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Procedure for Estimating Orbital Debris Risks

James L. Crafts and
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Procedure for Estimating Orbital Debris Risks

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NASA
National Aeronautics
and Space Administration

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TECHNICAL PAPER

PROCEDURE FOR ESTIMATING ORBITAL DEBRIS RISKS

SUMMARY

A procedure has been developed that will allow an estimation of risks associated with the eventual decay and reentry of spacecraft or upper stages left in orbit on future missions. A data base of detailed analyses has been developed and a correlation parameter has been selected that will give a good estimate of the amount of debris (lethal area) that will survive the reentry heat and pose a threat to the Earth's populace. The results obtained from this estimation procedure have been compared to detailed analyses that were performed over a number of years. The estimation technique appears valid for configurations ranging from small scientific payloads (ERTS-B) to large orbital assemblies (Skylab).

INTRODUCTION

This Nation has been exploring space for more than 25 years. During these years, hundreds of payloads and spent stages have been placed in orbit. Many have been left there to eventually decay, reenter the Earth's atmosphere, and have portions impact the Earth's surface. In order for NASA to be able to assess the potential risk to the world's populace for future spacecraft and missions, the procedure presented herein was developed. This approach provides a consistent, but simple, procedure to assess the risk due to random entry with an adequate accuracy level for making programmatic decisions on planned low Earth orbit missions.

PAST ANALYSES

For more than a decade the MSFC and Lockheed Missiles and Space Company worked together in developing techniques necessary to assess the risk associated with a stage or payload as it returned to the Earth's surface. In the early days of this activity, the approach was to assess only those items that had a high probability of surviving the reentry heat, resulting in a low estimate of potential risk to the Earth's inhabitants. This approach was necessary due to cost constraints and computer capability. With the development of larger and faster computer systems, the techniques used in the breakup, survival, and risk hazard analyses were greatly improved while maintaining a realistic cost per analysis. These improved techniques were first used on the Skylab program. Several other analyses, the ASTP Docking Module (DM) and Service Module (SM), ERTS-B, HEAO and Centaur, were performed using these same techniques so that any differences in results due to the analysis technique would be eliminated. Table 1 presents a summary of these analyses with detailed information contained in the references.

PROCEDURE FOR ESTIMATING RISKS FOR FUTURE MISSIONS

Based on information obtained from previous analyses, it seems reasonable that a "representative risk" associated with a future mission could be calculated without doing a detailed analysis. Various parameters have been investigated in an attempt to determine a method of correlating the resulting lethal area for a given configuration. The parameter (WXLXD), the product of the weight, length, and diameter of the configuration just prior to reentry, was found to give the best correlation for the different configurations analyzed to date. Using the most recent MSFC/LMSC analyses, along with four others performed by other agencies but with similar assumptions, a data base of information was compiled. Figure 1 presents the lethal area (LA) of the surviving debris from these analyses versus the correlation parameter (WXLXD). Figure 2 presents the probability of a casualty for one square foot of lethal area versus orbital inclination and reentry date.

Using Figures 1 and 2, a "representative risk" associated with a future mission can be calculated as follows:

1) Compute the parameter (WXLXD) for the configuration and obtain the lethal area from Figure 1.

2) Multiply the lethal area by the appropriate probability of casualty per square foot of lethal area from Figure 2.

3) Compare the calculated risk to those of previous analyses in Table 1.

COMPARISON OF DATA BASE APPROACH AND DETAILED ANALYSES

One of the largest differences in lethal area (and therefore risk) between the data base approach and the detailed analysis is for the ASTP Service Module (SM). The data base approach gives 480 square feet of lethal area compared to 800 square feet from the actual analysis. Much of this deviation is attributed to the unusual number of high pressure spheres/bottles and engines in this configuration. Twenty-six of the 57 parts predicted to survive fall into this category making up about 35 percent of the lethal area. From typical configurations (ERTS, Centaur, S-IVB and S-II) this contribution is on the order of 10 to 15 percent. Even for this "odd" configuration, a risk hazard of the same order of magnitude would be obtained by using either the data base or detailed analysis approach.

CONCLUSIONS

The resulting lethal area for a given configuration is a function of its weight, length, and diameter just prior to reentry. Using this predicted lethal area and the appropriate probability of a casualty for one square foot of lethal area, a "representative risk" can be calculated for the class of vehicles/payloads that NASA has launched and will launch in the future.

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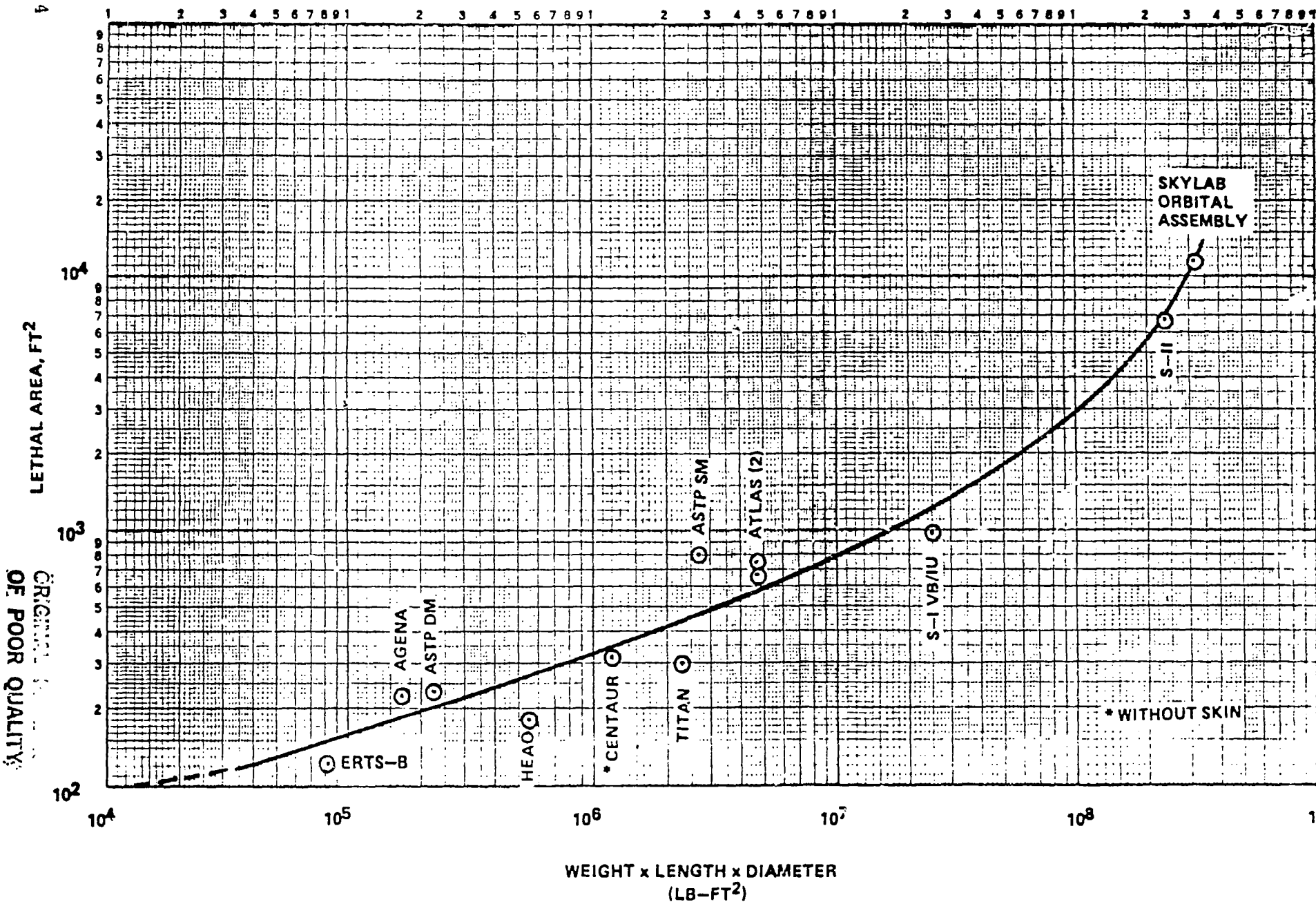

Figure 1. Lethal area versus (WXLXD) with a body radius of 1 ft.

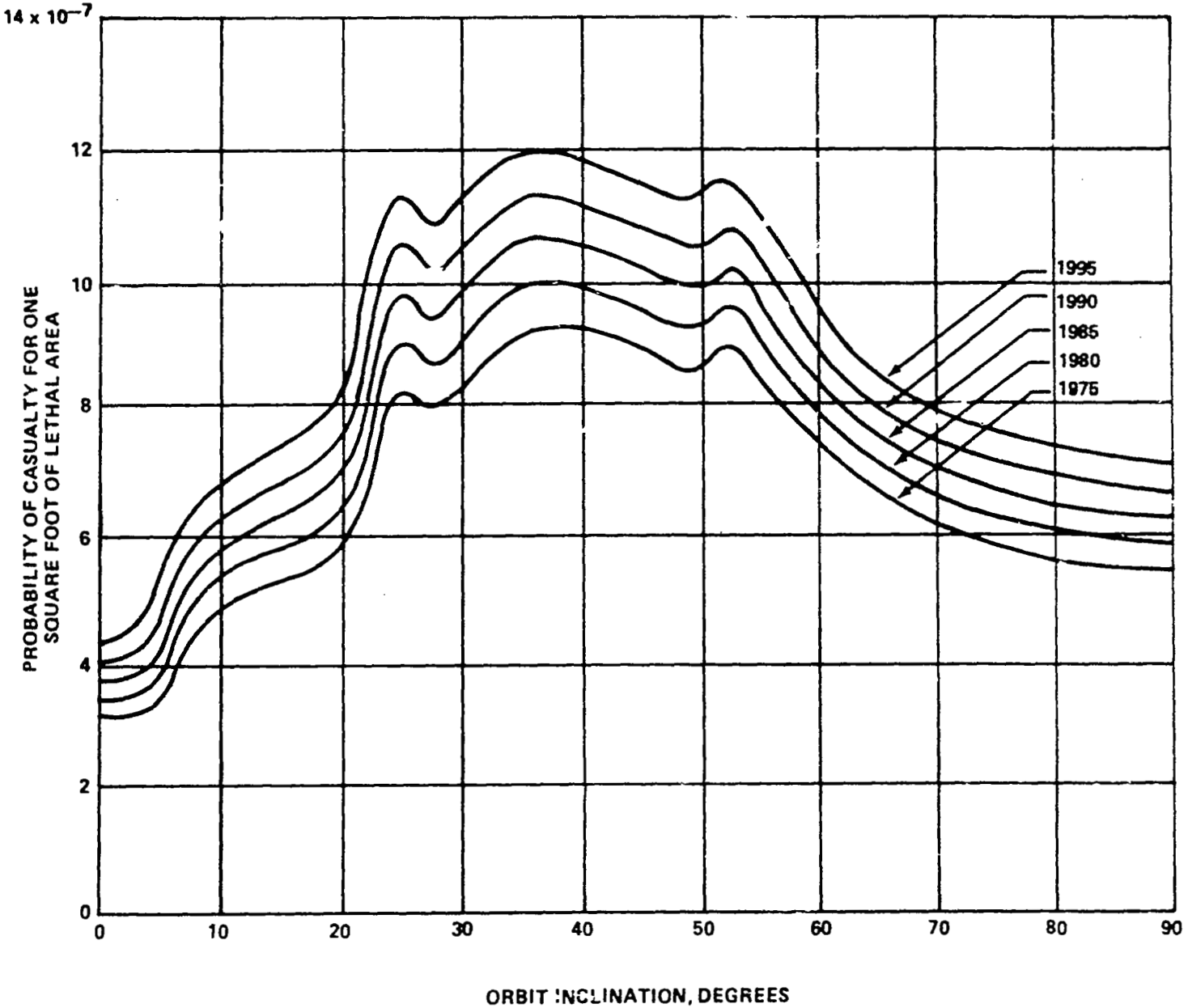

Figure 2. Probability of casualty for 1 ft^2 of lethal area versus orbital inclination.

TABLE 1. SUMMARY OF LETHAL AREAS AND PROBABILITY OF AT LEAST ONE CASUALTY (BODILY INJURY OR DEATH) PER REENTERING SPENT STAGE OR PAYLOAD

CONFIGURATION	LETHAL AREA (FT^2)	PROBABILITY OF CASUALTY FOR RANDOM REENTRY	INCLINATION (DEGREES)	PREDICTED YEAR OF REENTRY
SKYLAB ORBITAL ASSEMBLY	11125	.0105	50	1979
SKYLAB S–II STAGE	6723	.00640	50	1975
SKYLAB S–IVB/IU (3)	2919	** NOT AVAILABLE	50	DEORBITED BY COMMAND
ASTP DOCKING MODULE	228	.00020	51.8	1975
ERTS–B	122	.00011	51.8	1975
CENTAUR STAGE	316	.00025	27.8	1975
HEAO	180	.00013	22.5	1977
*ASTP SERVICE MODULE	800	.00069	51.8	1975

*ASSUMES A RANDOM DECAY – THE MISSION EMPLOYED A FORCED REENTRY TO A PLANNED RECOVERY AREA. REFERENCE 6 PRESENTS A PROBABILITY OF CASUALTY OF ZERO (0) BECAUSE THE DISPERSION FOOTPRINT DOESN'T ENCOMPASS ANY LAND MASSES.

**RISK CALCULATION IN REFERENCE 1 WAS FOR A SHORT LIFETIME.

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16. ABSTRACT

This report presents a procedure for estimating the potential orbital debris risk to the world's populace from payloads or spent stages left in orbit on future missions. This approach provides a consistent, but simple, procedure to assess the risk due to random reentry with an adequate accuracy level for making programmatic decisions on planned low Earth orbit missions.

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