aging from both environmental and extended cost-benefit exposure.

Very encouraging, however, is the observation that NASA Type "I" fires at the centers studied in this report have been well controlled by fire protection programs now in existence. Overall loss to NASA has been kept below $170.00 per average incident. Therefore, this type of fire is the natural noise level incident associated with the nature of NASA's basic R&D function or random mistakes in human judgment. Not much can be effectively done to eliminate them but a lot can be done to keep their magnitudes small by stringently adhering to present fire control and safety practice and upgrading personnel training, detection equipment and protection equipment with the latest technology.

The lack of any property losses from chemical explosions and pressure vessel failures at the NASA centers studied is a very significant factor in gauging the effectiveness of the Executive Safety Meeting technique of planning and implementing in-house safety programs. This technique should be expanded to those centers that do not now use it and an agency-wide Executive Safety Meeting should be held at least annually to evaluate, compare, implement and initiate overall NASA safety policy changes and resources.

Auto accident property damage is not a significant element in the NASA loss control picture although several traffic fatalities have occurred with NASA vehicles driven by contractor employees or involving civilians. These fatalities could not have been prevented through any particular safety policies or techniques.

Lost-time due to occupational injuries at all the NASA centers studied showed that "Acts of God" represented 66% at LRC and 48% at GSFC of the causal factors producing these injuries and that this type of incident has increased markedly (at least by a factor of two) in the last 2 years.

Lost-time occupational injuries attributed to "Unsafe Acts" on the part of the employee have dropped markedly at both GSFC and LRC in the past two years and represent 44% and 28%, respectively, of the total lost-time injury cause.

Lost-time occupational injuries attributed to "Unsafe Mechanical or Electrical" conditions are quite low at all centers studied and have been relatively constant for the last five years. At GSFC they represent 8% of the lost-time injuries and at LRC only 5.8%.

Therefore, the emphasis on reducing lost-time costs at the NASA centers studied must be focused in the future on those aspects of safety training, psychology and employee morale that will help the employee protect himself by recognizing potentially unsafe conditions and controlling his own on-the-job awareness, his behavior, and his work environment well enough to reduce human-failure type risks. Active recognition of particular types of "Act of God" and "Unsafe Behavior" accidents common to each center by that center's Health and Safety Office personnel and designing and implementing an effective training program for employees on this type of risk is a must for control of this type of loss.

Back injuries are the major cause of lost-time injury losses apparent over the last five years at the NASA centers studied. Accidents associated with an aging work force do not seem to be evident in the data reviewed for this study. It is the younger blue-collar worker that contributes most to lost-time. We found no relationship either statistical or causal between non-lost time and lost time injuries in the data sample available from LRC, GSFC or Headquarters. NASA's excellent loss record in non-mission failure industrial accidents can be attributed to the major technology and management transfer from the "Systems Safety" area of the aerospace "Mission Programs" directly into the OSHA area of facility operations.

Recommendations

1. Serious consideration should be given to an immediate study of the administration of Continuation of Pay policies at all NASA centers and the effects of Continuation of Pay abuse on total NASA lost-time costs should be undertaken. The results of this work should be used to develop a Continuation of Pay administration program to minimize employee abuse of Continuation of Pay without limiting justifiable claims. These programs should be tailored to each NASA center.
2. Wherever possible NASA should have a medical officer on-site at all centers and develop a joint "Medical-Safety Office" organization intimately familiar with the operational safety and health aspects of the center it serves.

9. Activate an independent safety/design review group at each center to support and critique NASA designed experiments and facility modifications in high risk situations. Have them report directly to NASA Center administrator through the Executive Safety Meeting organization.

I. INTRODUCTION

I. INTRODUCTION

Weiner Associates, acting as an independent contractor and evaluator for the NASA under contract NASW-2903, has undertaken and completed the following tasks in fulfilling the contract requirements of this study:

Specifically, Weiner Associates performed analysis of NASA's accident/injury/illness and health data by having:

1. Completed an on-site study of the existing data, cited above, at NASA Headquarters and two (2) NASA field installations; namely, Goddard Space Flight Center in Greenbelt, Maryland and Langley Research Center located in Hampton, Virginia. This on-site study included data from one (1) prime contractor at each of the designated NASA field centers. In conducting this study, Weiner Associates examined all available data, which included safety and health records, safety operations, and potential hazards at NASA Headquarters and the above NASA field centers, for the purpose of determining reported and unreported mishaps and/or losses in the areas required by the Occupational Safety and Health Act (OSHA) and NASA reporting systems.
2. Evaluated and analyzed the above study findings to develop criteria for the subsequent implementation of safety and health standards which will assist NASA in compliance with the Occupational Safety and Health Act (OSHA) of 1970 and Executive Order 11807.
3. Prepared a graphical loss control assessment of NASA efforts for the last three (3) years, in contrast to other governmental agencies and private organizations of a similar size and scope of operation, for the same duration of time.
4. Recommended means to reduce accident rates, and associated equipment losses, and improve the work environment and employee morale,

II APPROACH

by which the effectiveness of NASA safety, health and loss control efforts can be measured.

5. This work was completed during the period of July through December of 1976.

II. APPROACH

This study included five distinct tasks:

1. A compilation of available statistical data from NASA, government, and private sources and then, as required, revision* of these data according to a single reporting standard (OSHA).
2. An evaluation of these data, using autocorrelation**, to minimize the influence of random fluctuations on its general functional character. Autocorrelation is a modern analytical technique which is used extensively to process information.
3. A detailed survey of the in-depth reports of the accident and loss statistics gathered from the NASA facilities and NASA Contractors investigated.
4. Personal visits to and observations of the day-to-day workings and administration of the Safety and Health offices at the NASA centers investigated. This included discussions with the responsible safety officers on general and specific accident and loss situations at their facilities; sitting in as observers at the Executive Safety Meetings held at these facilities and in-depth discussions with the NASA contractor safety officers at LRC and GSFC.
5. Tests of certain key hypotheses through the use of personnel questionnaires to generate actual feedback on the attitudes and circumstances surrounding special lost time injuries.

Through the utilization of these five methods a picture of the accident and loss profile of the three NASA centers of interest has been generated which is based not only on a statistical treatment of available information but a real test of the hypotheses

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*Cf. Appendix B. Calculator program, Day-Count

**Cf. Appendix B. Calculator program, Autocorrelation

III OSHA of 1970
Exec. Order 11807

of the reasons for major loss items uncovered in this study. Our overall objective in this work was not to repeat statistical treatments of this data already available, but rather to look at it in a new way that would allow determination of significance and real cause trends of the losses reported.

III. THE OCCUPATIONAL SAFETY ACT OF 1970 AND EXECUTIVE ORDER 11807

The details of the Occupational Safety and Health Act of 1970 and Executive Order 11807 of 1974 are reproduced in Appendix A of this report.

Executive Order 11807 brought Federal workers under the same umbrella of occupational safety and health rules as workers in private industry. As such, the Federal government, and in particular each agency of the government, has been assigned certain specific responsibilities as to the creation, management and administration of the agency's occupational safety and health program consistent with the 1970 Occupational Safety and Health Act's provisions; establishment of an occupational safety and health management information system inclusive of detailed recordkeeping; establishment of procedures for the adoption of agency occupational safety and health standards consistent with the 1970 Act; provide adequate safety and health training for agency employees; preparation and submission to the Secretary of Labor of an annual report containing such information as the Secretary shall prescribe and to cooperate with and assist the Secretary of Labor in performance of his duties as well as observing the guidelines published by the Secretary pursuant to Section S of Executive Order 11807.

The framework and intent of Executive Order 11807 and the 1970 Act have been used as an evaluatory tool throughout this study in order to examine NASA compliance as called out in the contractual statement of work shown in Section I of this report.

IV NASA LOSS COMPARISONS

IV. NASA -- AGENCY-WIDE RELATIVE LOSS COMPARISONS

In order to put in proper perspective the significance of the injury frequency and severity data at LRC, GSFC and HQ, it was necessary to analyze the complete chronological loss profile from all sources of the entire agency from 1971 through 1975.

Table IV-1 below shows the chronological distribution of monetary losses for material, lost time and medical/death benefit compensation charge backs. Material losses are the sum of all fire, auto, aircraft and other mishaps at NASA centers. Mission failure costs and contractor losses are not included in these losses.

Table IV-1 Relative Loss Comparisons for All NASA Centers 1971-1975

Year	Total NASA Losses $\$x10^6$	Material Losses $\$x10^6$	Lost Time $\$x10^6$	Non-Aircraft Medical/Death Benefits $\$x10^6$
1971	6.92	5.9	.08	.94
1972	4.90	2.7	.93	1.27
1973	11.9	7.9	2.82	1.18
1974	3.0	.985	.223	1.80
1975	7.1	4.8	.180	2.12
Totals $\$x10^6$	33.82	22.29	4.23	7.31

Medical and death benefits are those costs charged against NASA as reimbursement to the Federal Employees Compensation Fund for payments made on account of work related injury or death of NASA employees or persons under the jurisdiction of NASA. Table IV-1 shows that about one-third of all NASA losses were associated with lost time and medical/death benefits while about two-thirds of the total NASA loss was tied to material losses.

Before a final comparison of these figures is attempted it is necessary to break down material losses into its component loss factors in order to identify the cost of those elements that are random catastrophies (i.e., auto accidents, aircraft crashes) that normal industrial safety programs have minimal influence on.

Table IV-2 below shows such a breakdown.

Table IV-2 Breakdown of NASA
Material Losses* 1971-1975

Year	$ x 10^6 Aircraft	x10^6$ Fire	$ x 10^6 All Auto	x10^6$ Other Material Losses	Totals
1971	2.0	.351	.010	3.6	5.9
1972	2.01	.133	.014	.540	2.7
1973	3.68	.18	.008	4.00***	7.9
1974	.148	.120	.018	.698	.985
1975	.092	4.0**	.019	.617	4.8
Totals	7.93	4.78	.069	9.524	22.3

* Does not include mission failure or contractor losses

** 1975 Small fire loss = $.827 x 10^6

1975 Major fire loss = $3.2 x 10^6

*** NASA contractor dropped payload

Therefore, based on Table IV-2, the material losses that can be considered as non-random and amenable to reduction from tighter administration of existing safety programs or the upgrading of these programs through better detection, training and equipment methods total about $14.3 x 10^6, or about 65% of the total for the six years evaluated in this study. This is about the same order of magnitude as the lost time and medical/death benefits portion ($11.54 x 10^6) of the total NASA loss spectrum over the years 1971-1975.

However, another important consideration must be injected into this evaluation before any conclusions are drawn as to loss significance of the total NASS loss profile. This consideration has to do with how real losses affect total NASA financial planning -- lost time and medical/death benefits are real costs that NASA must take out of its operating budgets and more important are costs that must be paid in the sense that they cannot be deferred.

Therefore, as lost time and industrial injuries grow, so do the costs NASA must pay to the Federal Employees Compensation Fund. These costs have more than doubled since 1971 while the overall NASA operating budget has dropped about 3% during this same period. Therefore, lost time and medical/death benefits are significantly affecting the available dollars that NASA has for its prime mission directives.

On the other hand, losses due to fire, explosion and material failures affect equipment, structures and/or facilities that may not have to be replaced immediately or, if they do, a capital cost outlay much smaller than real replacement costs could suffice to do the jobs (i.e., renting, relocating or borrowing from other NASA or Government activities). Certainly when a major piece of equipment such as a wind tunnel has a catastrophic failure in the middle of a priority program, the NASA Administrator must allocate reserves from other funds to repair the facility. However, this has been the exception, not the rule in the past.

Therefore, the significance of analyzing and reducing lost time and industrial injury losses represents a major factor in NASA loss control activities. In addition, the significance of losses from major fires and explosions at NASA facilities is also a key element in realizable overall loss control because of the potential for eliminating and/or controlling the magnitude of the loss through the application of new detection and firefighting technology and upgrading the administration of present safety programs.

V. THE DATA, SOURCES, REPORTING SYSTEMS AND PHILOSOPHY OF ANALYSIS

1. DATA USED AND SOURCES

The first source of data used extensively in this study came from the yearly summary documents completed by the NASA HQ Safety and Environmental Health Office between the years 1970 and 1975, as shown in Refs. 1-7. General injury and loss information is presented in these reports for all NASA facilities during the years listed and detailed summaries of both accident and property damage incidents are described.

Since the requirements of our contract focused in on just three of the NASA centers, LRC, GSFC and HQ, an in-depth survey of the accident and injury data at these centers was completed on-site. These surveys consisted of gathering all the Monthly Accident Experience Reports recorded on NASA form 344 for the years 1971 through the second quarter of 1976 for each facility.

These reports gave us the raw data necessary for the evaluation of lost time accidents, non-lost time accidents and property damage as a function of time, divisional elements of the facility, activity and number of employees. In-depth accident reports were reviewed for all the lost time and a representative sample of the non-lost time accidents at all three facilities. These reports were available from LRC, GSFC and HQ files as NASA Form 95 or the equivalent at each facility. Personnel records were reviewed in confidence by the NASA personnel offices at each facility, wherever cross-checks on lost time charges and medical histories were necessary for our study and the results transmitted to our technical staff in a non-personal way which complied with the "Privacy Act". The same technique was used in collecting data from the medical offices at these facilities.

Crosschecks of all NASA data generated internally were also made against the Quarterly OSHA reports submitted by NASA facilities directly to the U.S. Department of Labor DMDS-OSHA on 102F and 102FF forms.

NASA on-site contractor injury, accident and property damage information was also gathered primarily from the support contractors own quarterly OSHA 102 forms and personal interviews with the safety officers of each support contractor. These interviews were primarily geared to get overall perspective on the complete safety operations and programs of the support contractor in context to the actual facility and operations of that facility that the contractor was asked to fulfill. In addition, opinions as to the reasons for trends in accidents, various employee morale problems and the techniques of administration, management and judgments made as to cataloging various types of accidents in the reporting systems available to the support contractor were discussed.

In order to develop the data base necessary to make meaningful comparisons between changes in NASA accident injury and loss histories with those of the total Federal government and specific similar government and private organizations or segments of private industry, Weiner Associates researched, contacted and/or collected data from the following sources:

- The U.S. Department of Labor
- The National Safety Council
- The Department of Defense
- The Association of Aerospace Industries
- The U.S. Energy Research and Development Agency
- The American Society of Safety Engineers

Details of these data are shown in references 8 through 23.

Two other useful sources of information were used in completing or evaluating the results of this study. Observation of the workings of the Executive Safety Meetings at LRC and GSFC and the results of a special questionnaire circulated to LRC personnel who had major Continuation of Pay lost time claims. Details of both these sources are discussed in Section VI of this report.

2. REPORTING SYSTEMS

During the period 1972 through 1976 when the majority of the statistical data used for evaluation and comparisons in this study was generated, both the Federal government and private industry were making a major transition in their accident and injury reporting formats from the older ANSI Z16.1 formats to the new OSHA 102 and 101 forms of reporting industrial accident statistics.

The older Z16.1 standard established a uniform mechanism for recording occupational injuries and diseases and computing an incidence based upon employee exposure. It was designed to evaluate the progress in preventing accidents, injuries, and diseases in a given establishment or industry. The system is independent of workers compensation laws or the decisions of workers compensation agencies. The introduction of the standard states: "Thorough investigation of all factors relating to the occurrence of each reported injury is essential. Determination as to whether or not the injury should be considered a work injury under the provisions of this standard shall be based upon the evidence developed in such investigations." A work injury is defined as any injury or disease suffered by a person which arises out of and in the course of his employment.

If the definitions and procedures were followed objectively, it would be possible to compare the experience of different industries whether they were in the same state or different states with differing definitions of what constituted an injury.

However, it is doubtful that all injuries or diseases are investigated as thoroughly as the introduction suggests. Certain classes of injuries are treated as special cases. For example, inguinal hernias are recorded as work injuries only if they are precipitated by an impact,sudden effort, or severe strain and meet all three of these conditions.

Similarly, back injuries are recorded only if there is evidence of an accident or a task that could have produced the injury.

Another exception concerns injuries resulting from external events originating outside the employment, which are not recorded as work injuries. However, in many cases this type of injury is reported by the employee as a work-related injury and careful judgment by the Safety Office is required. Sometimes judgments are made that exclude the employee from a legitimate claim and sometimes the employee will prevail on an unjust claim.

From this it can be seen that the number of injuries that would be recorded for measurement purposes are inevitably going to be different than the correct number because of individual judgmental and extenuating factors made by the recording authorities.

Therefore, the government through OSHA developed a new recording system for reporting industrial and occupational injury data which had as its objective the elimination of the judgmental reporting factors that plagued the quality of the earlier ANSI Z16.1 reporting system.

Several basic factors had to be taken into consideration in this study that were effects of the change-over (from ANSI to OSHA) at NASA. They are:

- All NASA facilities did not change their reporting systems at the same time.
- The results of interpretation of total lost time from industrial accidents was inherently reduced by a factor of about 2/7ths between the ANSI and OSHA reporting systems because the ANSI system counted its total lost time inclusive of weekends while the OSHA system looks only at real lost work days.
- The literalness of the OSHA reporting system may have prompted the NASA safety officers at the facilities evaluated in this report to include accidents in their reports that would not have been considered under past Z16.1 systems. Weiner Associates, Inc.

did not question the judgment of the safety officer at each NASA facility relative to his classification, inclusion or non-inclusion of any individual accident reported by him. Rather, we reviewed the entire trends of such reported information and tried to make final judgment as to the significance of the data over the long term.

3. Accident Analysis Philosophy

There is a gap between the techniques used to evaluate the hazards of space missions and those used for large work operations. In this section we shall discuss how one can practically analyze the latter operations. The diversity of activity in these operations tends to preclude specific mathematical models. It can be argued that effort put into analysis might better be devoted to the business of detecting unsafe conditions and changing them. Nonetheless, some numerical records are kept mainly to determine the effectiveness of the continuing investment which most organizations make to maintain safe operations.

The contention that statistics lie is rarely true. The count of, e.g., number of injuries or number of lost work days, is usually very accurate. The problem with statistics usually has to do with their meaning, not only quantatively but also in a qualitative sense. To illustrate the latter aspect, good safety policy requires that minor accidents be reported because there may be some clues, in these accidents, to unknown hazards. Assume within a given operation such a policy was suddenly implemented. Obviously, the injury count would also increase. Quantative difficulty with accident statistics follows from the random timing of accidents. Here, to accurately calculate the frequency of accidents, the time interval must be large enough for the randomness to truly average out. The National Safety Council uses a three-year time interval to determine annual reference rates for entire industries. There are analytic techniques which can lend some quantitative meaning t accident data. Qualitatively, simply taking a probablistic view can provide insight into cause and effect relationships.

Any given accident is a physical event. It was caused by a set of physical conditions. If the event happened, the probability of its occurrence was one. Physical conditions are not all static, of course; some exist only momentarily as the consequence of some human act.

Essentially the same physical conditions may exist for protracted periods of time without the occurrence of an accident. This common observation has given rise to a probablistic view of accidents. Whether this view is of much use in identifying a particular set of unsafe conditions may be argued. An accident is usually a more complicated process than the definitions of accident probability terms simply imply. Be that as it may, the following terms which are in common use, represent useful concepts:

Hazard is a condition with the potential of causing an adverse effect, e.g., an injury. It is a possibility with units of number (fraction) per unit time or act.

Example:

$$H = 0.02 \text{ injuries/man hour}$$

Danger is exposure to a hazard. The units of danger may be a period of time or an act. Danger is the antonym of safety.

Example:

$$E = 2.5 \text{ man hours (of exposure)}$$

Accident Probability is the product of hazard and exposure to that hazard.

Example:

$$N = HE = (.02)(2.5) = 0.05 \text{ injuries}$$

Damage is the seriousness of an adverse effect. Damage is usually expressed in units which can be broadly applied.

Example:

$$\tau = 3.5 \text{ lost work days/injury or}$$
$$= \$450\text{/injury}$$

Risk is the product of the probability of an accident and the damage attending the accident.

Example:

$$R = N\tau = HE\tau = (.05)(3.5) = 0.175 \text{ lost work days or}$$
$$= (.05)(450) = \$22.50$$

Benefit is the favorable effect of an activity or an act. Presumably it represents the reason for the activity (or act). It is sometimes difficult to quantify, is usually expressed in economic units.

Example:

$$B = \$6000$$

Risk-Benefit is a quotient, risk divided by benefit, nominally dimensionless. Very low values are, of course, desirable.

Example:

$$R/B = \$22.50/\$6000 = 3.75 \times 10^{-3}$$

Probable events and observed events, of course, have the same physical dimensions. Thus, corresponding to an accident probability of 0.05 injuries, there may be a normalized number of 0.05 observed injuries. Note, that if a risk is realized it becomes a loss. In that instance, we shall replace the symbol R with the symbol L.

Socially, the acceptability of a risk depends on the risk-benefit quotient. The use of matches is a good example. There is a very small but finite probability, virtually every time a match is struck, that the head will fragment and that a fragment will hit the user in the eye (if the user does not wear glasses). The general feeling is that the benefit of this convenient and inexpensive means of starting fires outweighs the risk.

With regard to the individual, it has been said that every man is a safety expert. This is a true statement. We all continuously face risk-benefit situations and, in general, do a remarkably good job of handling them. People, consciously or unconsciously, take risks in inverse proportion to their preconception of the risk. When a willful act has contributed to an accident, there frequently was a faulty preconception of risk. The office worker who hurts his back while moving his file cabinet is an example.

Regarding accidents which may involve bodily injury, the usual unit of danger (exposure) is simply a willful act. In these situations, the risks may be classified as follows:

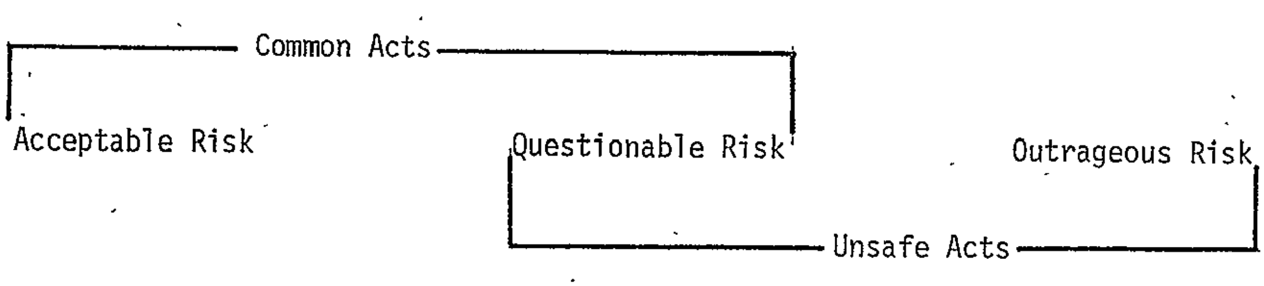

Fig. V-1 Risk and Exposure Classification

An example of acceptable risk is setting and hammering nails. Here the accident probability (chance) is low and the damage (consequence of the accident) is low. An example of a questionable risk is jerking on a wench handle in tight quarters. Here the accident probability is high, but the damage is usually low. The wench jerker in this example, in effect or in actuality, makes a risk-benefit judgment. An example of an outrageous risk is working in a high place without safety lines. Here the accident probability is generally classed as high and the damage is certainly high.

Acceptable risks, then, relate low probability and low damage and outrageous risks relate high probability and high damage. Questionable risks involve judgment because although one of the parameters is low the other one is high. (The probability of an accident is, of course, frequently a function of skill.)

It is possible to calculate the probability of an accident from scratch, starting with such basic things as the uncertainties in the structure of matter. Hazard calculations of this sort are made for nuclear reactors. For more ordinary accident situations, one must start with the record of prior accidents, i.e., the number of events.

With regard to work accidents which involve bodily injury, the usual measure of accidental damage is the injury period in number of lost work days. The injury statistics for a given work activity reflect the nature of the risk situations associated with that activity. That is, if the number of injuries is large enough to have statistical meaning. Thus, if the injury periods are short, the accidents associated with that activity probably involve, mainly, the taking of acceptable risks. If, in some entirely different work activity, the number of injuries per worker is high, even though the injury periods are short, then it appears that these workers are taking questionable risks.

A work operation which is large enough to generate meaningful statistics usually comprises a number of diverse activities. Particular activities do not usually stand out in the injury statistics. Nonetheless, it should be borne in mind that the nature of the risk associated with each activity is frequently unique (and may be acceptable). The hazards in the chemistry laboratory are independent of the hazards in the machine shop are independent of the hazards in the foundry, etc. Workers are generally localized relative to hazards, supervision, etc.

Consider a hypothetical example: a work operation involves just three activities; hammering nails, loosening nuts in tight places, and washing windows on high buildings. The consequences of accidents are, respectively; banged fingers, broken elbows, and "busted backs". The management of the work operation is devoid of safety consciousness, so the respective hazard values are fixed. Although the number of workers engaged in each activity is the same, they take chances according to their perception of risk. Hence, nail hammerers are injured more frequently than wrench jerkers and wrench jerkers are injured more frequently than window washers. Injury histograms appear as follows:

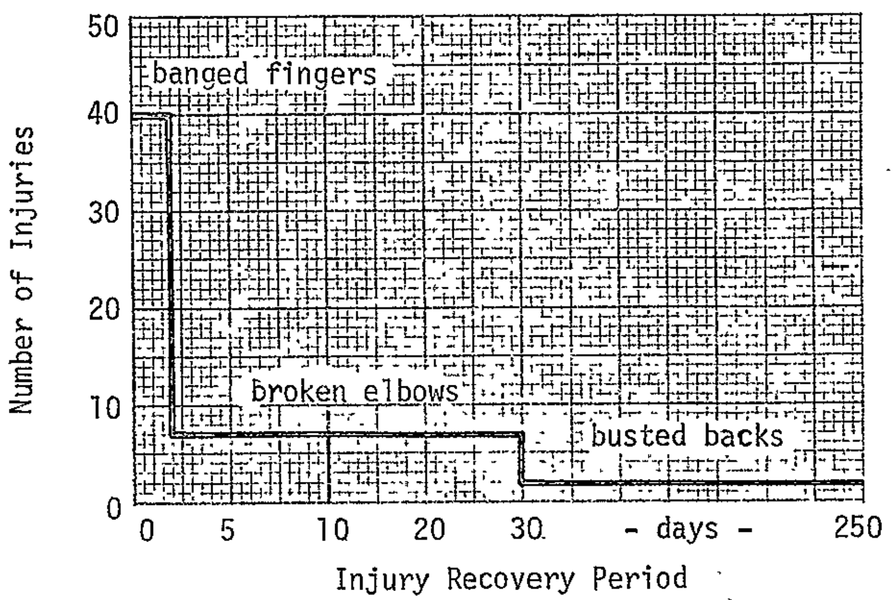

Fig. V-2. Hypothetical Injury Histogram

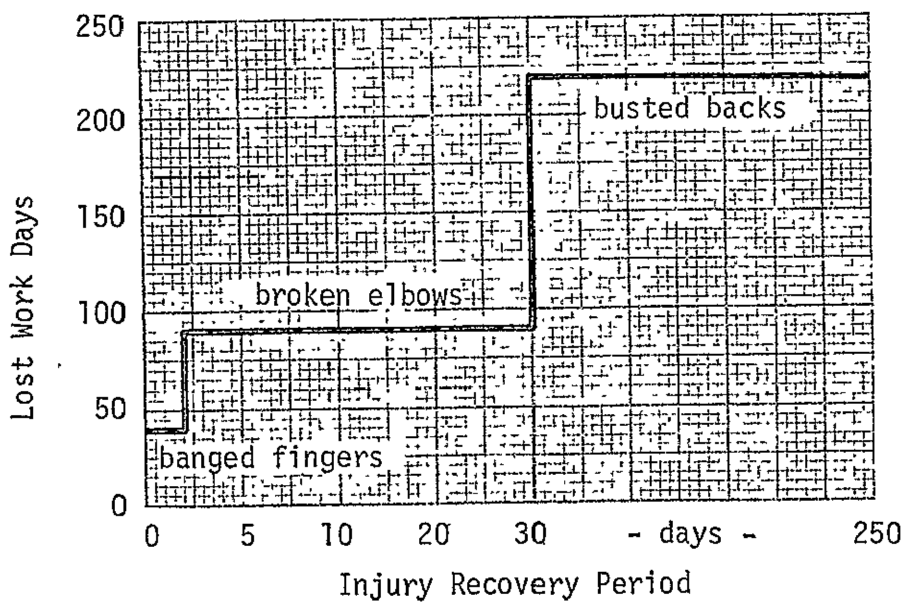

Fig. V-3. Hypothetical Loss Histogram

In this example, since the hazard values are fixed, the injury density is an exact measure of the productivity of the operation. If the number of injuries declines, the time that the workers are exposing themselves to work must also be declining. The objective of the management of this operation is, of course, net benefit, which is production minus loss. Looking at the functions, it appears that eliminating broken elbows and busted backs would cut lost work days markedly. It may also be noted that such a reduction in loss would not change the total number of injuries much. Conversely, reducing the number of banged fingers would not change the total number of lost work days much.

In actuality, of course, safety considerations are very much a part of most work operations and large operations have active safety programs. Managements are not solely motivated by net benefit. Exposing an employee to hazards which can cause him serious damage is considered immoral and is illegal relative to OSHA requirements. Be that as it may, the overall characteristics of the hypothetical example are fairly universal.

The fact that there is a class of risks generally held to be acceptable does not mean, in most instances, that these risks cannot be minimized without an undue effect on the associated benefits. Worker care and skill can reduce both danger and hazard. Of course, entirely apart from the worker, hazards can be reduced and eliminated.

As is common practice, we shall refer to the integral of a density function as a distribution function. Sometimes one function seems to carry more meaning than the other. At any rate, if, as has been stated, workers take chances according to their perception of risk (or any of the other probability terms), mathematical models for the injury and loss distributions (or densities) can be readily formulated. Unfortunately, these models do not correlate with the observed distributions very well, probably because hazards and workers are localized in unequal proportions. For large organizations engaged in diverse work activities, the observed injury distributuion appears more or less as a straight line on a semilog grid. We shall take this line as the reference injury distribution. It is qualitatively plausible and has the advantage of being mathematically simple. Fig V-4 shows the injury number distribution for 1973 for NASA Langley Research Center.

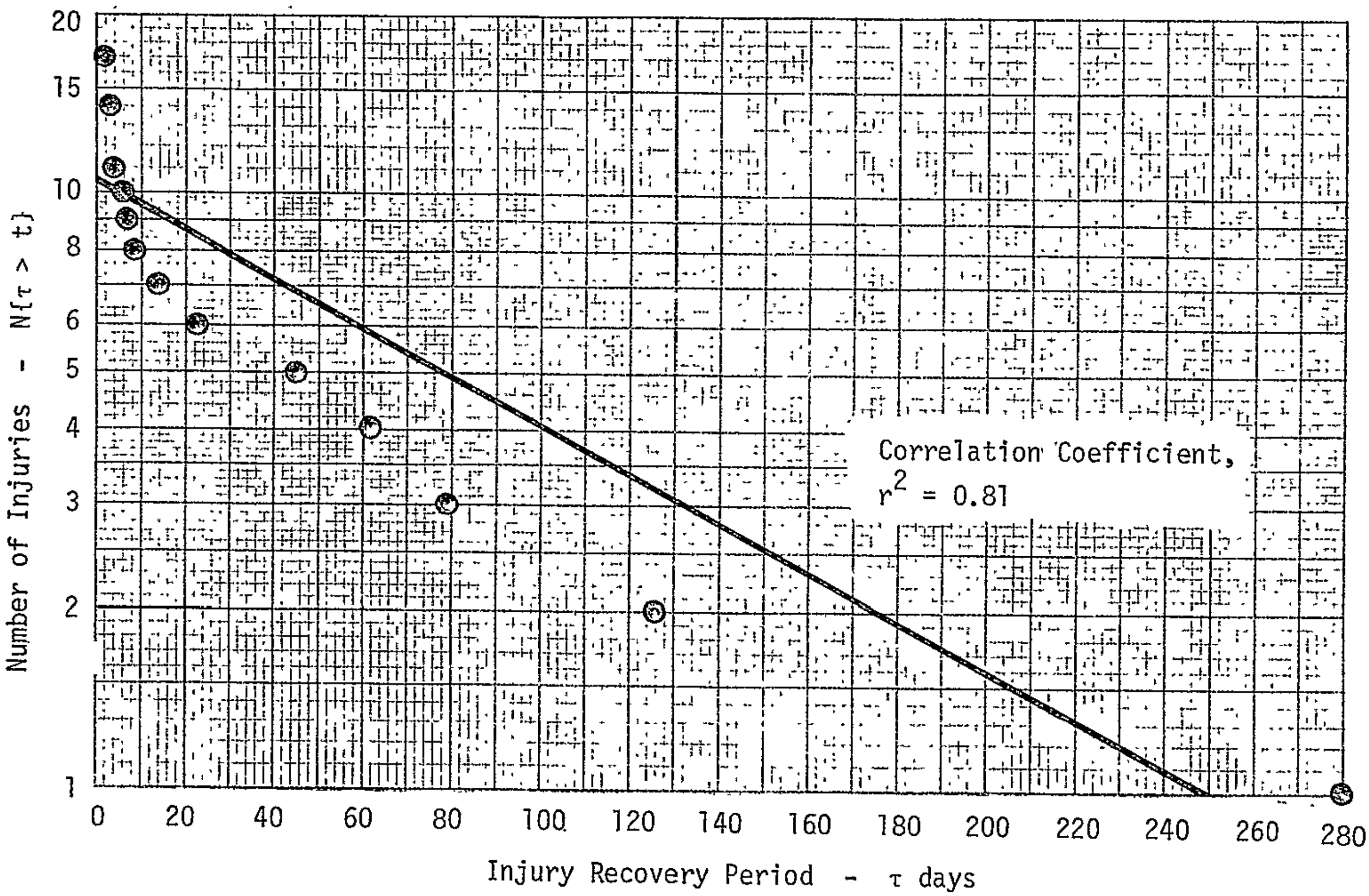

Fig. V-4. 1973 Langley Injury Distribution

Superimposed on the observed data is the reference distribution line, which was located by the method of least squares. In the process of fitting the line to the data, injury periods of one day or less were not considered. A datum point corresponding to non-lost-time injuries would be above the upper margin of the graph. Near-misses and short-term injuries appear to comprise a separate accident category.

The equation for the reference distribution of number of injuries as a function of injury period is

$$N\{\tau > t\} = N_0 e^{-t/A}; \qquad (1)$$

the number of injuries N having injury periods τ, equal or greater than some interval t, is a function of two parameters, N_0, the total number of injuries, and A, a characteristic of the work situation. If we weight each injury in equation (1) by the injury period, we obtain the distribution of injury lost-time as a function of injury period,

$$L\{\tau > t\} = N_0 (t + A) e^{-t/A}, \qquad (2)$$

the injury lost-time L associated with injuries having injury periods τ, equal or greater than some interval of time t. Note that when we consider all injury periods, i.e., when $t = 0$, the total injury lost-time equals N_oA. Thus,

$$A = \frac{L_o}{N_o}. \qquad (3)$$

The parameter A is, therefore, the mean injury period.

There are, of course, density functions for the distributions given in equations (1) and (2). The density function for injury lost-time has a maximum. This maximum represents the injury period which has the greatest differential impact, in terms of lost time, to the work operation as a whole. It also gives some additional meaning to the parameter A, since the maximum is located at

$$t_{max} = A \qquad (4)$$

If we divide L by L_o and equate the quotient to one-half, we can determine the injury period which cuts injury lost-time in half. It turns out that for this condition

$$t_{1/2} = 1.678A. \qquad (5)$$

As an example, consider the safety record at Langley in 1973:

N_o = 21 Injuries
L_o = 925 man days
A = 44 days

t_{max} = 44 days
$t_{1/2}$ = 74 days

$N(t_{max})$ = 7.7 injuries
$N(t_{1/2})$ = 3.9 injuries

About four employees accounted for half of the lost-time. A mean injury period of 44 days is relatively high.

The general proposition is that some faction of all accidents which occur are the result of taking acceptable risks. As the injury period approaches zero, the fraction becomes very large. When the injury is long, the fraction tends to be small, but not necessarily zero. The person who slips in an icy parking lot and breaks a hip has taken what is considered an acceptable risk, dangerous as walking on ice may be.

In recent years, safety work is commonly referred to as loss control. It is evident from both the hypothetical and from the Langley examples, that the loss from injuries comes mainly from the severe cases. As we shall see in the statistics section, VI, most of these accidents resulted from unsafe acts, the taking of risks which are generally held to be unacceptable. Actually, or effectively, the victim usually had a faulty preconception of the hazard. Generally, these accidents had little in common with those producing minor injuries where the risk taken was controlled and the physical consequence was limited.

4. Autocorrelation

There is a classic reliability anecdote about a new design for a fuse where the probability of malfunction had been precalculated as two per 100,000 fuses. The first fuse tested failed. The intent of the anecdote is to illustrate there is no preferred sequence for random events. With regard to accidents, if the physical conditions are essentially constant, when an accident occurs, is a matter of chance. Statistics, in general, frequently display major fluxuations which we cannot ascribe to basic changes in physical conditions. This characteristic is evident in the economy, in the climate, and in accident records.

The mathematical technique for removing random fluxuations from a time series, such as an accident record, is called autocorrelation. In the sections which follow most of the data has been autocorrelated. In most instances, the original data, un-autocorrelated, are also presented on the same graph or in an accompanying table. These autocorrelations are conservative in the sense that integrals of un-autocorrelated and autocorrelated data over a given period of time are equal. The term image is applied to any data which has been processed mathematically.

VI ON-SITE INVESTIGATION

VI. ON-SITE INVESTIGATION

1. NATURE OF FACILITIES

1.1 LANGLEY RESEARCH CENTER

General Discription

The NASA Langley Research Center is the oldest of NASA's laboratories and has been in continuous operation for almost 50 years. Its present compliment of scientists, engineers, technicians, workers and administrative personnel numbers approximately 3,400 employees. Present activities at LRC encompass the following operations:

- Basic Flight Research Programs such as
  - Flight Test Operations
  - Flight Dynamics and Control
  - Flight Instrumentations
  - Aeronautical Systems
  - Flight Research
- Basic Aeronautical and Space Research
  - Subsonic and Transonic Aerodynamics
  - High Speed Aerodynamics
  - Research Facility Engineering
  - Space Systems
  - Space Applications and Technology
- Special Projects Management
  - Viking Projects Group
  - Flight Projects Group
- Basic Support Research
  - Structures and Dynamics
  - Systems Engineering
  - Plant and Facilities Engineering
  - Etc.

This facility can be classified as a major aerospace systems facility. It is equipped to carry out complex fabrication and testing jobs of any magnitude on aerospace systems from models to full scale. Its wind tunnel operations and facilities are extensive and require the full gambit of heavy equipment and rigging support.

Its shops, hangar facilities, test chambers and physical plant are reminiscent of a heavy duty manufacturing and large aerospace test range environment.

General Observations

Langley augments its in-house safety programs through the use of --

a) A detailed monthly accident, injury and significant incident reporting system wherein all accidents of any nature are required to be reported and documented in sufficient detail to determine the cause of the accident, the nature of the injury, the time, place and activity in progress, the person involved, the nature and extent of any property damage, the extent of any required medical treatment and the amount of lost-time, if any, during the reporting period.

Personal injury reports that generate lost-time beyond one day are tracked by the Langley Safety Office on a month to month basis and carried through on each successive monthly NASA form 344 so that all lost time per individual accident can be summarized on an annual basis.

In addition, a separate quarterly OSHA form 102 is prepared for the entire facility from the internal monthly NASA 344's and sent to the Department of Labor.

b) A full time professional safety staff whose duties consist of:

- Evaluating, administrating and enforcing NASA safety standards and procedures on-site.
- Investigating and reporting on all Type A/Type B Accidents and Incidents and Mission Failure accidents with emphasis on cause, effect, and remedial action.
- Conducting overall safety training of LRC personnel and upgrading the general safety awareness of the work force.
- Overall emergency and disaster planning for the total LRC facility including on the scene administration of the event.
- Specification, procurement, installation and maintenance of general safety equipment, hazard detection, control and communications equipment and the operation of a complete firefighting and security force.

c) Administration and participation in a detailed hazards and potential hazards feedback loop through the mechanism of the monthly Executive Safety Meeting.

This most effective management tool brings together middle management personnel representing each major working element of the LRC complex with the Health & Safety Office and LRC Director's office management to discuss in detail progress on all in-house safety and security programs, emergency plans, and the reconstruction and critique of all on-site Type A/B accidents and incidents that occurred during the period.

Candid discussion of accidents, their cause, costs and effective remedial action is undertaken. Detailed technical reports, films and in some cases, complete reconstructions of the incident, are developed and detailed plans for elimination of the hazard or protection from future similar incidents are formulated. Follow-up on past recommendation and corrective actions of the Executive Safety Meeting are investigated and updated.

The concept of the Executive Safety Meeting is an effective and important tool in maintaining the quality of LRC's on-site safety activities.

1.2 GODDARD SPACE FLIGHT CENTER

General Discription

1.3 GODDARD SPACE FLIGHT LABORATORIES

The NASA Goddard Space Flight Lab is a modern research and operations center for the development, assembly, environmental testing and tracking, operational control and data collection of near-space civilian spacecraft. Its present compliment of scientists, engineers, technicians, workers and administrative personnel numbers approximately 3900 employees.

The general nature of the work at Goddard, while heavily research oriented, is not of the same nature as Langley. GSFC does not have the heavy industrial capability that LRC does. Its major fabrication programs are carried out by private contractors off-site and assembly of the space frame and attendant electronics are carried out by the contractor at GSFC.

Significant environmental testing is done, however, at GSFC including full scale spacecraft systems check-out in a large vacuum chamber, structural, vibration, electro-mechanical/electronic performance and qualification testing.

In addition to these activities, major long range mission planning and systems design as well as subsystem mock-ups are provided and tested. Sounding rocket programs are carried out in conjunction with launch facilities in the U.S. and abroad.

Finally, major tracking and computer control and data collection operations are administered by GSFC through their world wide network of tracking stations and ships. Data is processed at GSFC for the U.S. Weather Service as well as other scientific and defense oriented agencies of the U.S. Government, foreign governments and in some cases, commercial organizations. GSFC can be categorized as a light manufacturing assembly and softwear operation heavy in scientific research and systems testing.

General Observations

In general, GSFC augments its overall in-house safety programs through the use of the same administrative and operational tools as LRC. However, monthly accident and injury data is not published in the same manner as LRC although CA-1 and CA-2 forms are used. Quarterly OSHA reports are submitted to the U.S. Department of Labor and a formal annual report "GSFC Accident/Injury Summary" is published by the GSFC Office of Health and Safety which details, in depth, a complete analysis of all accident/injury information at the center as well as all causes, remedial actions and results of in-house activities to reduce and control Types A/B accident and incidents.

The activities of the GSFC Office of Health and Safety are similar to those detailed for LRC and the administrative mechanism of the Executive Safety Meeting is a major source of feedback and self-corrective activity at the center.

1.3 NASA HEADQUARTERS

General Description

The NASA Headquarters in Washington, D.C. can be categorized as a typical corporate headquarters operation. It is strictly involved in program management, computer operations, administrative guidance of the NASA centers around the country, budget control and liaison with other elements of the Federal Government as well as the private sector. Its present compliment of administrative and scientific personnel numbers approximately 1700. Its basic product is planning, paper, financial control and warehousing.

General Observations

In general, NASA Headquarters augments its overall in-house safety programs ghrough the efforts of a single, part-time safety officer. Because of the nature of the work done at Headquarters, major industrial accidents and injuries do not occur.

Headquarters does report its injuries on CA-1 and CA-2 type forms and complies with the record keeping requirements of Executive Order 1108 through quarterly OSHA 102 form submissions to the Department of Labor.

Headquarters does not use the mechanism of the Executive Safety Meeting to implement in-house safety programs.

2. RECORD OF EMPLOYEE INJURIES

2.1 ANALYTICAL APPROACH

In the safety arts, there are established ways of presenting injury statistics. These ways have some shortcomings of which we should be aware. The injury record is, in general, comprised of a pair of numbers. There are actually two such number pairs in common use, a raw data pair and a parameter pair. The raw data pair takes the form,

$$(N,L),$$

where N is the number of injuries and L is the time lost from work as a consequence of those injuries. The number of injuries is taken for a given time interval. The parameter pair takes the form,

$$(F,S),$$

where F is the injury frequency, the number of injuries per 200,000 man-hours worked during the given time interval and S is the injury severity, the time lost per 200,000 man-hours worked during the given time interval (OSHA definition).

Either pair of numbers can present some difficulty. Consider the raw data pair. The time lost from a given injury can readily extend beyond the time interval which one wants to consider. It may be a long time after the given time interval before the time lost as a consequence of the injuries occurring in that time interval is known. Calculation of the parameter pair ignores this problem since the data simply reflects the given time interval, but it must be borne in mind, that in terms of cause, the severity parameter does not necessarily correspond to the frequency parameter. That is, the injuries, which gave rise to the frequency in a given time interval, may appear in the severity in later time intervals. Serious injuries, which usually account for most of the lost time, run on and on. Moreover, the scaling which is done on the basis of time-worked in the current time interval may be misleading if the injury occurred at an earlier time interval when the time-worked was different.

Probably the greatest difficulty in the evaluation of a safety record comes about from the random nature of accidents. Within some fairly long period of time, the physical conditions attending an accident and employee exposure to these conditions is more-or-less constant -- or the probability of the physical conditions occurring and the probability of employee exposure is more-or-less constant. Hence, when an accident occurs, in a broad sense, is a matter of chance.

The safety records of most organizations show a great deal of fluctuation and the shorter the time intervals considered the more pronounced is the effect. Does an apparent increase or decrease in either of the number pairs, or one member of a number, represent a real change or is it simply a random fluctuation, is a common question; and, with regard to the severity parameter, how much of it represents carry-over from a prior injury.

For the study of the NASA injury records we have elected to use a third number pair,

$$(N_0, A),$$

where N_0 is the number of lost time injuries where the lost-time from each injury exceeds one day and where A is the total lost-time, L_0, from those injuries divided by N_0,

$$A = \frac{L_0}{N_0} .$$

The number of employees during the overall period of the study was nearly constant so that use of frequency and severity would be superflous. The one-day lost-time injuries have been omitted because they becloud the record. They frequently simply represent time required for diagnosis. Their contribution to the total lost time is usually small. The term "A" we believe is somewhat more meaningful than total lost-time; it not only indicates how serious the injuries have been, it also is the maximum of the hypothetical loss density function. In terms of loss, it indicates what really matters.

A study performed some time after the injuries have occurred, of course, has the advantage that the lost-time from serious injuries can be readily added up. To assure that the means of determination of lost-time for each injury was consistent, we have used the initial date(s) of absence from work and the date(s) of return to work in a perpetual calendar calculator program. The program calculates the number of working days missed due to the injury. The program simply assumes Monday through Friday are working days. The number L_0 contains some error because the employee may have had other working days and because it ignores holidays. Each of the accident reports was reviewed and a factor triplet,

$$(G_1, G_2, G_3),$$

was assigned to the accident, where the G's represent the cause of the accident. G_1 represents improper behavior, i.e., unsafe act, G_2 represents improper environment, i.e., unsafe mechanical conditions, and G_3 represents other cause, i.e., acts of God. The sum of the three factors equals one. Thus, the triplet (.2, .3, .5) represents a subjective judgment that an unsafe act contributed 20 per cent to the cause of an accident, unsafe conditions contributed 30 per cent to the cause of the accident, and 50 per cent of the cause was unassignable. Consider the accident where a man bends over to pick up a paperclip from the floor and as a consequence of the act suffers a serious back injury. Moreover, there is no prior history of back trouble. The representative triplet is (0, 0, 1).

Average values have been taken as the factors in the triplet for an organization on some time interval. Thus, the triplet (.36, .07, .57) represents an organization where 57 per cent of the accidents appear to be acts of God.

The injury statistics which we have developed for NASA are, then, comprised of the pair (N_0, A) and the triplet (G_1, G_2, G_3). We have taken these data for half-year intervals, starting with the first half of 1971 and ending with the first half of 1976. These data have been processed with an autocorrelation program to remove the characteristic fluctuations. The criterion used to select the value of the autocorrelation coefficient, α, was that the image, i.e., the product of the autocorrelation, should not show a significant component corresponding to the sampling frequency of two times per year. The value of α turned out to be 2 half-year intervals, 1 year. (This is a minimum rounded value for α. In the limit, as α becomes very large, the image becomes essentially constant -- the mean value of the data on the range.) Symbols capped with a wave vinculum represent autocorrelated data. Thus we have the injury statistics,

$$(\tilde{N}_0, \tilde{A}) \text{ and } (\tilde{G}_1, \tilde{G}_2, \tilde{G}_3).$$

2.2 STATISTICAL RESULTS

Injury data pairs and triplets have been prepared for Goddard Space Flight Center and Langley Research Center. The employee injury data from NASA Headquarters is too thin for much statistical treatment. It should be borne in mind that statistics do not explain themselves. The objective of statistical study is to show what is analytically meaningful. The physical explanation of things is usually a matter of logical inference.

Figures VI-1 through VI-4 which follow present images of the injury data pair (N_0, A), the number of lost-time injuries and the mean lost-time period.

Fig. VI-1 and Fig. VI-2 show both histographic N_0 and autocorrelation images $\tilde{N}_0$ of the number of lost-time injuries. For Goddard, the autocorrelation image shows that the number rate declined from 1971 until the latter half of 1974. From that time through the first half of 1976, the number rate has increased. The increase at Goddard in the last year and a half has been 24 percent. For Langley, the autocorrelation image shows a very similar pattern with the minimum occurring in the

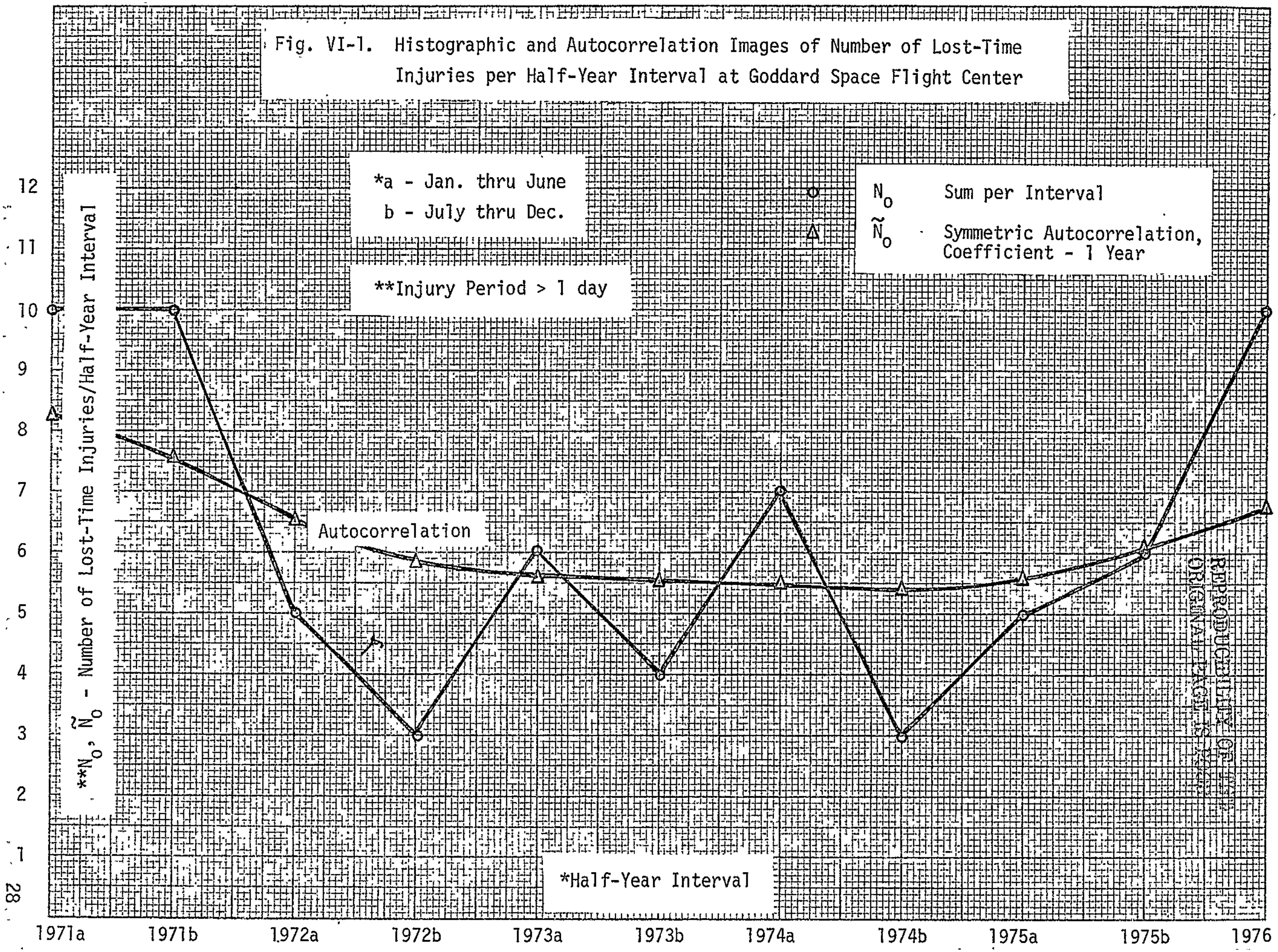
Fig. VI-1. Histographic and Autocorrelation Images of Number of Lost-Time Injuries per Half-Year Interval at Goddard Space Flight Center
*a - Jan. thru June
b - July thru Dec.
**Injury Period > 1 day
N0 Sum per Interval
Ñ0 Symmetric Autocorrelation, Coefficient - 1 Year
Autocorrelation
**N0, Ñ0 - Number of Lost-Time Injuries/Half-Year Interval
*Half-Year Interval
12
11
10
9
8
7
6
5
4
3
2
1
1971a
1971b
1972a
1972b
1973a
1973b
1974a
1974b
1975a
1975b
1976
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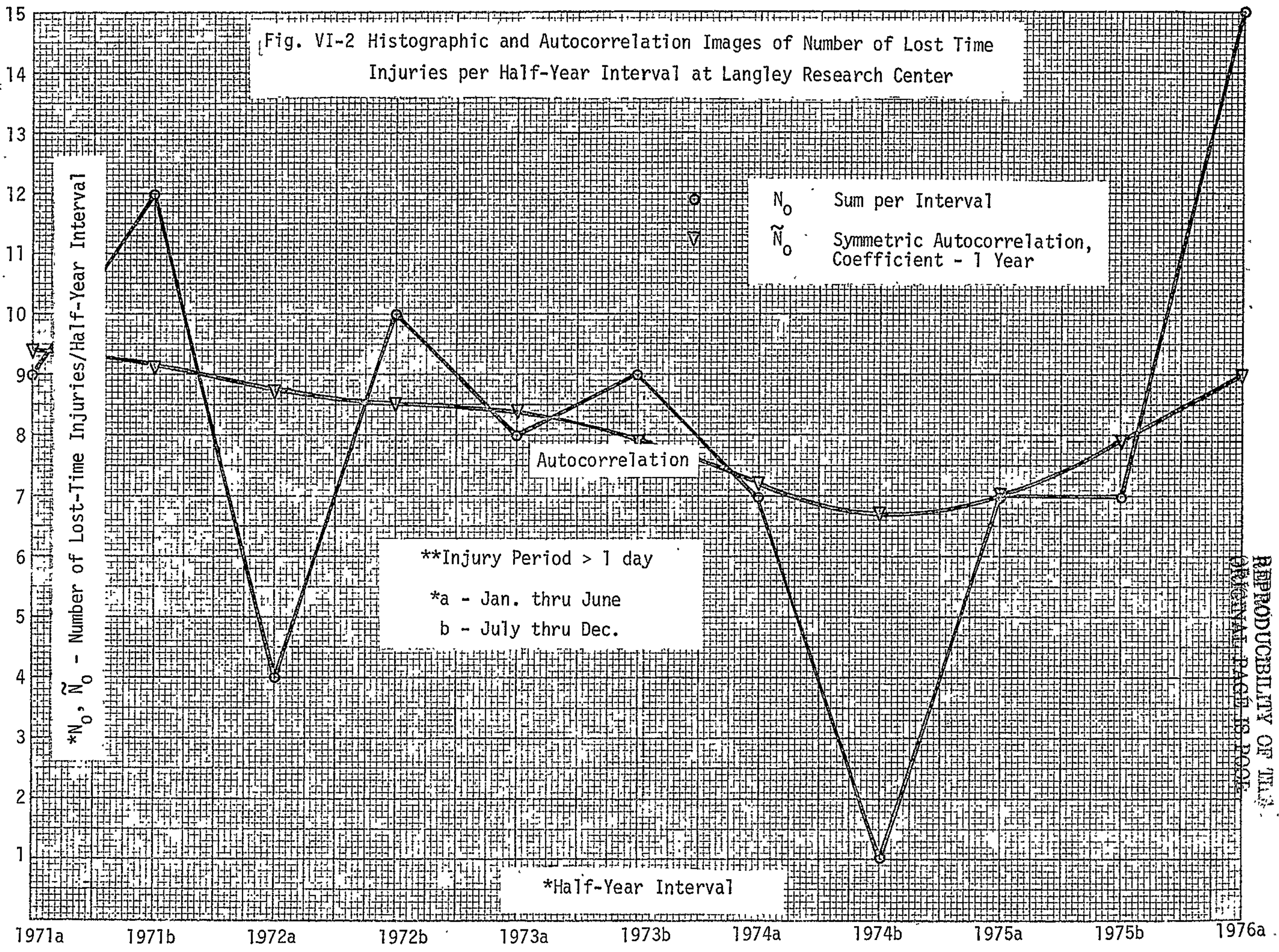


Fig. VI-2 Histographic and Autocorrelation Images of Number of Lost Time Injuries per Half-Year Interval at Langley Research Center same time interval, the latter half of 1974. The increase at Langley in the last year and a half has been 35 percent. The histographic data, of course, shows much greater changes in the injury number rate, but these changes are not, at this juncture, analytically defensible. They appear to be mostly random fluctuations.

Fig. VI-3 and VI-4 show the mean periods of lost-time from injuries, A and $\tilde{A}$, at the two centers. These two functions are not so similar. For Goddard, the mean period declined from 8.7 work days in the first half of 1971 to 5.4 days in the latter half of 1973 and began to increase, most markedly in 1975 and the first half of 1976, when it was 10.8 days. The increase from the minimum to the first half of 1976 is 100 percent. For Langley, the mean injury period was at a minimum in 1971, at about 20 work days. It rose to a maximum of 32.5 days in the latter half of 1973 and the first half of 1974 and it has been declining since that time. It now appears to be relatively constant at about 24 days.

It may be noted that in terms of magnitude the Langley injury number rate and the mean injury period are both at least twice as large as those at Goddard. This presumably is a reflection of differences in nature of the work at the two centers.

Fig. VI-5through 7, which follow, present images of the injury data triplets, $(\tilde{G}_1, \tilde{G}_2, \tilde{G}_3)$, the accident cause factors. These are, respectively, improper environment, improper behavior, and other and generally correspond to the more common factors, unsafe mechanical condition, unsafe act, and act of God. In terms of safety performance, cause factors may be ambiguous. In this regard, the product $N_0 \times \tilde{G}$ has more meaning, so we will examine it when it seems appropriate.

Fig. VI-5shows improper environment, $\tilde{G}_1$, for both Goddard and Langley. This appears to be a small causal factor, presently below 0.10 for both centers. The Goddard $\tilde{G}_1$ factor has declined from 0.10 for the first half of 1971 to 0.08 for the first half of 1976. The Langley $\tilde{G}_1$ factor has declined during the same overall period from 0.10 to 0.06.

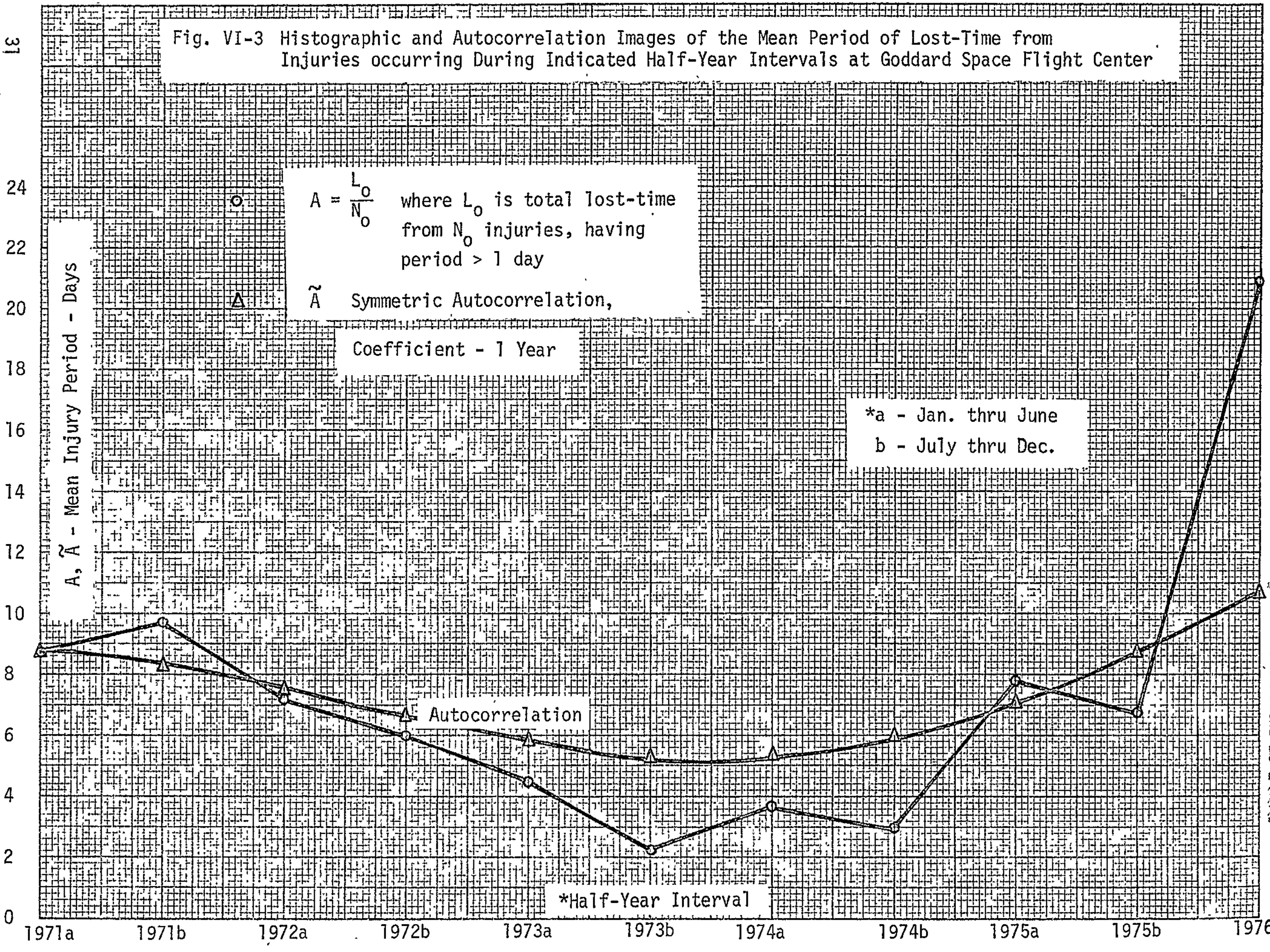
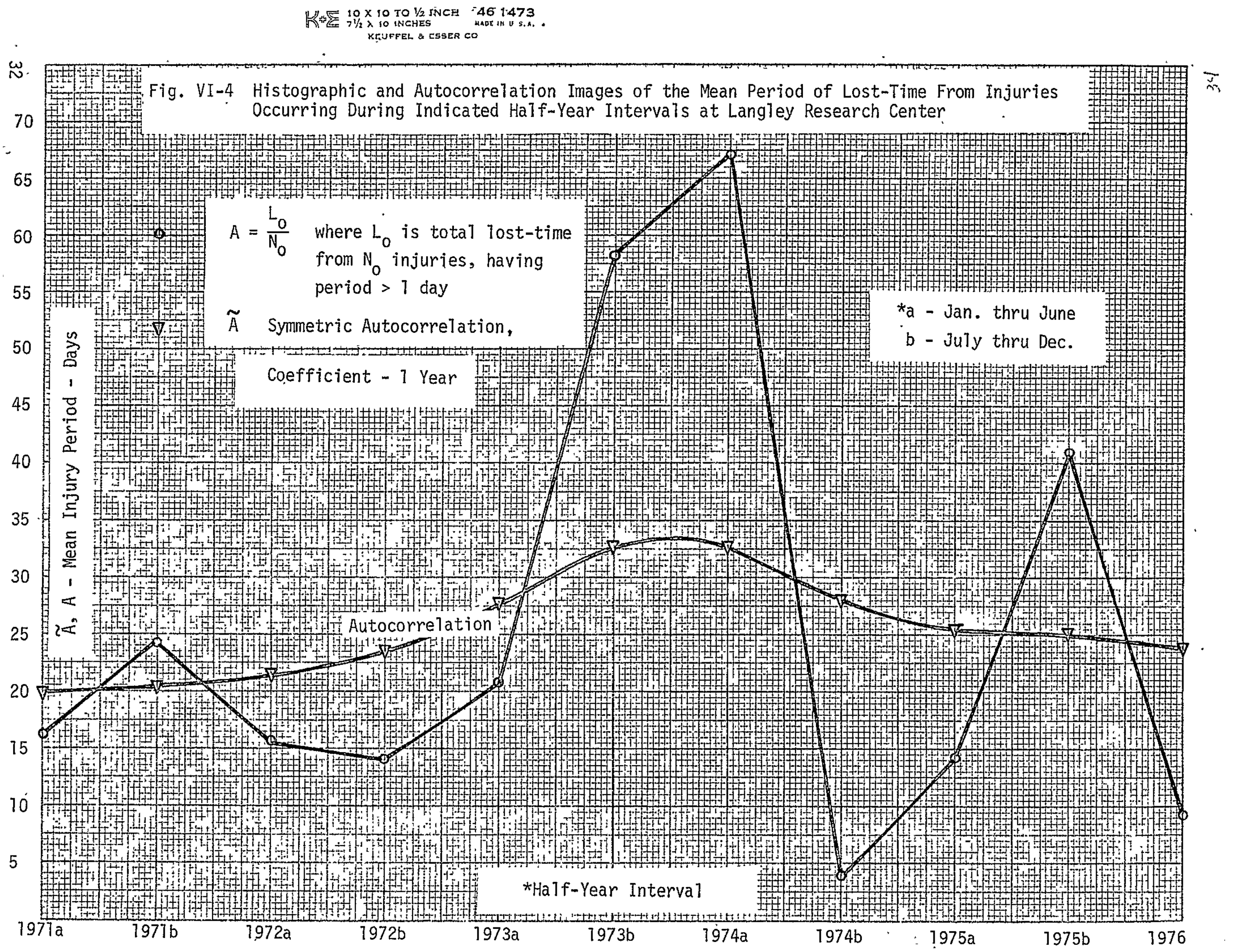


Fig. VI-3 Histographic and Autocorrelation Images of the Mean Period of Lost-Time from Injuries occurring During Indicated Half-Year Intervals at Goddard Space Flight Center

Fig. VI-4 Histographic and Autocorrelation Images of the Mean Period of Lost-Time From Injuries Occurring During Indicated Half-Year Intervals at Langley Research Center



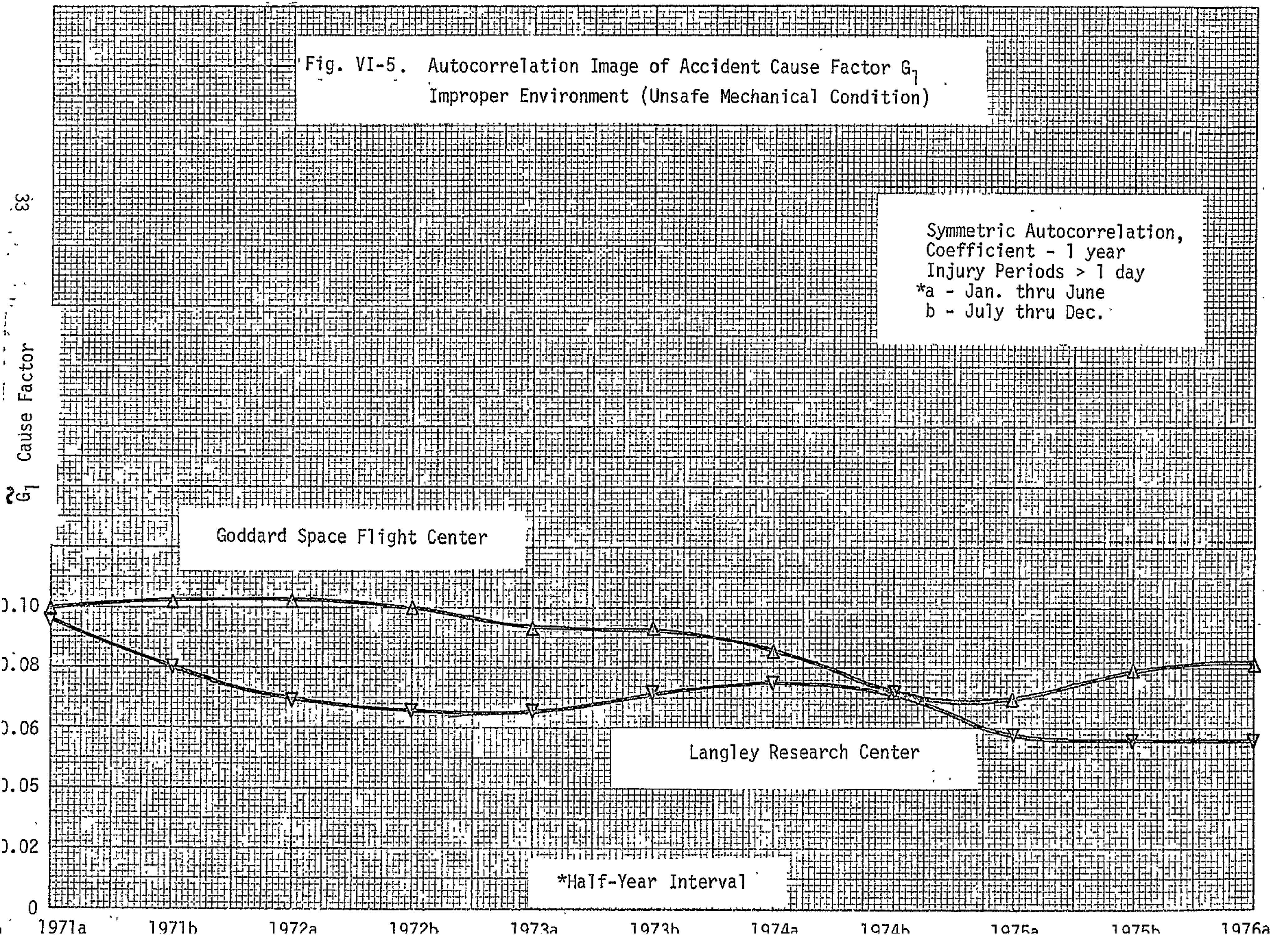


Fig. VI-5. Autocorrelation Image of Accident Cause Factor G_1
Improper Environment (Unsafe Mechanical Condition)

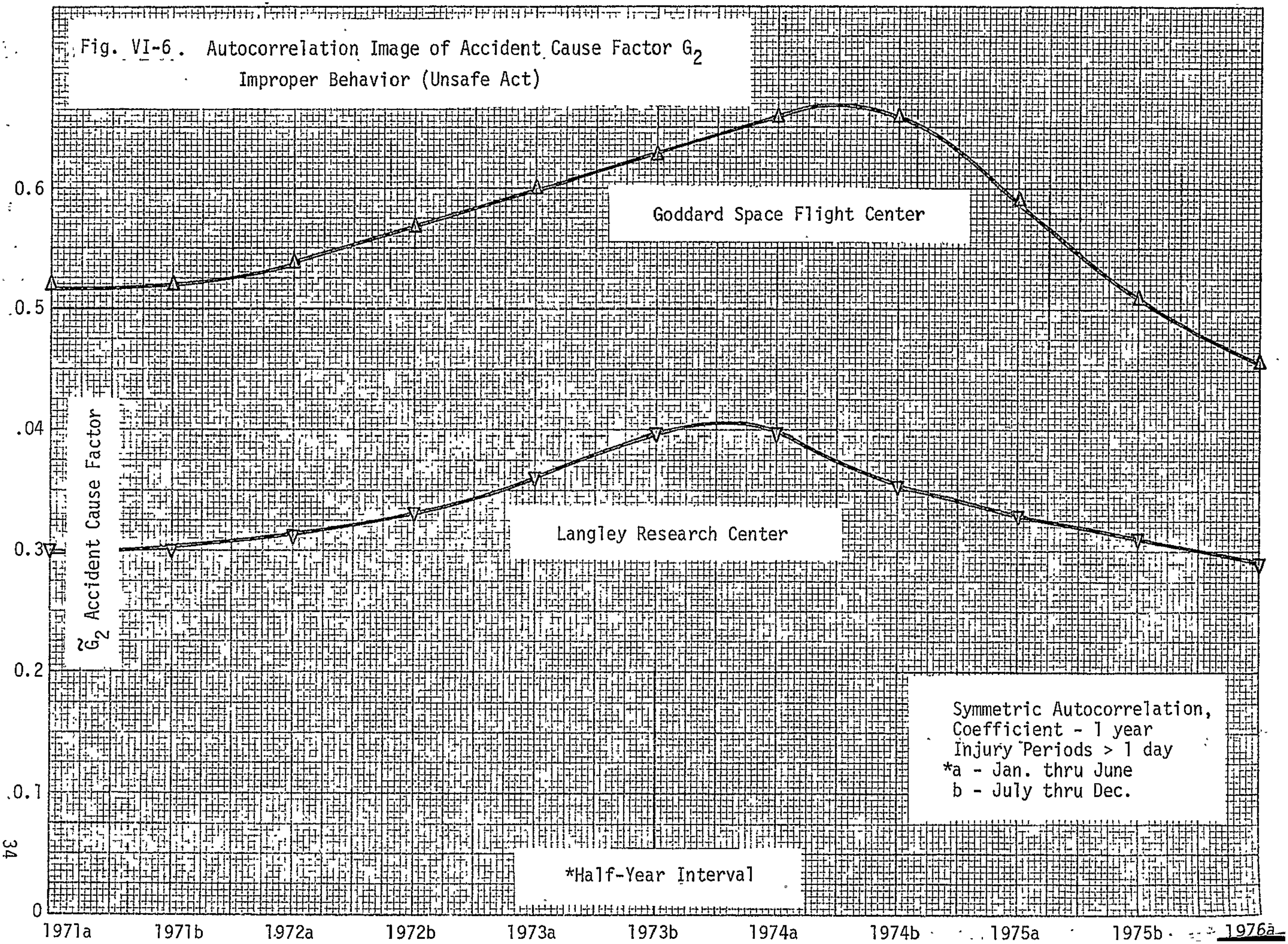


Fig. VI-6. Autocorrelation Image of Accident Cause Factor G_2 Improper Behavior (Unsafe Act)

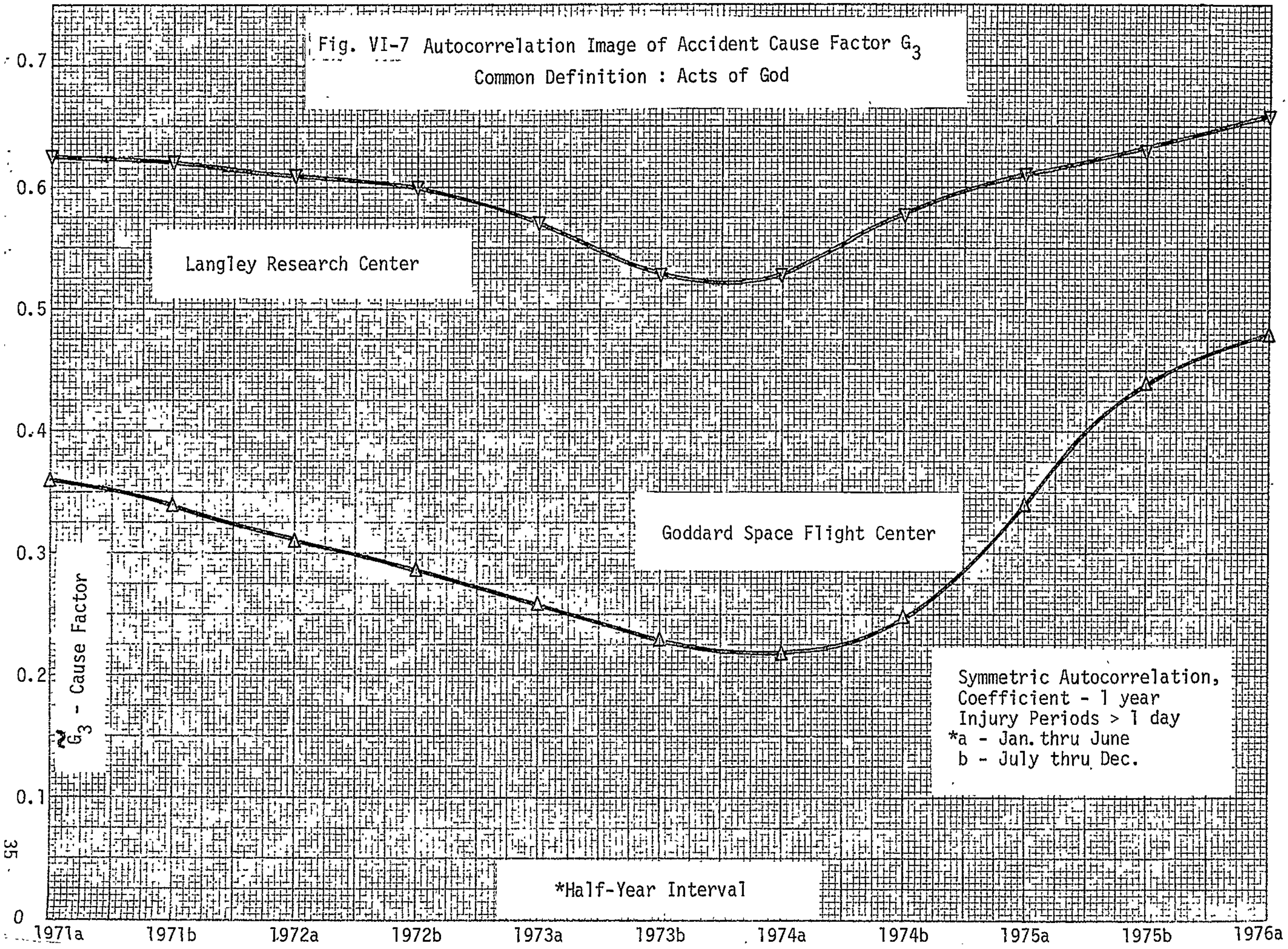


Fig. VI-7 Autocorrelation Image of Accident Cause Factor G_3
Common Definition : Acts of God

Fig. VI-6 shows improper behavior, $\tilde{G}_2$, for both centers. The two functions are quite similar. Each one has a maximum, the Goddard $\tilde{G}_2$ in 1974 and the Langley $\tilde{G}_2$ in the latter half of 1973 and the first half of 1974. At Goddard the factor reached 0.69 and at Langley it reached 0.40.

Fig. VI-7 shows acts of God, $\tilde{G}_3$, for both centers. Here the similarity between the two functions also are high. For Goddard, this factor increased from a minimum of 0.22 in the first half of 1974 to 0.48 in the first half of 1976, an increase of 109 percent. For Langley, this factor increased from a minimum of 0.52 in the first half of 1974 to 0.66 in the first half of 1976, an increase of 27 per cent. To see whether the $\tilde{G}_3$ is misleading, let us look at the product $N_o \times \tilde{G}_3$. For Goddard, the product was 1.36 in the first half of 1974 and it had increased to 3.25 in the first half of 1976. For Langley, the product was 3.84 in the first half of 1974 and it had increased to 5.88 in the first half of 1976.

2.3 GENERAL CONCLUSIONS

The analytically defensible conclusions which we have derived from the injury data for the two NASA centers studied are as follows:

Goddard Space Flight Center

1. The number rate of injury producing accidents is increasing, although probably not nearly as rapidly as the immediate raw data indicates.
2. The mean lost-time period per injury is also increasing, although probably not nearly as rapidly as the immediate raw data indicates.
3. The fraction of injury producing accidents which are due to improper work environment, viz., unsafe mechanical conditions, is low.
4. The fraction of injury producing accidents which are ascribed to what are commonly called acts of God have increased markedly, by a factor of two in the last two years.

Langley Research Center

1. The number rate of injury producing accidents is increasing, although probably not nearly as rapidly as the immediate raw data indicates.
2. The mean lost-time period per injury is stable and appears to be declining slightly. This parameter, however, has had a history at Langley of being high.
3. The fraction of injury producing accidents which are due to improper work environment, viz., unsafe mechanical conditions, is low and over the years has shown a steady decline.
4. The fraction of injury producing accidents which are ascribed to what are commonly called acts of God have increased markedly in the last two years.

VI-3 EXPLORATION OF SPECIAL FACTORS

Because of the real auto-correlated trends in "Act of God"-type accidents uncovered at Langley and Goddard in Section VI-2 above and the significance of these accidents to NASA overall "charge-back" losses in the near term, it was determined by WAI that a particular investigation of this type of accident should be undertaken during the course of this study to develop in-depth information on the specific causes of these trends.

3.1 BACKGROUND

In 1974 the Federal government instituted a new employee protection program which provided additional 45-day salary continuance protection for those workers injured in legitimate industrial accidents while on the job. The concept of the program was aimed at conserving for the employee his original accumulated "sick-leave" and "vacation" time if he were hurt in an accident associated with his job.

This separated for the first time the use of his sick-leave for legitimate off-the-job injuries and illnesses, while those caused by the work environment would be compensated for separately by what has become known at NASA as the "C.O.P." (continuation of pay) program.

In July, 1976 overall government statistics had shown a tripling of injury claims by Federal employees since the initiation of the C.O.P. program in mid-1974.

The chairman of the House group investigating the government's injury compensation program charged that it has turned into another "fringe" vacation and cash benefit for Federal and postal workers, through fraud and deception on the part of employees and lax administration by Labor's Office of Workers' Compensation Programs.

On July 24, 1976, the House Government Operations Manpower and Housing subcommittee wound up its investigative hearings on the program, and Rep. Floyd Hicks, D-Washington, asserted that government employees are faking or exaggerating on-the-job illnesses to get paid time off to "go fishing" or engage in other leisure tasks or even business pursuits.

Hicks accused the Office of Workers' Compensation Programs of "taking the easy way out" in these cases and approving most of them regardless of the merits of each case.

Hicks and his subcommittee colleagues said that not only is the program rapidly increasing in cost -- last year's cost was close to a half-billion dollars -- but that it is lowering morale among conscientious government workers who watch their colleagues get away with undeserved paid time off and cash injury compensation awards.

John C. Read, assistant secretary of labor for employment standards, and Herbert A. Doyle, Jr., director of the compensation program, testified there are "serious problems". (Ref. No. 24)

Based on the general investigations of this problem going on in House of Representatives' Hearings, WAI chose to investigate in-depth the nature of the lost time accidents at NASA by doing an in-depth workup on one of our designated centers, LRC.

3.2 NASA LRC LOST TIME AND C.O.P. ANALYSIS

3.2.1 LOST TIME

Lost time days at LRC havemushroomed in 1976 versus 1975 and 1974, but the number of lost time incidents have not markedly changed, i.e., 1973 = 21, 1974 = 12, 1975 = 17 and 1976 = 28. Between 1974 and 1976, lost time incidents have about doubled but C.O.P. incidents based on 1976 records through mid-July have gone up by a factor of 3, based on a comparison of all of 1975 to six months of 1976. Similar trends are appearing at GSFC.

For example: Nature of Lost Time accidents at Langley from 1973 through 1975 is quite interesting as shown in Table V-3.

Table VI-3 Chronology of Lost Time Accidents and Severity at LRC

	1973		1974		1975		Totals	
Body Part	Inc.	D.L.*	Inc.	D.L.	Inc.	D.L.	Inc.	D.L.
Back	7	288	5	92	4	99	16	429
Legs/Foot	5	133	2	102	5	33	12	268
Eye	1	5	0	0	1	11	2	16
Nose/Face	1	136	0	0	1	15	2	151
Arms	1	2	0	0	2	16	3	18

*D.L. = Days Lost
Inc. = Incidents

Table V-3 (continued)

Hands	5	338*	1	69*	3	34	9	141
Groin	0	0	0	0	1	0	1	17
Hip	0	0	1	276	0	0	1	276
Skull/Head	0	0	1	1	0	0	1	1
Neck	0	0	0	0	0	0	0	
Lungs	1	0	0	0	0	0	1	1
Hernia	0	0	1	68	0	0	1	68
Pinched Nerve	0	0	1	0	0	0	1	31
	21	902	12	608	17	158	50	1417 real days (1936 paid days)

Incidents (Inc.)
Days Lost (D.L.)
* One amputation (awarded equivalent of 289 days compensation but was absent from work only 16 days)

Back problems stemming from incorrect lifting, accidental muscle pulls, stooping for long periods over a work table or low file cabinet are the most serious.

Second are leg and foot injuries from dropping items being lifted or carried and from slips, trips, falls and jumps. These represent preliminarily 56% of the lost time incidents and 50% of the lost time and they are of such a nature that they cannot be reduced by direct guarding of equipment or warning actions of signs but must be approached through a direct person-to-person education basis as well as a change in operational standards around the center.

For example:

Procure and make mandatory for lab, shop and office personnel training programs and posters on how to correctly move heavy objects and how to bend and stoop safely for long periods if work requires it.

Tag all equipment with a small color label to show everyone if it can be safely moved by an individual or needs a dolly or maintenance crew, etc. to move it.

. A directive not to pick up bulk objects by oneself especially if it has no handholds, etc.

The next set of injuries are to the hands (18% frequency and 10% of lost time) which shows that the expected injuries in an R&D/fabrication center are not necessarily correct. People seem to be using their equipment in a proper manner. Careless use of hand tools seems to be predominantly the cause here and again it is a human problem, not necessarily the equipment. Although very expensive centrifugal guard equipment could be purchased, it really is notnecessary if workers stay alert to what they are doing. Backing into tools that are winding down or trying to stop the wheels by hand are evident here.

The balance of the lost time adds up to only 24% in frequency and 40% in actual lost time days with the largest of these being injuries to the eye,nose, face (9% frequency and 12% lost time). Hip injuries are rare but are associated with long lost time claims.

Accidents associated with advanced age (over 50, work force) like broken bones from a fall, trips and falls on stairs, etc. do not seem to be evident at Langley although we expected them. It is the younger blue collar worker in the more active pushing, lifting, climbing situations that contribute to the major lost times.

3.2.2 C.O.P. TIME ANALYSIS

There is no question that the data reviewed to date from LRC and GSFC shows a significant increase in C.O.P. time. Just why this is happening when the increase in the number of lost time accidents at those centers is significantly less than the increase in apparent severity (real days lost) must be evaluated. There are really two sources of key information that were tapped to get answers to this question.

The first, of course, is the administrators of the safety, health and personnel offices at the centers, and a dialogue was established with these offices during the course of this study.

The second is the people who have been claiming lost time. Our objective here was to try and determine whether the lost time claim is completely legitimate or not, and if not, what changes in the administration of the new Federal Government Employee Injury Compensation Law enacted in 1974 should be undertaken at NASA to tighten up the evaluation of claims so that the ratio of legitimate claims over the total time of the claimed injury can be maximized.

The method used to gather this information was to choose one NASA center of the three that were contracted to be evaluated in this contract and work with that center's "Office of Health and Safety" to develop administrative and employee non-personal questionnaires that could develop the in-depth information required. NASA-LRC was chosen as the representative center and a detailed questionnaire was distributed to all NASA-LRC employees that reported C.O.P. injuries from 1974 through 1976. The questionnaires were designed by WAI and modified by NASA-LRC administrative personnel to the specific climate of the center.

The questionnaire was designed to determine how C.O.P. time is assigned, whether it is voluntary or specified by the center, whether the length of time taken is legitimate relative to the injury,who determines when the employee returns to work, etc.

The following discussion highlights the questionnaires and the results of their evaluation by WAI.

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia
23665

NASA

Fig. VI-8

Reply to Attn of

October 14, 1976

MEMORANDUM

TO: Distribution

FROM: 114/Vice Chairman, Executive Safety Board

SUBJECT: Lost Time Accident Data

NASA Headquarters is conducting a study at selected field installations of lost time accidents. As a part of that effort, we have been asked to solicit from employees who have had lost time accidents the information shown on the enclosed questionnaire.

As you will see, the questionnaire is general in nature and completely protects the identity of those responding. Specifically, you are requested not to sign the questionnaire.

Please complete the enclosed form and return it to M/S 114 by October 29, 1976. Your participation is voluntary, but this office requests your support.

Walter C. Hoggard
Walter C. Hoggard
2411

Enclosure

Fig. VI-9

TYPICAL
ADMINISTRATIVE QUESTIONNAIRE

NASA Safety, Health & Personnel Offices

The objective of this questionnaire is to relate (1) lost time and (2) lost time charges to (a) the means by which medical treatment is supplied to and (b) the administrative procedures followed regarding injured employees.

1. What methods do you use to determine the employee's severity and prognosis of injury?

   o Outside doctor report Until October 1, 1976, outside Dr. was used

   o NASA or NASA contractor doctor report ______

     Effective October 1, 1976, Contract Physicians on Site

   o Personal judgements at the time ______

   o None of the above. Describe method used. ______

2. As a matter of administrative procedure

   o Are employees briefed when hired as to their medical and lost time benefits?

     Yes

   o Is an injured employee briefed at the time of his first report or after?

     Yes

   o Is Continuation of Pay (C. O. P.) automatic?

     Optional - Choice of C.O.P./A.L./S.L.

3. After initial report, is employee briefed at his request or as a matter of Center policy?

Center Policy - Briefed by Nurse in Attendance

4. Do safety, medical, or personnel administration employees make the decision on whether an injured employee is briefed on C. O. P. at the time of or after an injury?

Medical employees render the decision at the time injury is reported

5. Did NASA medical office or physicians follow up on independent medical exams or opinions on the employee with major C. O. P. claims, i.e., were claims medically verified during lost time period?

Medical substantiation is required before employee is given C.O.P.

For the period January 1974 through ~~August~~ July 1976, for lost time accidents, please list:

6. Lost Time (days) 1489 days

7. Diagnostic Physician/Treating Physician

7.1 Government Employee

7.2 Government Contractor

Government contractor and referred physicians

7.3 Private

Some employees elected private physician

8. Procedure Regarding Lost Time Charges

8.1 Was the employee given or did he have any option as to how his lost time was charged?

Yes (see 2)

8.2 Was he aware that he had an option, if he did, as to how his lost time was charged?

Yes

8.3 Who informed the employee regarding the foregoing and when was he informed, prior to being injured, immediately after the injury, or upon return to work?

Nurse in attendance - at the time injury was reported

Fig. VI-10

TYPICAL
NASA EMPLOYEE - WORK INJURY
QUESTIONNAIRE

We do not want your name. If you had more than one injury, fill out a separate questionnaire for each.

1. What year did your injury occur?

1975

2. Were you out more than one time for this injury? How many working days for each time?

yes 3 Times 1 day each Time

3. How was the lost time charged; sick leave, "45 day Continuation of Pay Plan", leave without pay, vacation?

"45 day Cont."

4. Where did the injury occur, i.e., work place, home, etc.?

Bldg 1199 NASA - LRC

5. Time of day? Type of injury? Was it treated at the Center?

6 pm BROKEN WRIST NO

6. What happened immediately after your injury?

DROVE TO Hospital

6.1 When did you report the accident to your supervisor or to the safety or medical office?

NEXT DAY

6.2 What did your doctor advise you to do about your injury?

____

____

____

6.3 Did you give a verbal or written report to NASA on the day of the accident?

VERBAL

____

6.4 What were you told to do by NASA safety, health or administrative personnel regarding your accident, injury and claims?

____

____

____

7. Was oral or written information given to you about your available injury, sick time and/or continuation of pay benefits on the day you were injured? During the week you were injured? Later than that?

YES

____

8. How was this information given to you?

Orally ✓

Written ✓

9. If oral, what office or union at the Center gave you the information?

Ccl Health

____

10. If written, what office at the Center gave you the information?

Occ Health

11. Were you given a choice as to how your lost time was to be charged? ✓

yes

12. Were you cared for by a NASA doctor, a NASA contract doctor or a private doctor?

private Doctor

13. Do you feel you had adequate time to recover from your injury?

yes

14. Did your physician specify the time at which you should return to work?

yes

15. Did you return to work prior to or later than the physician had recommended? Why?

Same

3.2.3 EVALUATION OF LRC -- C.O.P. WORK INJURIES QUESTIONNAIRES

The results from the NASA employee work injury questionnaire resulted in 33 detailed responses which were broken down as 23 in 1976, 4 in 1975 and 1 each for the years 1973, 1972 and 1971.

Of the 1976 responses, 15 out of the 26 represented C.O.P. time in excess of 1 day. Table VI-4 shows the detailed breakdown of all the cases returned with the questionnaire.

The basic characteristics of this data show the following trends.

1. The majority of all time charged is C.O.P. but there were some "sick leave" charges.
2. Most accidents from questionnaire reply were minor lost times and are broken down as shown below.

	Reported 1976 Lost Time Days	No. of Incidents
	25	1
	16	1
	7	1
	4	1
	3.5	1
	3	6
	2.5	1
	2	3
	0.5	8
Totals	63.5	23

3. The causes of the reported C.O.P. injuries appear to be in two categories, unsafe acts on the part of the employee or acts of God.

   The actual distribution being 32% unsafe acts, 59% acts of God and 9% unsafe conditions or mechanical failures of equipment.

   This indicates that the safety programs at LRC are indeed working well and that the majority of lost time injuries are in categories of personel carelessness or accidents that are caused by an uncontrollable set of random events.

TABLE VI-4

EVALUATION MATRIX OF NASA-LRC EMPLOYEE QUESTIONNAIRE

	1	2				3				4
	Yr of Injury	TIME LOST-DAYS/QUARTERLY PERIOD 1st	2nd	3rd	4th	COP	HOW CHARGED SL	AL	NONE	LOCATION OF ACCIDENT
1	1976	12.5	3.5			X				@ Work on Stairway
2	"	?				X				@ Work
3	"	25				X				"
4	"	1	1	1		X				"
5	"	1/2 (To	Go To	Dr.)		X				"
6	"	1/2	"			X				"
7	"	1/2	"				X			"
8	"	1/2	"			X				"
9	"	1/2				X				"
10	"	2				X				"
11	"	3				X				"
12	"	3					X			"
13	"	1.5	1/2						X(CODE Z)	"
14	"	U							X	"
15	"	1	3			X				"
16	"	1.5	1	1		X				"
17	"	7				X				"
18	"	1/2				X				"
19	"	2				X				"
20	"	1/2	1/8			X				"
21	"	3				X				"
22	"	3				X				"
23	"	0				-				"
24	"	2 1/2				X				"
25	"	2 1/2	1/2				X			"
26	"	1/2				X				"
27	1975	(SEVERAL)	115	14						
28	"	15				X				@ Work
29	"	9				X				"
30	"	1/2				X				"
31	1973	5	5				X			"
32	1972	3			Leave W/O Pay					"
33	1971	1/2	1/2				?			

Table VI-4 (cont'd)

	5				6	7			
	TYPE OF ACCIDENT				BODY PART & INJURY HISTORY		DOCTOR		
	Unsafe Act	Unsafe Cond.	Mech. Fail.	A.G.		Pri.	NASA	AF	Other
1		X			LEG-Sprained Ankle Pulled tendons & lig.		Contact	X	
2				X	Treated on scene/NASA nurse-BACK - STRAINED	X			
3		-			-	X			
4				X	LEG		X		
5				X	Back	X			
6	X				Finger - Cut		X		
7	X		X		Hand - Stitches		X		
8	X				Eye - Chem Burn	X			
9	X				Eye - Chem Burn		X		
10				X	Ribs - Fractured in Fall		X		
11				X	Back - Strain	X			
12				X	Arms, Back		X		
13		-			Eye		X		
14		-			Broken Arm	X			
15				X	Back - Strain		X		
16				X	Ankle - Sprain		X		
17				X	Back - Strain		X		
18	X				Hand-cut, Stitches		X		
19	X				Finger cut		X		
20	X				Elbow - Contusion	X			
21		X			Eyes - U.V. Burns	X			
22				X	Muscle Strain-Leg	X			
23				X	Head		X		
24				X	Knee - twisted		X		
25				X	Elbow & Neck Strain	X	X		
26					Finger - Cut off end	X			
27					Back - Slipped Disc Req. surgery	X			
28		-			Foot - Fracture	X			
29	X				Saw Cut - Extremity	X			
30					Finger - Broken		X		
31				X	Shoulder - Pulled Muscle		X		
32	X				Hand-Abrasions/Sander	X			
33	X				Finger Cut - Stitches		X		

	8	9		10			11		12	
	DOCTORS ADVICE	INSTRUCTIONS ON CHARGES		WHO DIR. EMPLOYEE AS TO LOST TIME CHGS.			ADEQUATE TIME TO RECOVER		RETURN TO WORK DECIS.	
		Employee Choice	NASA Directed	NASA Nurse	Union	Other	Yes	No	Employee	Phy.
1	Stay off foot - Use crutches		X	X (Oral +/or written)				X	X	
2	Rest and take Medicine		X	X	"	Health FSS?	X		X	
3			X	X			X			X
4	Go home, stay in bed - take med.		X	X			X			X
5	Get x-ray Light duty	X				Safety Office	X		X	
6	Keep dry - don't bend finger		X	X			X		X	
7	Stitches + bandage	X					X			X
8	Minor burn - no treatment		X	X			X			X
9	Minor - drops only		X	X			X		X	
10	Stay home 2 days	X				Br. Time Clerk	X			X
11	Lay on flat surface	X		X			X			X
12	Exercise					No One	X			X
13	Soak with cold water, take med.	X		X			X		X	
14	Taken to Hospital					No One	X		X Prior	
15	Rest - Pills		X	X			X			X
16	Stay in bed 5 days Stay off leg 2 wks.			X	X		X		X	
17	Bed Rest	X		X			X		X Prior	X
18	Keep hand dry	X		X			X		X	
19	Sent back to work same day	X				Branch Sec.	X			X
20	Rest arm - no time off		X	X		Safety Office	X			X
21	Rest eyes - bandaged		X			Supr.	X			X
22	Stay off leg for several days		X	X				X		X
23	Rest - 12 hours	-	-	X			X			X
24	Stay off leg - elevate		X	X			X			X
25	Nothing	-	-	X			X		X	
26	[illegible]	X		X			X		X	
[illegible]	[illegible]						X			X

Another observation on the questionnaires from LRC can be highlighted by comparison between the lost time injuries reported by questionnaires from 1972-1976 and the lost time injuries reported by NASA Form #344 compiled directly from mandatory accident reports required by OSHA in this same period.

Comparison of the official data with the voluntary returns of the questionnaires show that 55 disabling injuries yielding lost time greater than one day occurred at LRC from January, 1974 through June, 1976, while the return of the voluntary questionnaires only show 18.

Therefore, about 67% of the people injured during this period and who received the questionnaire from the Health and Safety Office did not return it.

While no conclusions as to the causation of major lost time incidents and C.O.P. injuries can be reached from this fact, the lack of cooperation may be indicative of a general attitude contributing to abuse of C.O.P. privileges.

Most important also is that no responses were received by questionnaire from the majority of the major lost time (10 days or more) claimants during the 1974 through 1976 period, since the C.O.P. plan has been in effect.

VI-4 NASA ON-SITE CONTRACTOR DATA ANALYSIS

Based upon the requirements of the NASW-2903 contractual statement of work WAI interviewed three NASA on-site service contractors in order to obtain an idea of their accident and injury experience from the year 1972 through the first half of 1976.

It was felt that this data might provide a comparison between government and private operations in similar environments.

To this end data was obtained at NASA LRC from the Klate-Holt Co. and the Metro Services Co., on-site contractors. For NASA GSFC data were obtained from the Bendix-Field Engineering Corp. NASA-HQ does not have any major services contractors augmenting staff operations at this center.

4.1 THE NATURE OF THE CONTRACTOR'S WORK

4.1.1 KLATE-HOLT CO.

The Klate-Holt Co. is engaged in providing general transportation services to the NASA LRC facility in the following areas:

- Heavy and light truck operations
- Hauling
- Warehousing
- Furniture & equipment packing and moving
- Forklift operations
- Mail and taxi service

4.1.2 METRO CONTRACT SERVICES, INC.

Metro Contract Services, Inc. is engaged in providing general construction and maintenance services to the NASA LRC facility in the following areas:

- Heavy duty rigging operations
- Road service
- Equipment maintenance and repair
- Carpentry
- Electrical work
- Plumbing & painting
- General laborer services
- Roofing
- Truck & light vehicle operations to support above.

Unfortunately, Metro has been keeping records on accident and injury for only one year since its contract began hence chronological comparisons with this contractor were not felt to be statistically meaningful.

4.1.3 BENDIX FIELD ENGINEERING CORP.

Bendix Field Engineering Corp. is primarily engaged in engineering and operational support of GSFC's worldwide tracking station network. They provide these services on-site at the following locations:

- Goldstone, Calif.
- NASA GSFC, Md.
- Merritt Island
- Kokee Park

4.2 RESULTS OF CONTRACTOR DATA ANALYSIS

Tables VI-5A and VI-5B show injury frequency and severity data for Klate-Holt and Bendix employees along with the corresponding data for government employees at Langley and Goddard, respectively. The contractor data in each of the two tables is consistent with the nature of the work they do.

Both the frequency and severity for the Klate-Holt operation have been and are higher than the values for government employees at Langley. The Klate-Holt injury frequency, for the first-half of 1976, is about 3 injuries per 200,000 man hours as compared to about 0.8 injuries per 200,000 man hours for Langley government workers. The Klate-Holt injury severity for the first half of 1976, is 180 man days per million man hours as compared to 40 man days per million man hours. Since the Klate-Holt operation is inherently more physical than typical Langley operations, the Klate-Holt data should not be surprising. The Klate-Holt injury frequency is approximately that of American industry as a whole for 1975 (i.e., 2.62). The Klate-Holt frequency shows an increase during the reporting period; the severity rate is essentially constant. The data has been autocorrelated.

On the other hand, one might expect that Bendix employees and the government employees at Goddard would be exposed to about the same hazards the same fraction of the time because both the calibre of employee and their job assignments are comparable. The frequency of injury for Bendix employees is about the same as it is for government employees at Goddard, although it is consistently somewhat lower. The Bendix injury frequency, for the first half of 1976, is 0.49 injuries per 200,000 man hours as compared to 0.67 injuries per 200,000 man hours for Goddard government workers. The Bendix injury severity, by comparison, tends to be significantly lower than that for Goddard government employees. For the first half of 1976, the respective values were 17.8 and 44.8 man days lost per million man hours. This, again, is autocorrelated data.

TABLE VI-5A Klate-Holt Frequency & Severity Data

YR	K-H MAN HOURS WORKED	K-H # of LOST TIME ACC.	F INJURY FREQ	NASA F LRC	K-H D.L.	SEVERITY S KH	NASA S LRC
1972	6.04×10^5	2	1.6	.63	78	200	55
1973	2.46×10^5	3	2.1	.60	69	210	61
1974	2.24×10^5	3	2.4	.55	36	180	66
1975	2.34×10^5	2	2.7	.64	24	160	49
1976**	1.37×10^5	4	3.2	.82	40	180	50

TABLE VI-5B Bendix Field Engineering Freq. & Severity Data

YR	BENDIX MAN HOURS WORKED	BENDIX # of LOST TIME ACC.	F_B INJURY FREQ.	NASA F GSFC	BENDIX D.L.	SEVERITY S_B	NASA S GSFC
1972	4.48×10^6	3	.21	.37	19	6.8	16.0
1973	5.47×10^6	6	0.28	0.45	42	9.6	14.9
1974	5.47×10^6	11	0.39	0.52	77	14.2	16.5
1975	5.14×10^6	17	0.49	0.57	145	18.5	27.3
1976**	2.41×10^6	5	0.49	0.67	18	17.8	44.8

Where: F = frequency = LOST TIME accidents per 200,000 man hrs worked

D.L. = Days Lost

S = Severity = Days Lost per 1,000,000 man hrs. worked

** = Data through the 2nd quarter of the year, K-H and Bendix, through August of the Year, LRC and GSFC

K-H = Klate-Holt

Autocorrelation coefficient = 1 year

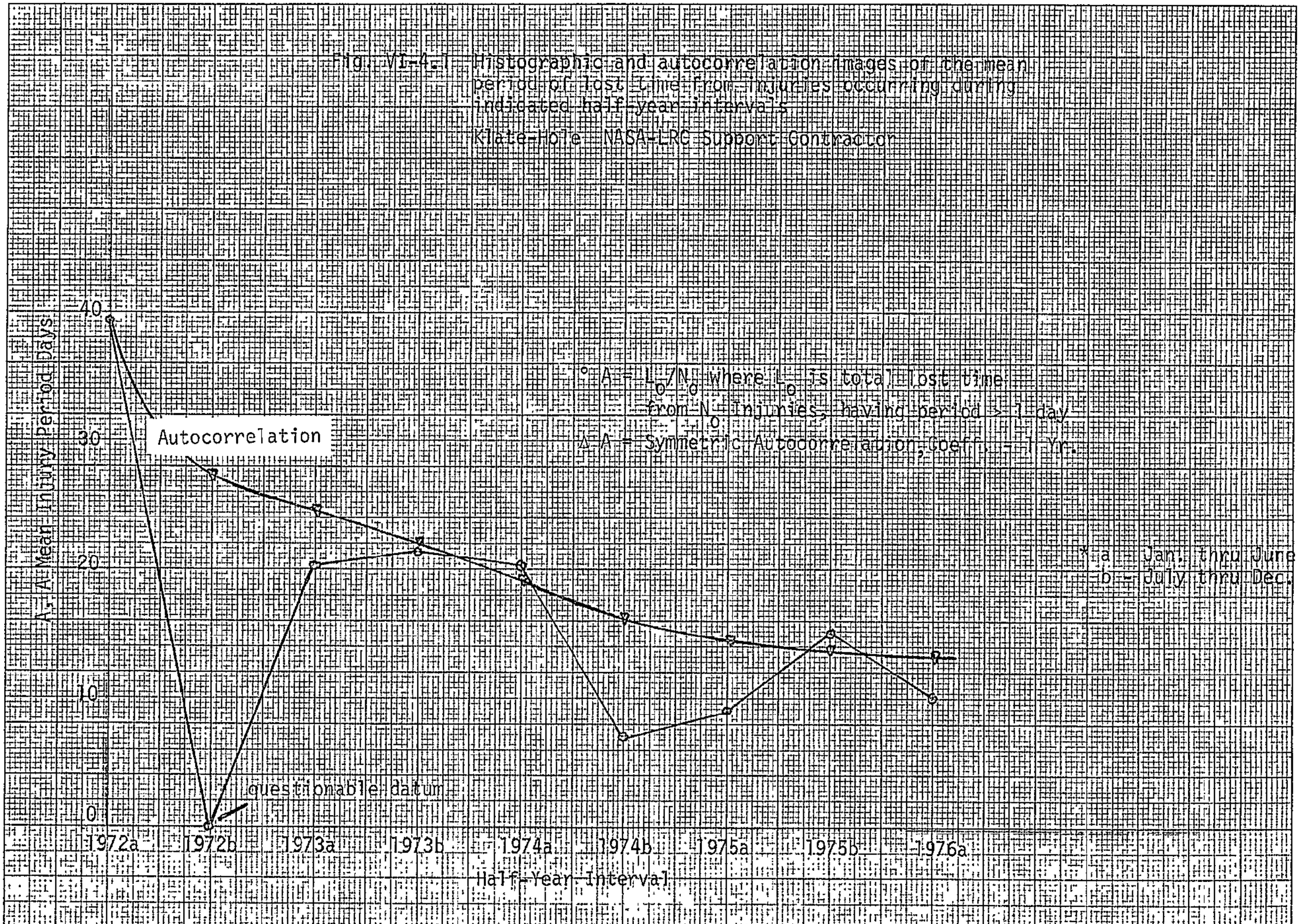


Fig. VI-4.1 Histographic and autocorrelation images of the mean period of lost time from injuries occurring during indicated half-year intervals
Klate-Holt NASA-LRC Support Contractor

Fig. VI-4.2 Histographic and autocorrelation images of the mean period of lost time occurring during indicated half-year intervals

Bendix Field Eng. Corp. - NASA GSFC Support Contractor

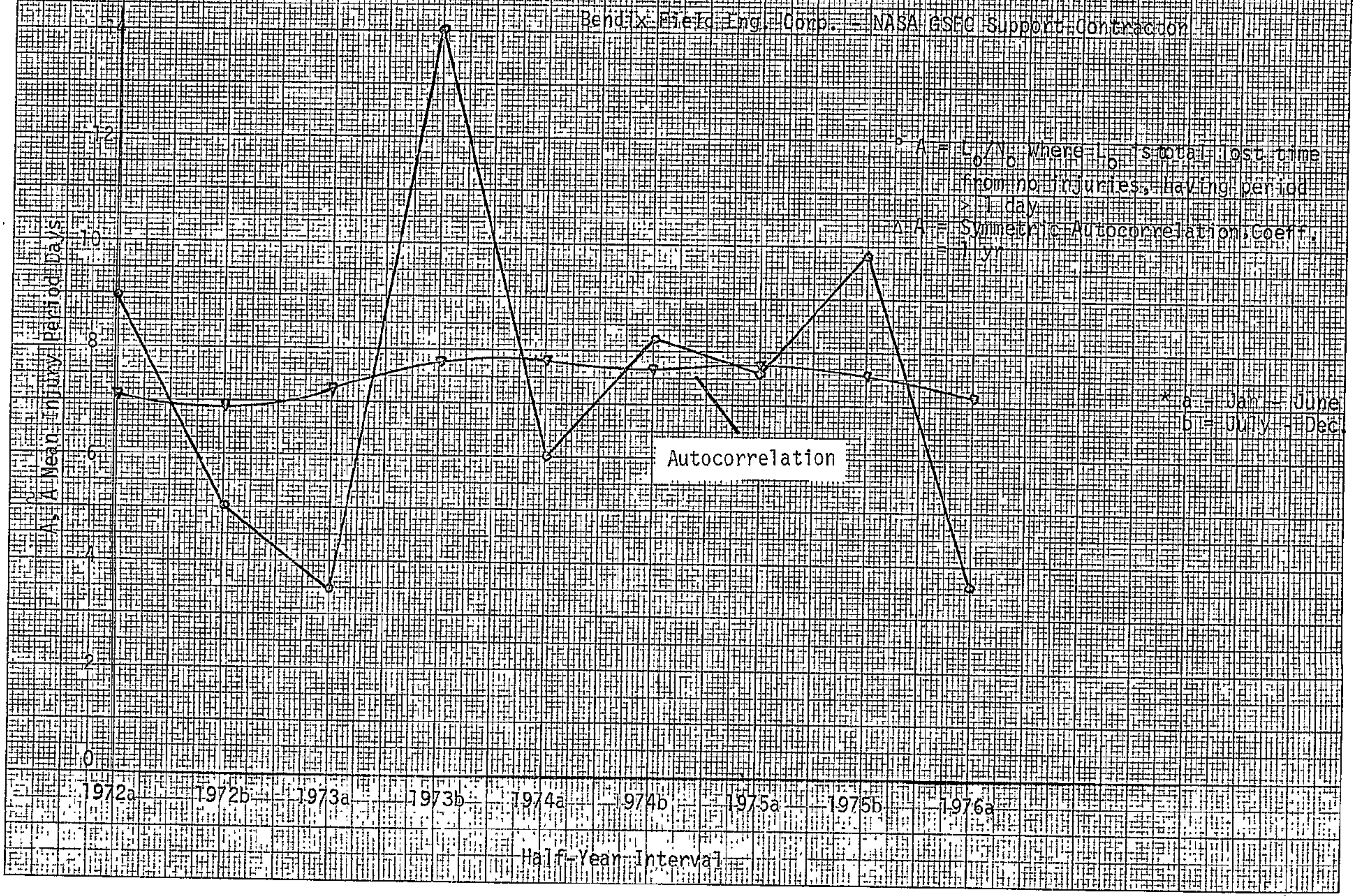


Table VI-7 (con't.)
Summary of GSFC Property Damage History
1972 - 1976*

NASA Facility	Character of Accident	Type	Yr	Total No.	$K Costs	Identification of Accident or Equipment Involved	Cause	Corrective Actions
	Fire	I	1976*	17	$ 2.7K			
			1975	23	$ 5.8K	Large No. of small fires that were controlled occured in 1975 at GSFC & its Tracking Stations		
			1974	20	$ 0.58K	" "		-
			1973	1	$ 5K	Goldstone fire in vacated room	Unknown	-
				1	-	Fire in old transformer	Ageing	Inspection & Replacement
				1	$ 2K	Trailer Fire	Electric heater on when trailer unattended.	Turn off heaters when trailers not in use
				19	-	Small mishap fires	Trash cans, Short Circuits, Auto fires etc.	-
			1972	38	-	" "	" "	-
		Totals		120	20K			-
GSFC	Explosion or Pressure Vessel Failure	A, B & I	1975	0	-	-	-	-
			1974	0	-	-	-	-
			1973	0	-	-	-	-
			1972	0	-	-	-	-
		Totals		0	0			
GSFC	Collisions (Non-Aircraft) Govt. Vehicle	A&B = 0 I as shown	1976*	15	4.2	Failure to maintain Control	Improper Action by Driver	Veh. Accident Freq. Rate Per 10^6 Miles 6.55 (1976*)
			1975	32	9.8	Auto 12	19	5.9

Table VI-7 (con't)
Summary of GSFC Property Damage History
1972 - 1976*

NASA Facility	Character of Accident	Type	Yr	Total No.	$K Costs	Identification of Accident or Equipment Involved	Cause	Corrective Actions
	Misc. &/or Prime Function Related		1973	1	3.0	Contractor dropped		Load test
			1972	1	3.0	Antenna tower collasped		
		Total		13	21.3			

pressure vessel operations which includes structural analysis, x-ray inspection and hydro and pneumatic testing according to ASME codes.

GOVERNMENT VEHICLE LOSS

From 1972 through the third quarter of 1976 no Type A or Type B losses have occurred from the operation of government vehicles. However, during this same period 19 type I accidents occurred yielding a total loss of $3221.00. More significant, however, is the major increase in the accident frequency rate per 10^6 miles driven at LRC. This index has increased from zero in 1972 and 1973 to 18.6 in 1975 and 18.9 through the third quarter of 1976. This is almost three times the national average of 6.66 for the same period and indicates that a major driving safety program should be undertaken by the Office of Health and Safety at LRC to reduce the government auto accident rate before it rises any further.

5.3 SUMMARY OF NASA HQ PROPERTY DAMAGE PROFILE

No major property damage in any category has been recorded occurring at NASA HQ from 1972 through the third quarter of 1976 except one auto accident in 1974 that resulted in $944.00 of property damage. This yields an average auto accident frequency rate of 2.15 for the period 1972 through the third quarter of 1976 which is about one-third of the national average during the same period.

VII. GRAPHICAL COMPARISONS

VII. GRAPHICAL COMPARISONS OF NASA VS GOVERNMENT AND INDUSTRY

The approach to setting safety comparisons between NASA and other elements of the government and private sector can only be meaninful if the elements of comparison are of the same or similar set. Therefore, looking at NASA safety records in comparison with the coal mine industry, while making NASA look good by comparison, is not a proper comparison because the nature of the operations in both organizations are completely different.

It was, therefore, determined that the only way to evaluate the relative effectiveness of NASA's present health and safety programs was to compare NASA with only those other government and private organizations that had the same or similar function, employed the same or similar types of spersonnel, and, where possible, were organized in a similar fashion.

Two basic groups of organizations were identified as meaningful comparisons with NASA. They are the National Laboratory Complex of ERDA and R&D portions of the aerospace industry.

The ERDA laboratories fill the same type of function for ERDA as NASA centers do for NASA; that is, they are advanced technology, development and research centers employing high level scientists, engineers and skilled technicians engaged in directed research towards national scientific policy goals. Their capabilities cover the entire gamut of analytical research and concept formulation through design, fabrication, assembly and full scale testing of prototype systems.

The only difference between ERDA and NASA is that all ERDA labs are staffed and run by private contractor organizations. These contractors, however, are very similar to government in how they organize, how they administer and in the type of people employed. Universities like University of California, Columbia and University of Chicago and corporations like Union Carbide are typical of the private contractors running these labs. ERDA was chosen specifically to explore the reasons for any major differences in contractor vs government administration of similar operations.

In order to assess the effect of well run profit making organizational methods on safety, classical comparisons with various elements of the aerospace industry were made. Since these contractors play a major part in helping NASA fulfill its program goals and there is a constant interchange of ideas, methods and personnel between the two types of

Electronics (cont'd)

Hughes Aircraft, Fullerton, Calif.

Research & Development (Private)

Atomics International, Los Angeles, Calif.
General Atomics, San Diego, Calif.
Hughes Research Labs, Malibu, Calif.
Hercules-Allegheny Ballistics Labs, Md.
Martin-Marietta, Vandenberg, Calif.
Aeroneutronics - Philco, Los Angeles, California
Hughes Aircraft, Canoga Park, Calif.
Martin-Marietta, Cape Canaveral, Fla.
Lockheed Missiles & Space, Vandenberg, Calif.
Chrysler Corp., Huntsville, Ala.
Hughes Space Comm., Los Angeles, Calif.
Hughes Aircraft, Culver City, Calif.
Lockheed Missiles & Space, Huntsville, Ala.
Martin-Marietta, Michoud, Ala.

Tables VII-1 through VII-3 show the Z16.1 or OSHA reported and autocorrelated values of injury frequency and severity data computed for all the government and private industries listed above. Table VII-4 details a comparison of average severity rates from 1972 - 1976 for pertinent government agencies and industries vs NASA.

Fig. VII-1 summarizes NASA Images of Autocorrelated Injury Frequency and Severity data obtained during this study. It is evident that since 1973 NASA injury frequency has been increasing linearly at the rate of .085 injuries per 200,000 man hours worked/year, or by a factor of approximately 33% per year. GSFC and Headquarters roughly approximate the total agency rate increase through this period, however, LRC has been dropping from 1971 to 1974 and then markedly reverses its trend to a slightly larger slope than the total agencies from 1974 through 1976.

During the same period, however, although the autocorrelated accident frequency is increasing, the autocorrelated severity for the entire NASA shows a marked decrease of almost 64% from 1972 - 1976. This cross reversal between frequency and severity trends associated with NASA occupational injuries is quite significant and indicates that

Table VII-1 NASA Injury Data

VII-1A *Frequency - Injuries/200,000 Man Hours

Year	1971	1972	1973	1974	1975	1976 (thru Aug.)
GSFC	0.33 (.35)	0.24 (.37)	0.44 (.45)	0.55 (.52)	0.44 (.57)	1.16 (.67)
LRC	0.66 (.67)	0.56 (.63)	0.63 (.60)	0.35 (.55)	0.52 (.64)	1.56 (.82)
HQ	0.05 (.06)	0.05 (.07)	0.05 (.11)	0.19 (.18)	0.29 (.24)	0.34 (.28)
All NASA	0.30 (.33)	0.30 (.35)	0.37 (.40)	0.49 (.47)	0.54 (.53)	0.73 (.57)

VII-1B *Severity - Man Days Lost/Million Man Hours

Year	1971	1972	1973	1974	1975	1976
GSFC	15.8 (17.5)	17.4 (16.0)	6.0 (14.9)	7.9 (16.5)	16.7 (27.3)	103.5 (44.8)
LRC	100.0 (72)	21.7 (55)	163.4 (61)	95.7 (66)	3.7 (49)	94.9 (50)
HQ	**378	2.0 (2.2)	-- (2.4)	2.0 (3.0)	5.4 (4.1)	5.3 (4.7)
All NASA	59.0 (115)	270 (137)	**917 (95)	62.2 (68)	44.9 (55)	38.6 (50)

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*Injuries counted relate to time lost from work. Autocorrelated data are in parenthesis. Autocorrelation was taken at 6-mo intervals with autocorrelation coefficient of 1 year.

**Omitted from autocorrelation as not a proper member of the data set.

Table VII-2 ERDA Injury Data

VII-2A *Frequency Lost Time Injuries/200,000 Man Hours

Year	1971	1972	1973	1974	1975	1976 (thru June)
ORNL (Union Carbide)	0.12 (.20)	0.28 (.25)	0.24 (.30)	0.27 (.39)	0.79 (.57)	0.65 (.63)
BNL (Columbia U)	0.45 (.54)	0.53 (.63)	.67 (.81)	-- (1.07)	-- (1.19)	1.12 (1.20)
LLL (U of Calif)	0.19 (.23)	0.19 (.24)	0.13 (.29)	0.33 (.46)	0.85 (.75)	1.54 (.98)
ANL (U of Chicago)	0.41 (.35)	0.30 (.31)	0.27 (.29)	0.27 (.28)	0.30 (.28)	0.174 (.26)
LASL (U of Calif)	0.31 (.36)	0.43 (.39)	0.33 (.39)	0.40 (.42)	0.51 (.48)	0.62 (.51)
Average of Above	0.30 (.34)	0.33 (.36)	0.33 (.42)	0.26 (.52)	1.01 (.65)	0.82 (.72)

VII-2B *Severity - Man Days Lost/Million Man Hours

Year	1971	1972	1973	1974	1975	1976 (thru June)
ORNL	298 (188)	52 (105)	23 (54)	23 (34)	16.5 (24)	4.0 (19.2)
BNL	85 (80)	76 (72)	60 (58)	9 (47)	73 (59)	96 (70)
LLL	5 (25)	20 (46)	152 (69)	21 (51)	26 (37)	42 (36)
ANL	70 (51)	29 (37)	**1624 (27)	15 (23)	32 (25)	11.4 (24)
LASL	**744 (52)	55 (49)	39 (42)	**650 (36)	26 (31)	36 (31)
Average of Above	(79)	(62)	(50)	(38)	(35)	(36)

*Autocorrelated data are in parenthesis. Autocorrelation was taken at 6-mo intervals with autocorrelation coefficient of 1 year.

**Omitted from autocorrelation as not a proper member of the data set.

Table VII-3A Aerospace Industry Injury Frequency Data

*Lost Time Injuries/200,000 Man Hours

Year	1971	1972	1973	1974	1975	1976
Air Frame	0.37 (.39)	0.44 (.39)	0.38 (.36)	0.26 (.32)	0.28 (.31)	0.39 (.32)
Engine	0.70 (.63)	0.52 (.59)	0.66 (.58)	0.49 (.54)	0.49 (.51)	0.48 (.50)
Electronics	0.25 ((.26)	0.29 (.27)	0.26 (.28)	0.30 (.30)	0.37 (.32)	0.25 (.32)
R&D	0.16 (.22)	0.32 (.24)	0.16 (.24	0.25 (.26)	0.36 (.31)	0.39 (.34)
All Aerospace	0.34 (.31)	0.38 (.35)	0.34 (.33)	0.27 (.31)	0.28 (.30)	0.38 (.31)

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*Autocorrelated data are in parenthesis. Autocorrelation was taken at 6-mo intervals with autocorrelation coefficient of 1 year.

Table VII-3B. Aerospace Industry Injury Severity Data (Based on Z16.1 Reports)

Lost Time Days / Million Manhours Worked

Year	1972	1973	1974	1975	4-Yr Average
Air Frame			204		182
		160			
Engine			119		115
		111			
Electronics			49		55
		61			
R&D			518		490
		462			
Rocket Engine			200		208
		216			
All Aerospace			240		225
		210			

Table VII-4 Comparison of Average Lost-Time Occupational Injury Severity Rates

Days Lost Per Million Man Hours Worked
1972-1976

Rank	Agency/Industry	Av. Severity Rate	Years
1	All Industry	656	1972-75
2	All Aerospace R&D	490	1972-75
3	All Aerospace	225	1972-75
4	All Fed. Gov't. Civilian Employees	114	1972-74
5	All NASA	104	1972-76
6	LRC	76	1972-76
7	GSFC	30	1972-76
8	Headquarters	4	1972-76

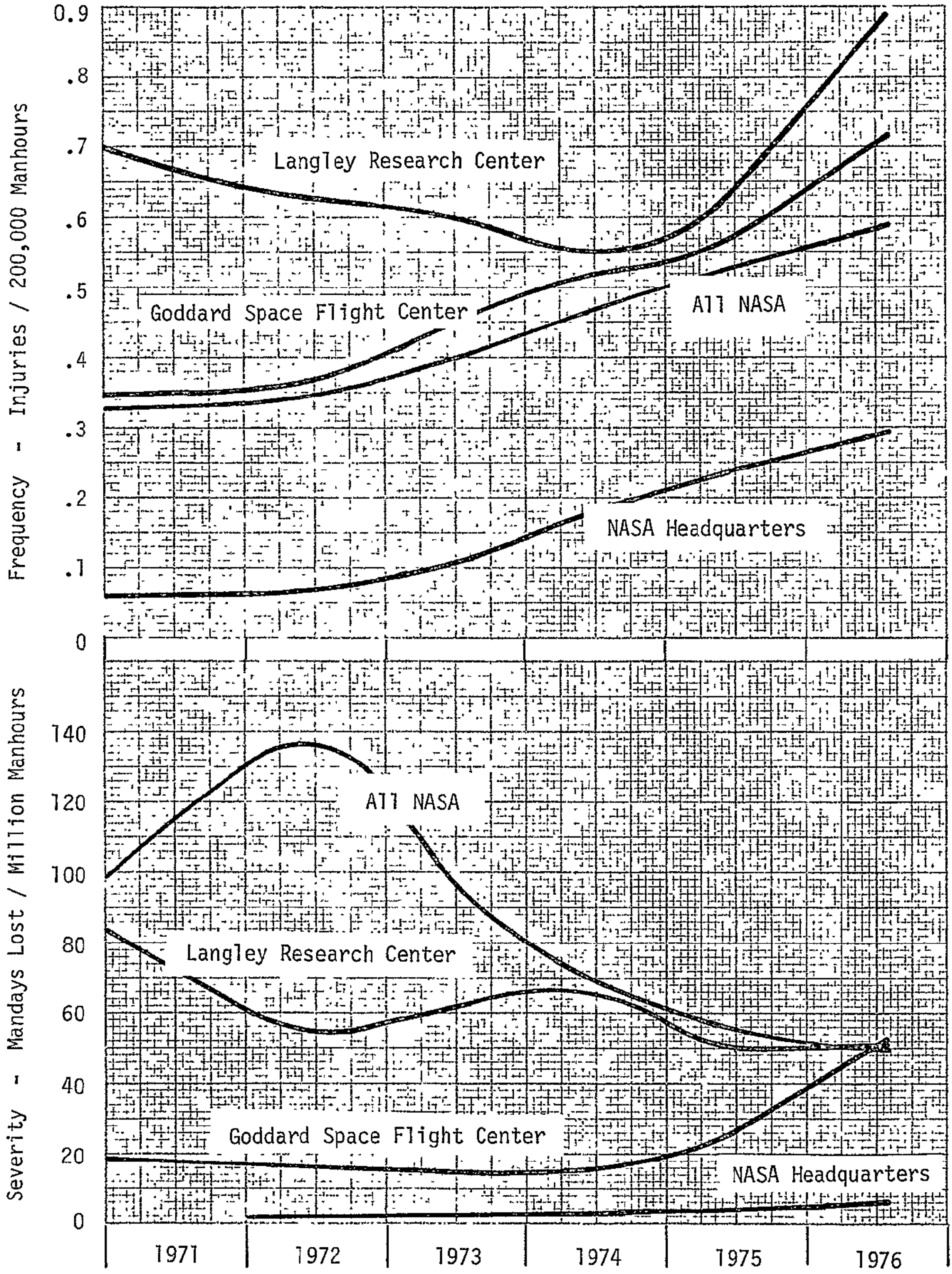

Fig. VII-1 Autocorrelation Images of NASA Injury Data
Cf. Table

more minor accidents of very little consequence to real "loss" are being reported in recent years. If the same spectrum of real accidents were maintained as in 1972 and frequency of these accidents increased at the rate shown in Fig. VII-1 then all autocorrelated severity values would have to increase. The fact that they do not and are markedly decreased, while the employee population has been reduced during this same period by 18%, indicates that the literal interpretation of accident reporting rules imposed by OSHA by NASA Safety Office administrative personnel is the most plausible reason for the marked rise in frequency data that has been reported over the last five years.

While there is no doubt that these injury events are real, they are not significant to the total loss picture. Severity frequencies in this case are the significant parameter and do follow the real trends expected from a drop in agency personnel and a continual upgrading of industrial safety programs stimulated by both NASA and OSHA activities over the past five years.

Fig. VII-2 details the accident frequency and severity histogram of five ERDA R&D centers. The most important observation on this set of figures compared to Fig. VII-1 is that the trends of both the frequency and severity indices generally match what has been observed at NASA for the same periods. That is, frequency data shows a definite upward trend on the ERDA average curve and severity is markedly decreasing during this same period. Even the absolute magnitude of the average "Frequency" and "Severity" histories of NASA and the five selected ERDA laboratories is remarkably similar.

Therefore, Fig. VII-2 yields further corroboration to the significance of the change in reporting systems from Z16.1 to OSHA 102 on the interpretation of real occupational injury "Loss" information. Fig. VII-3 shows the autocorrelation images of aerospace industry industrial accident frequencies from 1971 - 1976, while Table VII-3B shows the available information on average severity for this same period in the industry.

Unlike both NASA and ERDA, frequency and severity profiles in the aerospace industry for the last five years have been almost constant. The engine and airframe portions of the industry exhibit a 20 - 25% drop in frequency and while the electronics and R&D portions of the industry compensate by increasing their frequencies by about the same amount. It is difficult to specify why this type of a trend is appearing

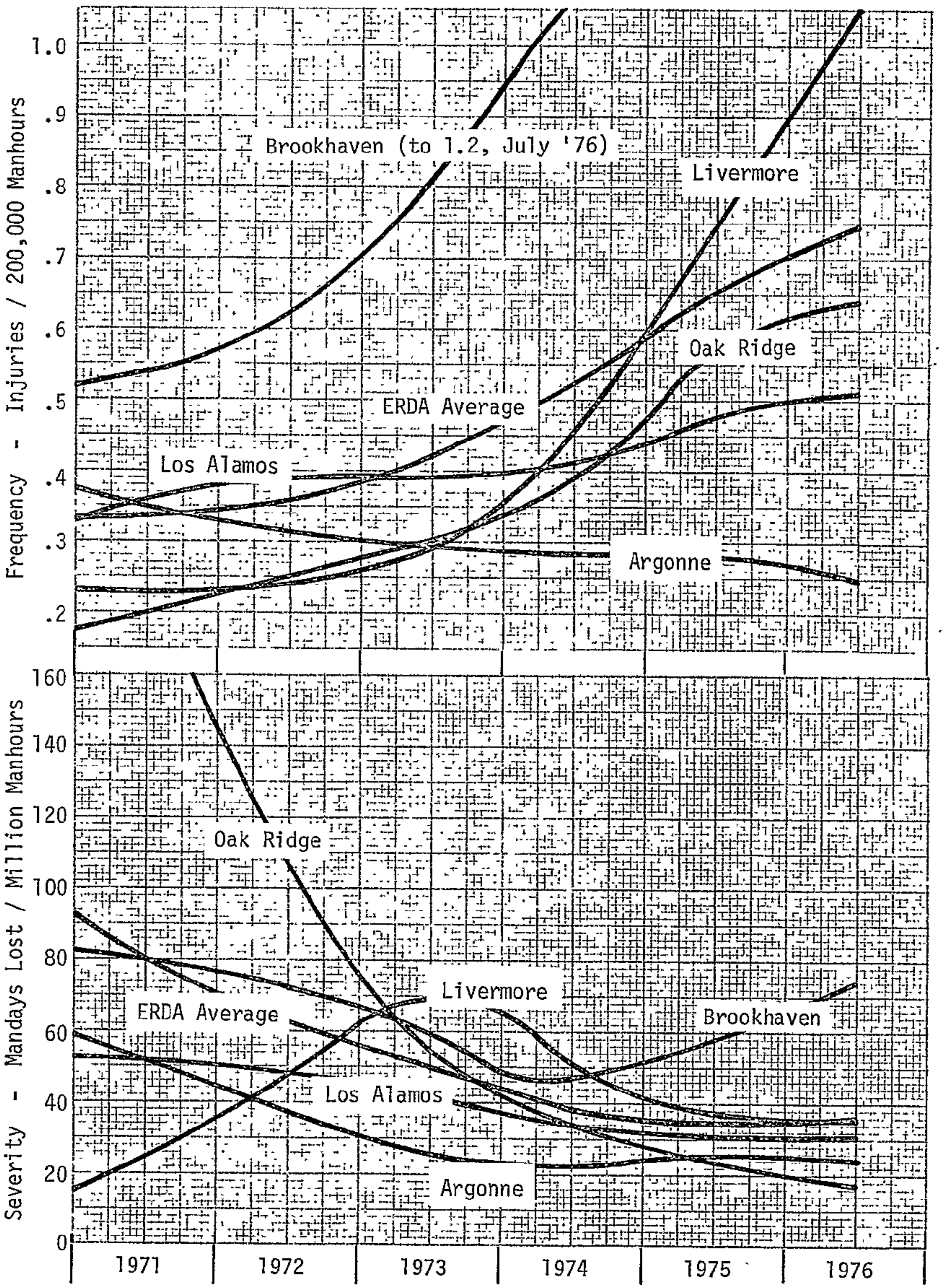

Fig. VII-2 Autocorrelation Images of ERDA National Laboratory Injury Data
Cf. Table

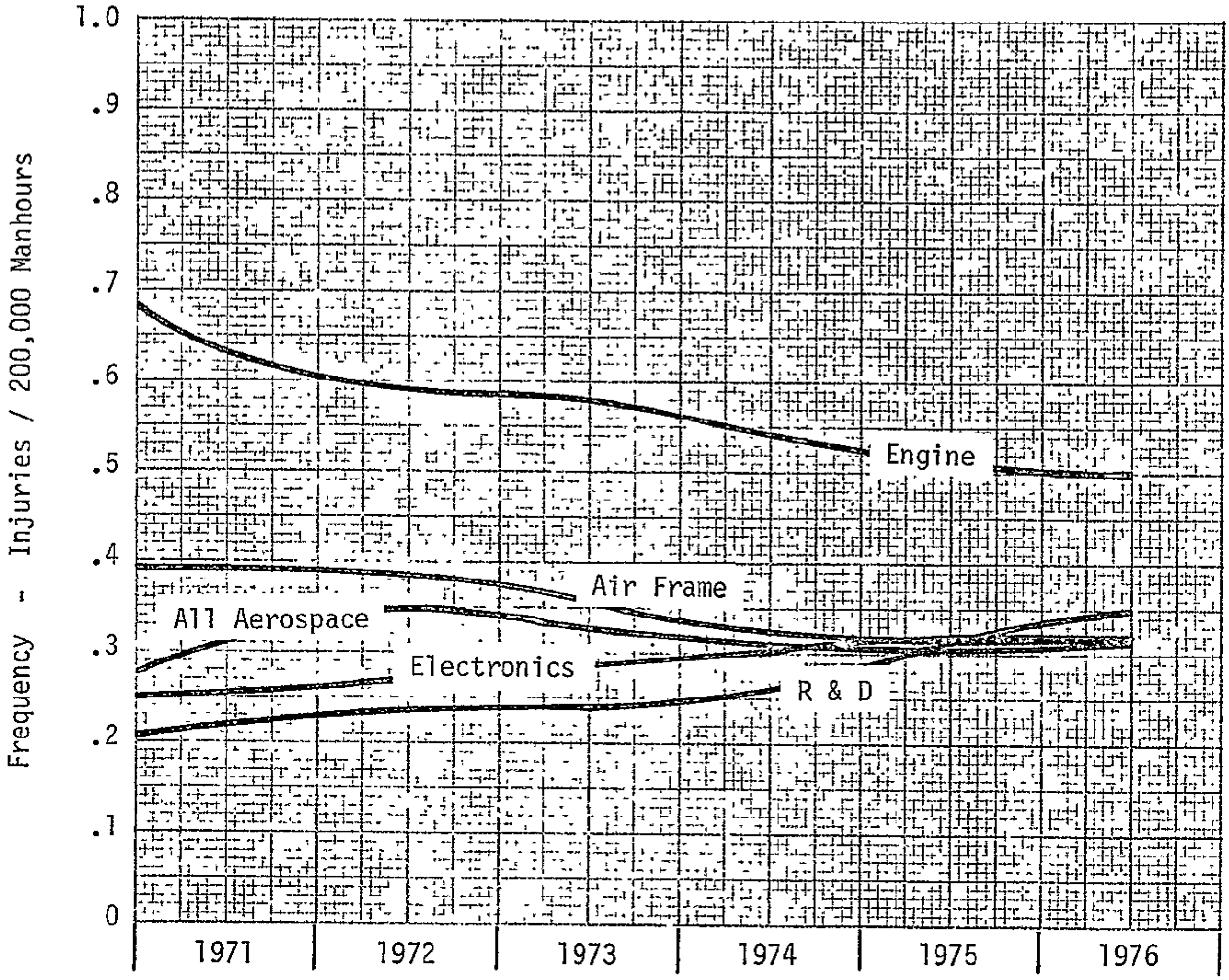

Fig. VII-3 Autocorrelation Image of Aerospace Industry Data
Cf. Table

without further indepth analysis of this industry. However, it is felt that both the engine and airframe portions of the aerospace industry can respond well to the classic OSHA formula for reducing industrial accidents. The electronics and R&D portions of the industry, however, experience more unique and constantly changing work environments, processes and production requirements which are not as easily controlled due to their transient and new character as the more stereotyped industrial environment in the engine and airframe part of the business.

Because of the existence of only average values of severity data over the last five years in this industry, not much can be said about the trends in real lost time except that they are on the average higher by a factor of five to six than NASA's and ERDA's and that they have not changed markedly from 1972 - 1975.

Fig. VII-4 summarizes the relative occupational injury frequency performance of industry, government, ERDA labs, NASA and the aerospace industry between 1971 and 1976. Of most significance is the relative position of NASA to all government and industry. Although NASA has increased its accidental injury frequency rate during the last several years, its rate of change as an agency is only about half of the rate of increase in frequency experienced by all government and all industry.

However, average severities during this same period for NASA are very close to all of government as shown in Table VII-4 and are about 1/6th those of all American industry, 1/5 of the severities in the aerospace R&D portion of the aerospace industry and about 1/2 those found in the total aerospace industry.

Again, the marked increase in all government injury frequency rates since 1974 is most probably based on the change-over from Z16.1 to OSHA reportingformats. This momentum is reflected in both the frequency trends of ERDA and NASA while the aerospace industry stays about constant reflecting increased safety in the heavy manufacturing side balanced by poorer performance in the R&D section due to drops in funding and personnel which foster cheaper operations in a hazardous experimental environment not inherently protected by tried procedures and methods as in the volume manufacturing side of the industry.

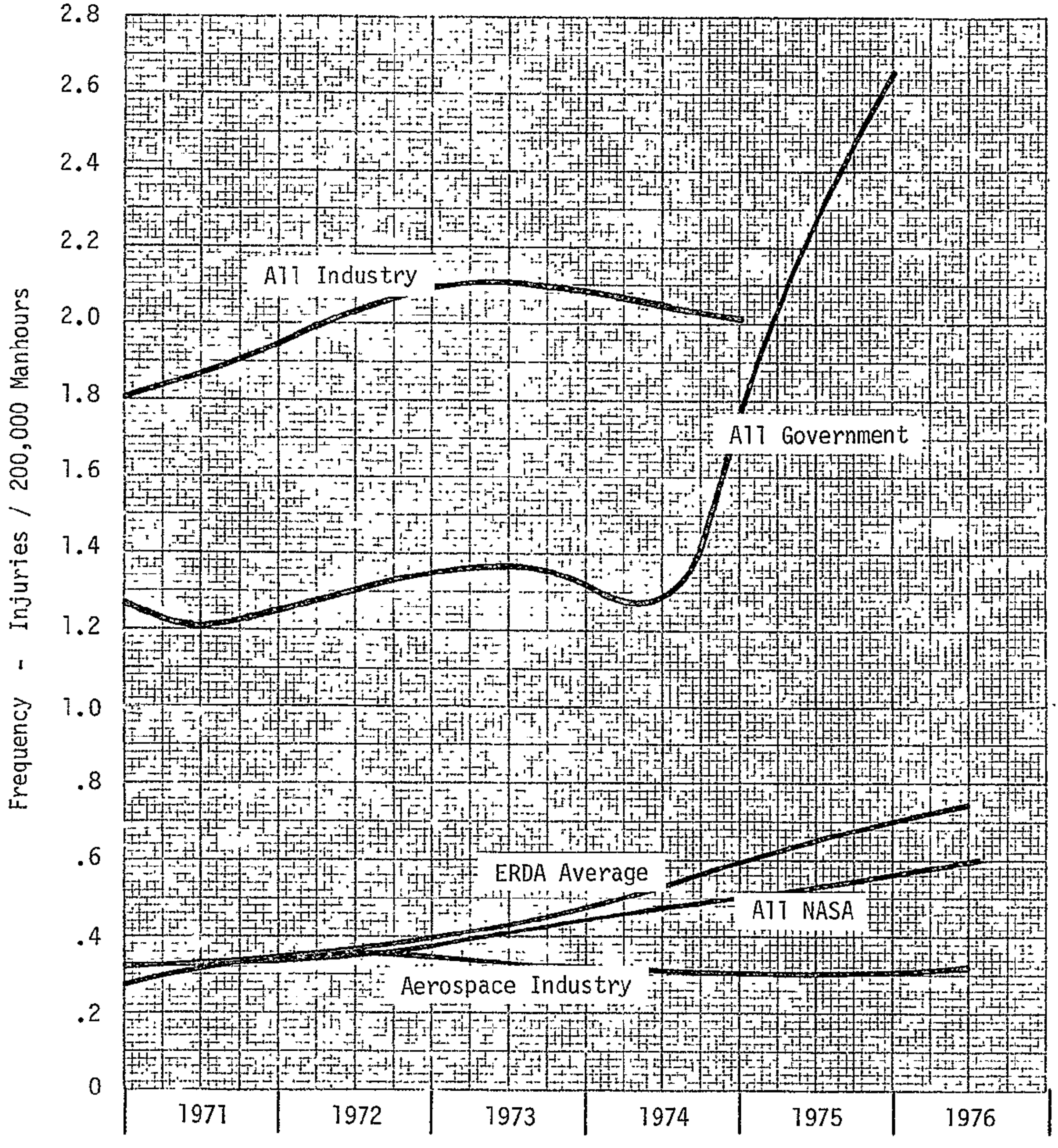

Fig. VII-4 Comparison of Injury Frequencies, All NASA, Aerospace Industry, ERDA Average, All Government, and All Industry (Autocorrelation Images)

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VIII. REFERENCES

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IX APPENDIXES

IX. APPENDIXES

A. Executive Order 11807 and the Occupational Safety and Health Act of 1970

B. Calculator Programs

APPENDIX "A"

Executive Order 11807 and the
Occupational Safety and Health Act of 1970

EXECUTIVE ORDER 11807

Occupational Safety and Health Programs for Federal Employees

As the Nation's largest employer, the Federal Government has a special obligation to set an example for all employers by providing a safe and healthful working environment for its employees.

For more than three years, the Federal Government has been seeking to carry out these solemn responsibilities under the terms of Executive Order No. 11612, issued in 1971 and based upon the authorities granted by the landmark Occupational Safety and Health Act of 1970 as well as section 7902(c) of title 5, United States Code.

Considerable progress has been achieved under the 1971 executive order, but it is now clear that even greater efforts are needed. It is therefore necessary that a new order be issued, reflecting this Nation's firm and renewed commitment to provide exemplary working conditions for those devoted to public service.

The provisions of this order are intended to ensure that each agency head is provided with all the guidance necessary to carry out an effective occupational safety and health program within the agency. Further, to keep the President abreast of progress, this order provides for detailed evaluations of the agencies' occupational safety and health programs by the Secretary of Labor and transmittal of those evaluations, together with agency comments, to the President. In addition, the Federal Safety Advisory Council on Occupational Safety and Health is continued because of its demonstrated value as an advisory body to the Secretary of Labor.

Experience has shown that agency heads desire and need more detailed guidance from the Secretary of Labor to make their occupational safety and health programs more effective. This order provides that the Secretary of Labor shall issue detailed guidelines and provide such further assistance as the agencies may request.

NOW, THEREFORE, by virtue of the authority vested in me by section 7902(c) (1) of title 5 of the United States Code, and as President of the United States, it is hereby ordered as follows:

Scope of This Order

SECTION 1. For the purposes of this order, the term "agency" means an Executive Department, as defined in 5 U.S.C. 101, or any employing unit or authority of the Government of the United States not within an Executive Department. This order applies to all agencies of the Executive Branch of the Government: and by agreement between the Secretary of Labor (hereinafter referred to as the Secretary) and the head of an agency of the Legislative or Judicial Branches of the Government, the provisions of this order may be made applicable to such agencies. In addition, by agreement between the Secretary of Labor and the head of any agency, and to the extent permitted by law, the provisions of this order may be extended to employees of agencies who are employed in geographic locations to which the Occupational Safety and Health Act of 1970 is not applicable.

Duties of Heads of Agencies

SEC. 2. The head of each agency shall, after consultation with representatives of the employees thereof, establish and maintain an occupational safety and health program meeting the requirements of section 19 of the Occupational Safety and Health Act (hereinafter referred to as the act). In order to ensure that agency programs are consistent with the standards prescribed by section 6 of the act, the head of each agency shall:

(1) Designate or appoint, to be responsible for the management and administration of the agency occupational safety and health program, an agency official with sufficient authority to represent effectively the interest and support of the agency head.

(2) Establish an occupational safety and health management information system, which shall include the maintenance of such records of occupational accidents, injuries, illnesses and their causes, and the compilation and transmittal of such reports based upon this information, as the Secretary may require pursuant to section 3 of this order.

(3) Establish procedures for the adoption of agency occupational safety and health standards consistent with the standards promulgated by the Secretary pursuant to section 6 of the act; assure prompt attention to reports by employees or others of unsafe or unhealthful working conditions; assure periodic inspections of agency workplaces by personnel with sufficient technical competence to recognize unsafe and unhealthful working conditions in such workplaces; and assure prompt abatement of unsafe or unhealthful working conditions, including those involving facilities and/or equipment furnished by another Government agency, informing the Secretary of significant difficulties encountered in this regard.

(4) Provide adequate safety and health training for officials at the different management levels, including supervisory employees, employees responsible for conducting occupational safety and health inspections, and other employees. Such training shall include dissemination of information concerning the operation of the agency occupational safety and health program and the means by which each such person may participate and assist in the operation of that program.

(5) Submit to the Secretary on an annual basis a report containing such information as the Secretary shall prescribe.

(6) Cooperate with and assist the Secretary of Labor in the performance of his duties under section 19 of the act and section 3 of this order.

(7) Observe the guidelines published by the Secretary pursuant to section 3 of this order, giving due consideration to the mission, size and organization of the agency.

Duties of the Secretary of Labor

SEC. 3. The Secretary shall provide leadership and guidance to the heads of agencies to assist them in fulfilling their occupational safety and health responsibilities by, among other means, taking the following actions:

(1) Issue detailed guidelines to assist agencies in establishing and operating effective occupational safety and health programs appropriate to their individual missions, sizes, and organizations. Such guidelines shall reflect the requiement of section 19 of the act for consultation with employee representatives.

(2) Prescribe recordkeeping and reporting requirements to enable agencies to assist the Secretary in meeting the requirements imposed upon him by section 24 of the act.

(3) Provide such consultation to agencies as the Secretary deems necessary and appropriate to ensure that agency standards adopted pursuant to section 2 of this order are consistent with the safety and health standards adopted by the Secretary pursuant to section 6 of the act; provide leadership and guidance to agencies in the adequate occupational safety and health training of agency personnel; and facilitate the exchange of ideas and information throughout the Government with respect to matters of occupational safety and health through such arrangements as the Secretary deems appropriate.

(4) Perform for agencies, where deemed necessary and appropriate, the following services, upon request and reimbursement for the expenses thereof: (a) evaluate agency working conditions; and recommend to the agency head appropriate standards to be adopted pursuant to section 2 of this order to ensure that such working conditions are safe and healthful; (b) conduct inspections to identify unsafe or unhealthful working conditions, and provide assistance to correct such conditions; (c) train appropriate agency safety and health personnel.

(5) Evaluate the occupational safety and health programs of agencies, and submit to the President reports of such evaluations, together with agency responses thereto. These evaluations shall be conducted at least once annually for agencies employing more tha 1,000 persons within the geographic locations to which the act applies, and as the Secretary deems appropriate for all other agencies, through such headquarters or field reviews as the Secretary deems necessary.

(6) Submit to the President each year a summary report of the status of the Federal agency occupational safety and health program, as well as analyses of individual agency progress and problems in correcting unsafe and unhealthful working conditions, together with recommendations for improving their performance.

Federal Advisory Council on Occupational Safety and Health

SEC. 4. (a) The Federal Advisory Council on Occupational Safety and Health, established pursuant to Executive Order No. 11612, is hereby continued. It shall advise the Secretary in carrying out responsibilities under this order. This Council shall consist of fifteen members appointed by the Secretary and shall include representatives of Federal agencies and of labor organizations representing employees. At least five members shall be representatives of such labor organizations. The members shall serve for three-year terms with the terms of five members expiring each year, provided that this Council is renewed every two years in accordance with the Federal Advisory Committee Act. The members of the Federal Advisory Council on Occupational Safety and Health established pursuant to Executive Order No. 11612 shall be deemed to be its initial members under this order, and their terms shall expire in accordance with the terms of their appointments.

(b) The Secretary, or a designee, shall serve as the Chairman of the Council, and shall prescribe such rules for the conduct of its business as he deems necessary and appropriate.

(c) The Secretary shall make available necessary office space and furnish the Council necessary equipment, supplies, and staff services, and shall perform such functions with respect to the Council as may be required by the Federal Advisory Committee Act.

Effect on Other Powers and Duties

SEC. 5. Nothing in this order shall be construed to impair or alter the powers and duties of the Secretary or heads of other Federal agencies pursuant to section 19 of the Occupational Safety and Health Act of 1970, sections 7901, 7902, and 7903 of title 5 of the United States Code, or any other provision of law, nor shall it be construed to alter the provisions of Executive Order No. 11491, as amended, Executive Order No. 11636, or other provisions of law providing for collective bargaining agreements and procedures. Matters of official leave for employee representatives involved in activities pursuant to this order shall be determined between each agency and these representatives pursuant to the procedures under Executive Order No. 11491, as amended, Executive Order No. 11636, or applicable collective bargaining agreements.

Termination of Existing Order

SEC. 6. Executive Order No. 11612 of July 26, 1971, is hereby superseded.

The White House
September 28, 1974.

Gerald R. Ford

(Filed with the Office of the Federal Register, 1:30 p m., September 30, 1974)

Public Law 91-596
91st Congress, S. 2193
December 29, 1970

An Act

84 STAT. 1590

To assure safe and healthful working conditions for working men and women; by authorizing enforcement of the standards developed under the Act; by assisting and encouraging the States in their efforts to assure safe and healthful working conditions; by providing for research, information, education, and training in the field of occupational safety and health; and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Occupational Safety and Health Act of 1970".

Occupational Safety and Health Act of 1970.

CONGRESSIONAL FINDINGS AND PURPOSE

SEC. (2) The Congress finds that personal injuries and illnesses arising out of work situations impose a substantial burden upon, and are a hindrance to, interstate commerce in terms of lost production, wage loss, medical expenses, and disability compensation payments.

(b) The Congress declares it to be its purpose and policy, through the exercise of its powers to regulate commerce among the several States and with foreign nations and to provide for the general welfare, to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources—

(1) by encouraging employers and employees in their efforts to reduce the number of occupational safety and health hazards at their places of employment, and to stimulate employers and employees to institute new and to perfect existing programs for providing safe and healthful working conditions;

(2) by providing that employers and employees have separate but dependent responsibilities and rights with respect to achieving safe and healthful working conditions;

(3) by authorizing the Secretary of Labor to set mandatory occupational safety and health standards applicable to businesses affecting interstate commerce, and by creating an Occupational Safety and Health Review Commission for carrying out adjudicatory functions under the Act;

(4) by building upon advances already made through employer and employee initiative for providing safe and healthful working conditions;

(5) by providing for research in the field of occupational safety and health, including the psychological factors involved, and by developing innovative methods, techniques, and approaches for dealing with occupational safety and health problems;

(6) by exploring ways to discover latent diseases, establishing causal connections between diseases and work in environmental conditions, and conducting other research relating to health problems, in recognition of the fact that occupational health standards present problems often different from those involved in occupational safety;

(7) by providing medical criteria which will assure insofar as practicable that no employee will suffer diminished health, functional capacity, or life expectancy as a result of his work experience;

(8) by providing for training programs to increase the number and competence of personnel engaged in the field of occupational safety and health;

(9) by providing for the development and promulgation of occupational safety and health standards;

(10) by providing an effective enforcement program which shall include a prohibition against giving advance notice of any inspection and sanctions for any individual violating this prohibition;

(11) by encouraging the States to assume the fullest responsibility for the administration and enforcement of their occupational safety and health laws by providing grants to the States to assist in identifying their needs and responsibilities in the area of occupational safety and health, to develop plans in accordance with the provisions of this Act, to improve the administration and enforcement of State occupational safety and health laws, and to conduct experimental and demonstration projects in connection therewith;

(12) by providing for appropriate reporting procedures with respect to occupational safety and health which procedures will help achieve the objectives of this Act and accurately describe the nature of the occupational safety and health problem;

(13) by encouraging joint labor-management efforts to reduce injuries and disease arising out of employment.

DEFINITIONS

SEC. 3. For the purposes of this Act—

(1) The term "Secretary" mean the Secretary of Labor.

(2) The term "Commission" means the Occupational Safety and Health Review Commission established under this Act.

(3) The term "commerce" means trade, traffic, commerce, transportation, or communication among the several States, or between a State and any place outside thereof, or within the District of Columbia, or a possession of the United States (other than the Trust Territory of the Pacific Islands), or between points in the same State but through a point outside thereof.

(4) The term "person" means one or more individuals, partnerships, associations, corporations, business trusts, legal representatives, or any organized group of persons.

(5) The term "employer" means a person engaged in a business affecting commerce who has employees, but does not include the United States or any State or political subdivision of a State.

(6) The term "employee" means an employee of an employer who is employed in a business of his employer which affects commerce.

(7) The term "State" includes a State of the United States, the District of Columbia, Puerto Rico, the Virgin Islands, American Samoa, Guam, and the Trust Territory of the Pacific Islands.

(8) The term "occupational safety and health standard" means a standard which requires conditions, or the adoption or use of one or more practices, means, methods, operations, or processes, reasonably necessary or appropriate to provide safe or healthful employment and places of employment.

(9) The term "national consensus standard" means any occupational safety and health standard or modification thereof which (1), has been adopted and promulgated by a nationally recognized standards-producing organization under procedures whereby it can be determined by the Secretary that persons interested

and affected by the scope or provisions of the standard have reached substantial agreement on its adoption, (2) was formulated in a manner which afforded an opportunity for diverse views to be considered and (3) has been designated as such a standard by the Secretary, after consultation with other appropriate Federal agencies.

(10) The term "established Federal standard" means any operative occupational safety and health standard established by any agency of the United States and presently in effect, or contained in any Act of Congress in force on the date of enactment of this Act.

(11) The term "Committee" means the National Advisory Committee on Occupational Safety and Health established under this Act.

(12) The term "Director" means the Director of the National Institute for Occupational Safety and Health.

(13) The term "Institute" means the National Institute for Occupational Safety and Health established under this Act.

(14) The term "Workmen's Compensation Commission" means the National Commission on State Workmen's Compensation Laws established under this Act.

APPENDIX B. CALCULATOR PROGRAMS

Two programs entitled, "Autocorrelation" and Day-Count" were written and used to process data presented in this report. The calculator used was a Texas Instruments SR-52. Listings for these programs, which follow, were prepared on Texas Instrument PPX-52 forms. The programs can be readily rewritten for a Hewlett-Packard HP-67 programmable calculator or for any scientific computer. In the latter instance, the programs or major fractions thereof may exist as library subroutines.

Abstract

Program Title: Autocorrelation	Rev

Description of Program:

An image of a set of data is formed by autocorrelation. The image, which is also a set of data, is, in general, much smoother than the original set. The autocorrelative technique used is both symmetric and conservative in effect.

User Benefits:

The objective of an autocorrelation of a set of data is to ascribe to the set, through the means of an image, attributes of a smooth and continuous function, e.g., maxima, minima, periodicity.

Category	Related Progs.	Prog Steps	Data Registers
29	ST1-14 *	319	20

*Program Manual ST1, <u>Statistics Library</u>, Texas Instruments Inc., Dallas, Texas

Program Description

Program Title: Autocorrelation	Rev.

Method, Equations, Sketches, Limitations, References:

The autocorrelation of a function removes its fine structure, usually its more random qualities. The objective of an autocorrelation is to disclose some fundamental characteristics of the function, i.e., maxima or minima or periodicity. The relative effect of the process is determined by a coefficient, a small coefficient having a small effect and a very large coefficient essentially reducing the function to a constant (the mean value of the function on the range being considered). An advantage of autocorrelation over regression, the formal means, commonly used, for removing fine structure, is that the latter process is constrained to a specific equation or equation set.

Autocorrelation is a rather general term and there are formulations of more or less sophistication. The following is both symmetric and conservative. In terms of continuous functions, the autocorrelation of f(x) yields the image, $\tilde{f}(x)$;

$$\tilde{f}(x) = \frac{\int_{\lambda=0}^{x^*} f(\lambda)\,d\lambda}{\int_{\lambda=0}^{x^*} j(\lambda)\,d\lambda} \cdot j(x), \qquad (1)$$

$$j(x) = \int_{\lambda=x^*}^{0} h(\lambda)\, e^{-\frac{x \pm \lambda}{\alpha}}\, d\lambda, \qquad (2)$$

$$h(x) = \int_{\lambda=0}^{x^*} f(x-\lambda)\, e^{-\frac{\lambda}{\alpha}}\, d\lambda, \qquad (3)$$

and where, of course, $x \leq x^*$ and α is the coefficient of the autocorrelation. (Equations (2) and (3) are known as convolution integrals.)

X Continued on attached sheets

This program evaluates eq. (3), (2), and (1) numerically using the trapezoidal rule. The program takes a set f_i, comprised of up to 14 data, corresponding to the function f(x), and yields a set $\tilde{f}_i$, corresponding to the image function $\tilde{f}(x)$. the datum points must be located on uniform intervals of the argument x. In cases where the number of data n exceeds 14, program ST1-14, Histogram Construction, can be used to reduce the number. The units of the coefficient α relate to the argument interval. If, e.g., α=2 and the argument interval is 6 mo, α = 2x6 mo = 1 y. The program uses two cards; card 1 yields an intermediate set c_i which the user must record on a work sheet and key-in later when card 2 is in use. (Set c_i is a correction vector which compensates for the coarseness of the integration.)

Figure 1 shows three images, calculated with the program, of a delta function located at i=7. Each of these images may be regarded as the density function for the probability distribution of the location of the delta function on the argument i. Thus, when α=1, an event, represented by the delta function, could have occurred at i=9 rather than at i=7, the odds being 0.076 ÷ 0.346 or about 1 out of 5.

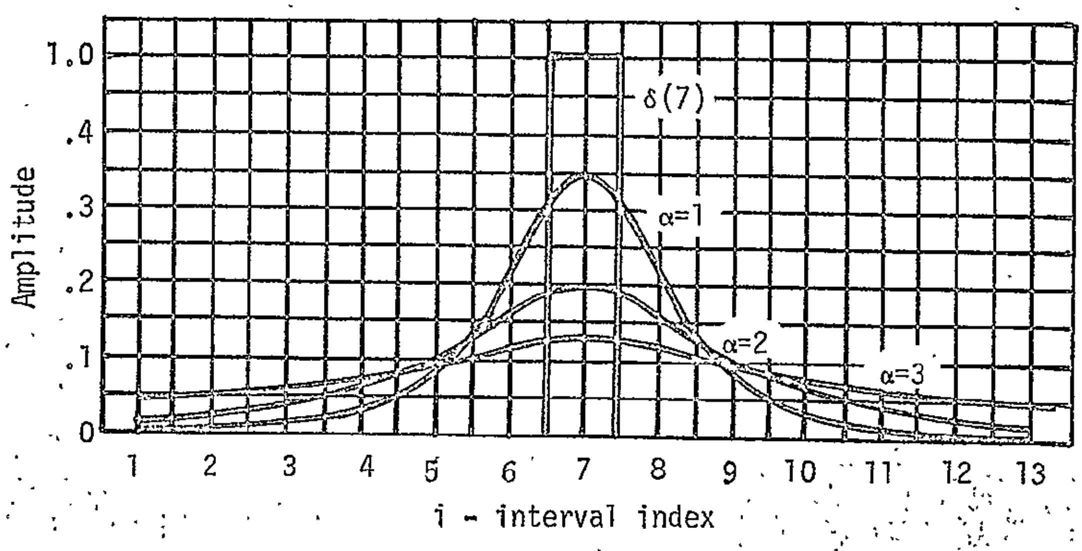

Fig. 1 Autocorrelation Images of a Delta Function

Figure 2 shows two images, calculated with the program, of a step function. The image of the step function is comprised of the sum of the images of delta functions, one located on each of the intervals, i=1,6. These image functions are conservative, viz., their integrals are equal to the integral of the original function, i.e., 6. Taking the probablistic view, for the given coefficients α, the respective images are analytically defensible density functions for the occurrence of six events.

- Robert Magladry

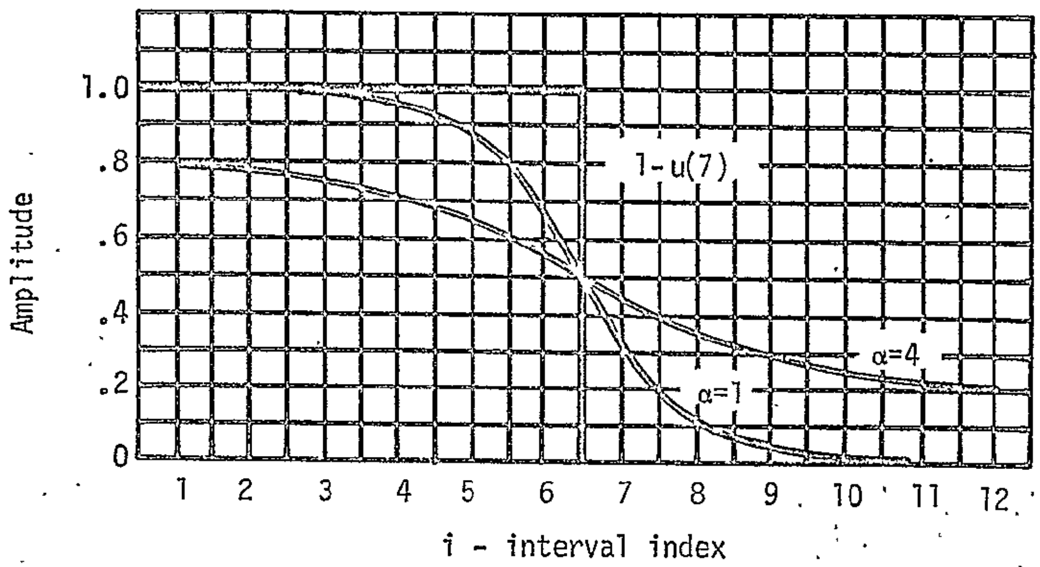

Fig. 2 Autocorrelation Images of a Step Function

Reference: W. Jay Merrill, Jr. and Corwin A. Bennett, The Application of Temporal Correlation Techniques in Psychology, "Journal of Applied Psychology", Vol. 40, No. 4, 1956

Sample Problem

Statement of Example

The average number of days lost from work per employee injury at a space flight center has been determined for 11 consecutive 6-mo intervals. These data comprise the following set. The index i to members of the set, of course, takes values 1 through 11.

f_i: 16.4, 24.3, 15.8, 14.2, 20.8, 58.2, 67.1, 4.0, 14.3, 41.0, 9.3.

Using an autocorrelation coefficient of 1 y, calculate the autocorrelation image set, $\tilde{f}_i$.

☐ Continued on attached sheets

ENTER	PRESS	DISPLAY	COMMENT
Load sides A and B of card 1.			
n = 11	A		
α = 2	B		1 y ÷ 6 mo
i = 1,11	C	c_i	
c_i: 2.479, 3.121, 3.497, 3.701, 3.786, 3.773, 3.66, 3.417, 2.982, 2.244, 1.016.			
	D	i = 1	Initialize
f_i	E	i + 1	
Load side A of card 2.			
	A	i = 1	Continue
c_i	C	i + 1	
	D		Continue
i = 1,11	E	$\tilde{f}_i$	
$\tilde{f}_i$: 20.1, 20.8, 21.7, 23.9, 28.3, 33.0, 33.1, 28.5, 25.8, 25.6, 24.4.			

☒ Over

Sample Problem (cont'd)

ENTER	PRESS	DISPLAY	COMMENT

The value of α used in the foregoing example was determined by trial and error. It is the lowest whole-number value which did not produce a 6-mo ripple in the autocorrelation image.

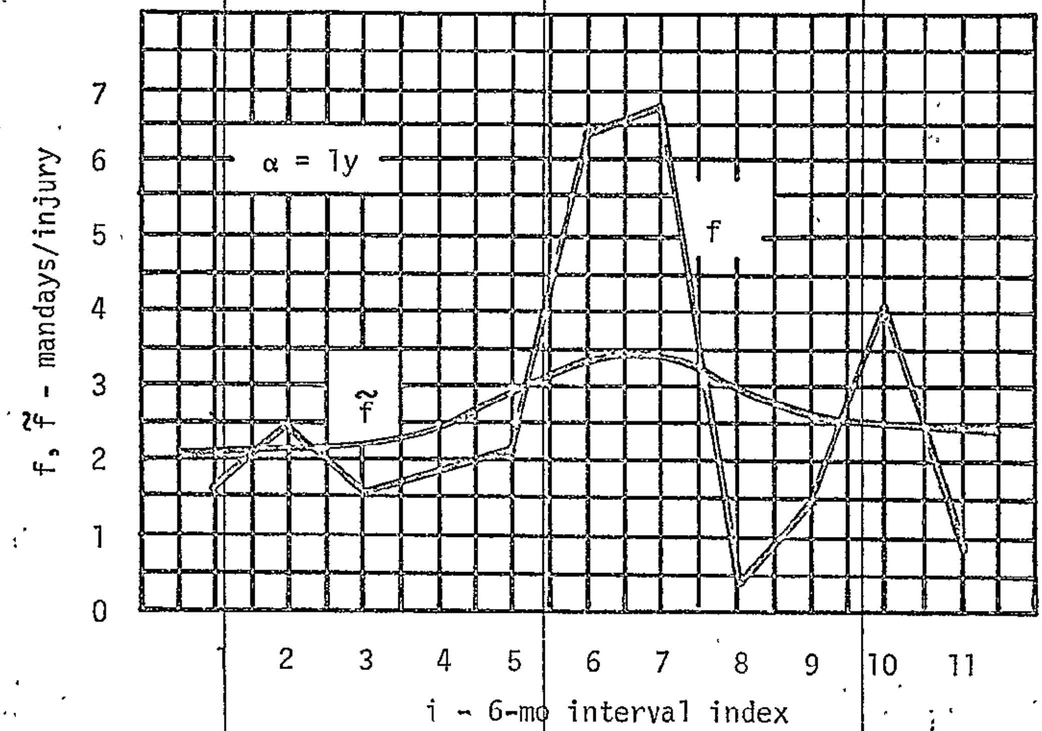

Fig. 3 Raw Data and Autocorrelation Image of Foregoing Example

Program Title Autocorrelation

User Instructions

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
	Note: Program will handle $n \le 14$.			
1	Load sides A and B of card 1.			0
2	Enter number of data.	n	A	1.
3	Enter coefficient.	α	B	
	(When n = 14, running time to step 4 is approx 3.6 m)			--
	Do step 4, i = 1, n; record c_i on work sheet.			
4	Display correction set.	i	C	c_i
5	Initialize.		D	i=1
	Do step 6, i = 1, n.			
6	Enter data set.	f_i	E	i+1
7	Load side A of card 2.			0
8	Continue program.		A	
	(When n = 14, running time to step 9 is approx 3.6 m)			i=1
	Do step 9, i = 1, n.			
9	Enter correction set from work sheet.	c_i	C	i+1
10	Continue program.		D	--
	Do step 11, i = 1, n.			
11	Display autocorrelated data.	i	E	$\tilde{f}_i$
12	To run another data set, load side A of card 1 and go to step 2 or 5.			0

USER DEFINED KEYS

	Card 1		Card 2
A	n	A	Continue
B	α	B	
C	i	C	c_i
D	Initialize	D	Continue
E	f_i	E	$\tilde{f}_i$

REGISTERS

00	i, m, n, i	10	
01	c_1, f_1	11	
02		12	
03		13	
04		14	c_{14}, f_{14}
05		15	Sum f_i
06		16	$-\alpha$
07		17	f_m
08		18	i, b
09		19	n
98		99	
0		5	
1		6	
2		7	
3		8	
4		9	

FLAGS

0	1	2	3	4

LABELS

INV	GTO	)	HLT	[illegible]	[illegible]	× 2'	[illegible]
lnx	STO	÷	RUN	[illegible]	[illegible]	× 3'	[illegible]
CE	RCL	×	[illegible]	[illegible]	[illegible]	4'	[illegible]
CLR	SUM	−	[illegible]	[illegible]	[illegible]	5'	[illegible]
sin	yˣ	+	[illegible]	[illegible]	[illegible]	6'	[illegible]
cos	SBR	=	[illegible]	[illegible]	[illegible]	7'	[illegible]
tan	EE	.	[illegible]	[illegible]	[illegible]	8'	
∜	(	+/−	[illegible]	[illegible]	× 1'	9'	

Listing - Card 1

LOC	CODE	KEY	COMMENTS
000	46 11	*LBL A	n input
002	42 01 09	STO 19	
005	42 00 00	STO 00	
008	01	1	
009	36 42 00 00	*IND STO 00	
013	58 00 00 08	*DSZ 008	
017	81	HLT	
018	46 12	*LBL B	α input
020	94	+/-	−α
021	42 01 06	STO 16	
024	51 88	SBR *2	Convolute
026	51 89	SBR *3	Reverse
028	51 88	SBR *2	Convolute
030	51 89	SBR *3	Reverse
032	81	HLT	
033	46 13	*LBL C	i input
035	42 00 00	STO 00	
038	36 43 00 00	*IND RCL 00	c_i
042	81	HLT	display
043	46 14	*LBL D	initialize
045	01 42 00 00	1 STO 00	i=1
049	81	HLT	display
050	46 15	*LBL E	f_i input
052	36 42 00 00	*IND STO 00	
056	01 44 00 00	1 SUM 00	
060	43 00 00	RCL 00	i+1
063	81	HLT	display
064 thru 071	blank		

LOC	CODE	KEY	COMMENTS
	Summation	Subroutine	
072	46 87	*LBL *1	
074	43 01 09	RCL 19	n
077	42 00 00	STO 00	
080	36 43 00 00	*IND RCL 00	g_i
084	85	+	
085	58 00 08 00	*DSZ 080	
089	00 95	0 =	Sum g_i
091	56	*RTN	
	Convolution	Subroutine	
092	46 88	*LBL *2	
094	43 01 09	RCL 19	n
097	42 00 00	STO 00	initial m
100	01	1	m-loop
101	42 01 08	STO 18	initial i
104	36 43 00 00	*IND RCL 00	g_m
108	65 93 05 95	x .5 =	
112	42 01 07	STO 17	f_m
115	22	INV	i-loop
116	58 01 04 07	*DSZ 147	i-exit
120	43 01 08	RCL 18	i
123	55	÷	
124	43 01 06 95	RCL 16 =	-i/α
128	22 23	INV ln x	
130	65	x	
131	36 43 00 00	*IND RCL 00	g_{m-i}
135	95	=	
136	44 01 07	SUM 17	f_m
139	01 44 01 08	1 SUM 18	i+1
143	41 01 01 05	GTO 115	i-return
147	43 01 07	RCL 17	

LOC	CODE	KEY	COMMENTS
150	36 42 01 08	*IND STO 18	
154	43 01 08	RCL 18	i+1
157	75 01 95	- 1 =	m-1
160	90 01 07 01	*IF 0 171	m-exit
164	42 00 00	STO 00	
167	41 01 00 00	GTO 100	m-return
171	56	*RTN	
	Reversal	Subroutine	
172	46 89	*LBL *3	
174	01 42 01 08	1 STO 18	i
178	43 01 09	RCL 19	
181	42 00 00	STO 00	n
184	36 43 00 00	*IND RCL 00	loop
188	36 48 01 08	*IND *EXC 18	
192	36 42 00 00	*IND STO 00	
196	43 01 08	RCL 18	
199	65 02 95	x 2 =	
202	75 43 01 09	- RCL 19	
206	95	=	
207	80 02 02 03	*IF POS 223	exit
211	01	1	
212	22 44 00 00	INV SUM 00	
216	44 01 08	SUM 18	
219	41 01 08 04	GTO 184	return
223	56	*RTN	

☒ Continued on attached sheets

LOC	CODE	KEY	COMMENTS
000	46 11	*LBL A	Continue
002	51 87	SBR *1	Sum
004	42 01 05	STO 15	
007	51 88	SBR *2	Convolute
009	51 89	SBR *3	Reverse
011	51 88	SBR *2	Convolute
013	51 89	SBR *3	Reverse
015	01 42 00 00	1 STO 00	i = 1
019	81	HLT	display
020	46 13	*LBL C	c_i input
022	36 22	*IND INV	
024	49 00 00	*PROD 00	
027	01 44 00 00	1 SUM 00	
031	43 00 00	RCL 00	i + 1
034	81	HLT	display
035	46 14	*LBL D	continue
037	51 87	SBR *1	Sum
039	55	÷	
040	43 01 05 95	RCL 15 =	b
044	42 01 08	STO 18	
047	81	HLT	
048	46 15	*LBL E	i input
050	42 00 00	STO 00	
053	36 43 00 00	*IND RCL 00	
057	55	÷	
058	43 01 08 95	RCL 18 =	f_i
062	81	HLT	display
063 thru 071	blank		

LOC	CODE	KEY	COMMENTS
072 thru 111	same as Card 1		
112 thru 223	blank		

LOC	CODE	KEY	COMMENTS

Abstract

Program Title	Rev
Day-Count	

Description of Program

The number of days which have (or will have) transpired between two calendar dates is determined, also the number of those days which were used (or will be used) according to a specified weekly schedule.

User Benefits:

Because the rate the Earth revolves around the Sun does not divide evenly and conveniently into the rate the Earth rotates on its axis, given two dates it may be a chore to determine the exact number of days between them. Number of days is, of course, a common measure of many things, e.g., biological processes, production machine life.

Category	Related Progs.	Prog Steps	Data Registers
29		386	19

Program Description

Program Title: Day-Count	Rev.

Method, Equations, Sketches, Limitations, References

This program is applicable to situations where relatively long time periods are defined by initial and final dates and also where those time periods are further reduced by specified weekly schedules.

The program was originally used in the development of some work injury statistics. An employee may be injured on one date and may return to work on another. The number of days between the two dates is a measure of the seriousness of the injury. If the employee's pay is continued during his absence, the number of work days which he misses is a measure of the loss to his employer. To determine the latter number, the program must also carry his weekly work schedule. The program does not account for holidays, but if the holiday schedule is known, identifying and subtracting missed holidays, after the calculation, is easy to do.

The program is recorded on two cards. Card 1 is used to calculate the total number of days between an initial date and a later date:

$$\text{Card 1 } (mo_1/d_1/y_1,\ mo_2/d_2/y_2) = d,$$

where the subscript 1 refers to the initial date and the subscript 2 refers to the later date. If the two dates are both in the same century, each year may be represented by its last two digits. Card 2 is used to calculate the number of days, between corresponding dates, where the total number is reduced by a weekly schedule:

$$\text{Card 2 } (W,\ d_t,\ d_s) = d_w,$$

where W is the weekly schedule, d_t is the total number of days between an initial date and a final date, and d_s is the total number of days between the initial date and the date of any Sunday occurring after the final date. Card 1 can be used to calculate both d_t and d_s. A nominal weekly schedule which simply excludes Saturday and Sunday is a part of the card 2 routine. Alternatively, the program user may specify a weekly schedule. Specified

X Continued on attached sheets

schedules can be comprised of fractional days.

There are no clever algorithms used on either card. The calculational procedures are essentially those one would use if working with a perpetual calendar. Card 1 uses a list of the number of days in respective months in registers R_{01}, R_{11}. Card 2 uses a twelve-day sequence, corresponding to respective days of the week, in registers R_{01}, R_{12}. For the nominal schedule, this sequence is comprised of 1s and 0s. The number of days to a Sunday, d_s, is used within the program to locate the summing process relative to the sequence.

Both cards are based on the following convention: The day corresponding to the initial date is not counted or considered for counting; the day corresponding to the later date is counted and is considered for counting according to the weekly schedule.

- Robert Magladry

Sample Problem

Statement of Example

On 9/10/73, two employees at a tracking station, transporting electronic gear, were injured when wind blew the vehicle, which they were using, off the road. Their respective recovery periods ended 10/3/73 and 2/27/74. How many days did each employee take to recover? Disregarding holidays, how many work days did each employee miss? Both employees had nominal weekly work schedules. The date of a Sunday is 11/14/76.

Continued on attached sheets

ENTER	PRESS	DISPLAY	COMMENT
Load both sides of card 1.			
$mo_1 = 9$	STO 14		date of injury
$d_1 = 10$	STO 15		
$y_1 = 73$	STO 16		
$mo_2 = 11$	STO 17		date of a Sunday
$d_2 = 14$	STO 18		
$y_2 = 76$	STO 19		
	E	$d_s = 1161$	days to Sunday
$mo_2 = 10$	STO 17		
$d_2 = 4$	STO 18		
$y_2 = 73$	STO 19		
	E	$d_t = 23$	recovery days, one employee
$mo_2 = 2$	STO 17		
$d_2 = 28$	STO 18		
$y_2 = 74$	STO 19		
	E	$d_t = 169$	recovery days, other employee

X Over

Sample Problem (cont'd)

ENTER	PRESS	DISPLAY	COMMENT
Load both sides of card 2.			
	D		nominal schedule
$d_t = 24$	A		
$d_s = 1161$	B	$d_w = 17$	missed work days, one employee
$d_t = 171$	A		
$d_s = 1161$	B	$d_w = 121$	missed work days, other employee

Program Title	Day-Count

USER DEFINED KEYS

A	Enter total days	A'	
B	Enter days to Sun and run card 2	B'	
C		C'	
D	Enter nom. schedule	D'	
E	Run card 1	E'	

REGISTERS

	card 1	card 2		card 1	card 2
01	Jan	W	10	Oct	F
02	Feb	Th	11	Nov	S
03	Mar	F	12	$y_1<y<y_2$	S
04	Apr	S	13	d	a,b
05	May	S	14	mo_1	a,b
06	June	M	15	d_1	d_T
07	July	T	16	y_1	i
08	Aug	W	17	mo_2	f
09	Sept	Th	18 / 19	d_2 / y_2	d_w

FLAGS

0	1	4
	set - not leap year	

LABELS

X 2' X 3' X 4' X 5' X 1'

User Instructions

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	Load both sides of card 1.			
2	Enter initial date.	mo_1	STO 14	
		d_1	STO 15	
		y_1	STO 16	
3	Enter later date.	mo_2	STO 17	
		d_2	STO 18	
		y_2	STO 19	
4	Run program.		E	$d - d_t, d_s$
5	To rerun, enter changes; go to step 4.			
6	Load both sides of card 2. Do step 7 if weekly schedule is not nominal. Otherwise skip step 7.			
7	Enter weekly schedule. Each entry is the decimal fraction, i.e., 0 to 1, of a day to be counted for corresponding day of week. Note, the repeated days of the week require repeated entries. Go to step 9.	W	STO 01	
		Th	STO 02	
		F	STO 03	
		S	STO 04	
		S	STO 05	
		M	STO 06	
		T	STO 07	
		W	STO 08	
		Th	STO 09	
		F	STO 10	
		S	STO 11	
		S	STO 12	
8	Select nominal weekly schedule.		D	
9	Enter total days.	d_t	A	
10	Enter days to a Sunday.	d_s	B	d_w
11	To rerun, enter weekly schedule changes, if any. Go to step 9.			

Listing - Card 1

LOC	CODE	KEY	COMMENTS
000	46 15	*LBL E	run card
002	43 01 09	RCL 19	y_2
005	51 87	SBR *1	Leap ^{2}Flg
007	51 88	SBR *2	Days Mo
009	43 01 07	RCL 17	m_2
012	51 89	SBR *3	Days ^{2}Yr
014	43 01 08 95	RCL 18 =	d_2
018	42 01 03	STO 13	d^2
021	43 01 06	RCL 16	y_1
024	51 87	SBR *1	Leap ^{1}Flg
026	51 88	SBR *2	Days Mo
028	43 01 04	RCL 14	m_1
031	51 89	SBR *3	Days ^{1}Yr
033	43 01 05 95	RCL 15 =	d_1
037	22 44 01 03	INV SUM 13	d^1
041	43 01 09 75	RCL 19 -	
045	43 01 06 95	RCL 16 =	y_2-y_1
049	90	*IF 0	same yr
050	00 06 08	068	exit
053	03 06 05	365	
056	44 01 03	SUM 13	
059	60 01	*IF FLG 1	not leap
061	00 06 08	068	exit
064	01 44 01 03	1 SUM 13	d
068	43 01 06	RCL 16	y_1
071	42 01 02	STO 12	
074	01 75 01 02	1 SUM 12	y-loop
078	43 01 02	RCL 12	
081	51 87	SBR *1	Leap Flg
083	43 01 02 75	RCL 12 -	
087	43 01 09 95	RCL 19 =	y-y_2
091	80	*IF +	
092	01 01 04	114	exit
095	03 06 05	365	
098	44 01 03	SUM 13	
101	60 01	*IF FLG 1	not leap
103	01 01 00	110	

LOC	CODE	KEY	COMMENTS
106	01 44 01 03	1 SUM 13	
110	41 00 07 04	GTO 074	y-return
114	43 01 03	RCL 13	d
117	81	HLT	
118 thru 123	blank		
	Leap Year Flag Subroutine		
124	46 87	*LBL *1	y
126	55 04 95	÷ 4 =	
129	42 00 00	STO 00	
132	57 00 52	*FIX 0 EE	
135	22 57 75	INV *FIX -	
138	43 00 00 95	RCL 00 =	
142	22 52	INV EE	
144	90 01 05 04	*IF 0 154	leap yr
148	50 01	*ST FLG 1	
150	41 01 05 07	GTO 157	exit
154	22 50 01	INV *ST FLG 1	
157	56	*RTN	
	Days in Month Subroutine		
158	46 88	*LBL *2	
160	01 01 42	11 STO	
163	00 00 03 01	00 31	loop
167	36 42 00 00	*IND STO 00	
171	58 01 06 05	*DSZ 165	loop rtn
175	01 94	1 +/-	
177	44 00 04	SUM 04	Apr
180	44 00 06	SUM 06	June
183	44 00 09	SUM 09	Sept
186	44 01 01	SUM 11	Nov
189	03 94	3 +/-	
191	44 00 02	SUM 02	Feb
194	60 01	*IF FLG 1	
196	02 00 03	203	exit
199	01 44 00 02	1 SUM 02	Feb
203	56	*RTN	

LOC	CODE	KEY	COMMENTS
	Days in Year	Subroutine	
204	46 89	*LBL *3	mo
206	42 00 00	STO 00	
209	22 58	INV *DSZ	loop
211	02 02 03	223	exit
214	36 43 00 00	*IND RCL 00	
218	85	+	
219	41 02 00 09	GTO 209	loop rtn
223	56	*RTN	

X Continued on attached sheets

Listing - Card 2

LOC	CODE	KEY	COMMENT	LOC	CODE	KEY	COMMENT	LOC	CODE	KEY	COMMENT
000	46 14	*LBL D		096	01 01 00	110	exit				
002	51 78	SBR *5	Nominal	099	36 43 00 00	*IND RCL 00					
004	81	HLT		103	44 01 08	SUM 18					
				106	58 00 08 07	*DSZ 087	loop rtn				
005	46 11	*LBL A	d_T	110	43 01 08	RCL 18	d_w				
007	42 01 05	STO 15		113	81	HLT					
010	94 85	+/- +									
012	81	HLT		114							
				thru	blank						
013	46 12	*LBL B	d_s	169							
015	95	=	$d_{s_a}=d_T$								
016	55 07 95	÷7=			Remainder Subroutine						
019	51 77	SBR *4	Remainder								
021	43 01 04	RCL 14		170	46 77	*LBL *4					
024	65 07 95 94	x7= +/-		172	42 01 04	STO 14					
028	85 01 02 95	+12=	i	175	75 93 05 95	-.5=					
032	42 01 06	STO 16		179	57 00 52	*FIX 0 EE					
				182	42 01 03	STO 13					
035	43 01 05	RCL 15	d_{T_b}	185	22 44 01 04	INV SUM 14					
038	55 07 95	÷7=		189	22 57	INV *FIX					
041	51 77	SBR *4	Remainder	191	22 52	INV EE					
043	43 01 04	RCL 14		193	56	*RTN					
046	65 07 95 94	x7= +/-									
050	85 43 01 06	+ RCL 16	i_f		Nominal Schedule Subroutine						
054	95	=		194	46 78	*LBL *5					
055	42 01 07	STO 17		196	01 00	10					
				198	42 00 00	STO 00					
058	07 42 00 00	7 STO 00		201	01	1	loop				
062	36 43 00 00	*IND RCL 00		202	36 42 00 00	*IND STO 00					
066	85	+		206	58 02 00 01	*DSZ 201	loop rtn				
067	58 00 06 02	*DSZ 062		210	00	0					
071	00 95	0=	d	211	42 01 02	STO 12					
073	65 43 01 03	x RCL 13		214	42 01 01	STO 11					
077	95 42 01 08	= STO 18	d_w	217	42 00 05	STO 05					
				220	42 00 04	STO 04					
081	43 01 06	RCL 16	i	223	56	*RTN					
084	42 00 00	STO 00									
087	43 01 07 75	RCL 17 -	loop								
091	43 00 00 95	RCL 00 =									
095	80	*IF+									