



EFFECT OF WSMR IMPACT DATA  
ON RELEASE PARAMETER EVALUATION

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DATA ON RELEASE PARAMETER EVALUATION  
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## INTRODUCTION

The phenomenon of high-velocity, crash-landing of spacecraft on the surface of a planet has been analyzed<sup>(1)</sup> as a potential mechanism for the release of encapsulated microbial burden. One of the key factors in this analysis is the extent of fracturing of the spacecraft material. From theoretical considerations one can postulate that the degree of fracturing depends upon such factors as the impact velocity experienced, the physical properties of the surface and of the spacecraft material, the angle of incidence with the surface, and the prevailing atmospheric conditions. Of these, the impact velocity is generally felt to be the dominant factor in the determination of the extent of fracturing within the range of concern herein.

In an attempt to establish the relationship between the extent of fracturing and impact velocity, tests were conducted by the Boeing Company<sup>(2)</sup>, under the direction of the Jet Propulsion Laboratory, in which plastic pellets of spacecraft type materials were impacted on sand and steel at several velocities in the range of 160 to 1500 m/sec. These tests also provided data regarding the survivability of the buried burden since the pellets were inoculated with microorganisms.

These tests, in combination with theoretical predictions, established the baseline velocity-fracture data used in the release analysis referred to previously. These data, from reference 1, are reproduced below:

| Velocity, m/sec | Fracture Ratio, f,<br>in meter <sup>-1</sup> |
|-----------------|----------------------------------------------|
| 160             | 400                                          |
| 450             | 1000                                         |
| 920             | 10000                                        |
| 1500            | 40000                                        |



The fracture ratio is a parameter devised to express the extent of fracturing of the material and is defined as the ratio of newly created surface area to the original volume of the material. In the metric units selected, it can range from 0 (no break up) to about 10,000,000 (complete break up into pieces of dimensions of  $10^{-6}$  meter or less). The fracture ratio values shown in the table were determined by measuring the physical size of the fragments obtained in the Boeing impact tests. Pertinent details are provided in reference 1.

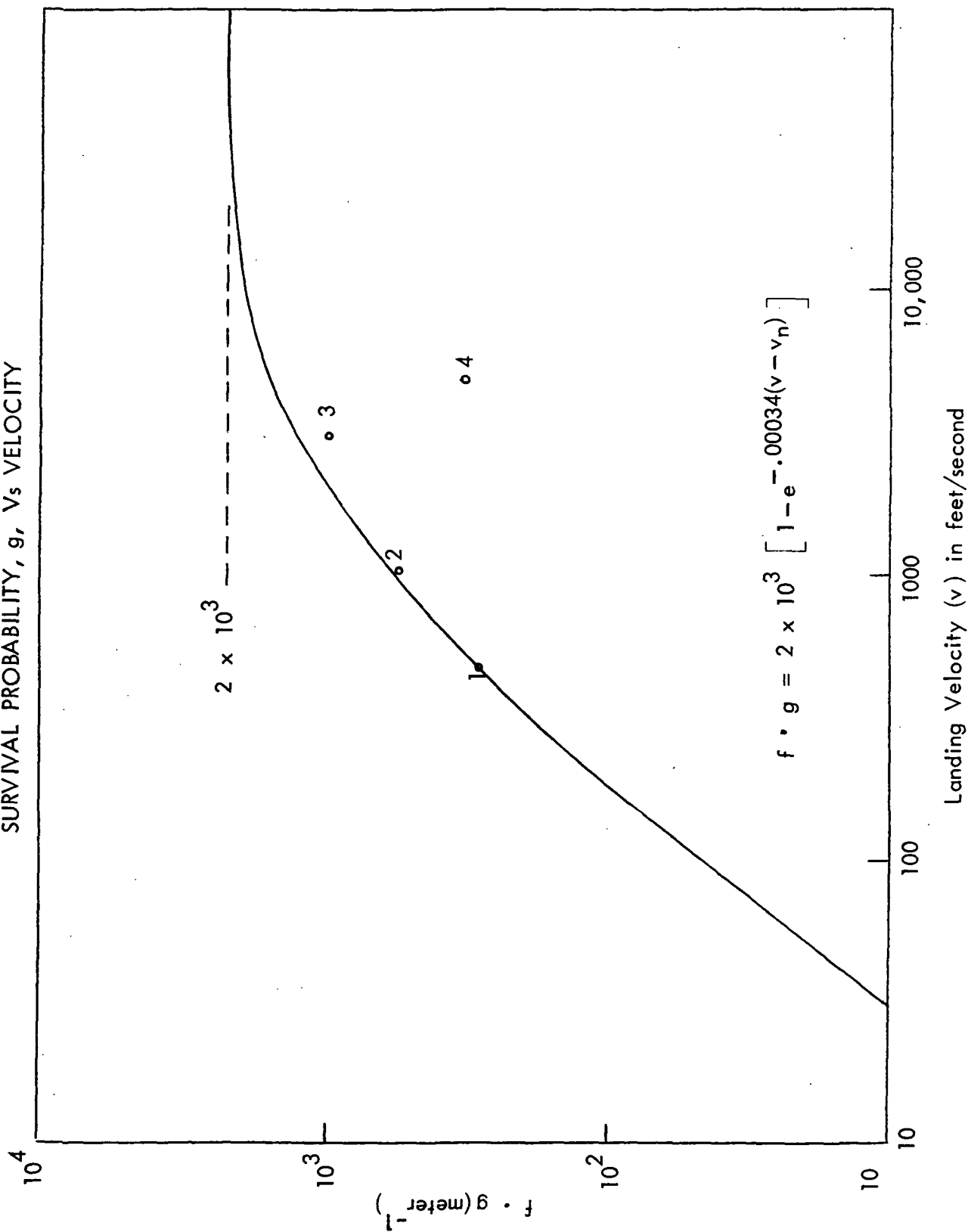
In microbial release applications, the fracture ratio was combined with a factor,  $g$ , expressing the fraction of the original burden which survived the impact. The product of  $f$  and  $g$  (Fracture Factor) was then related to impact velocity. By curve fitting, it was found that an exponential curve adequately contained all data points (see Figure 1) and could be used as a conservative upper limit in release estimations.

The limited experimental data available to help substantiate the relationship between fracturing and impact velocity has been of concern to the Planetary Quarantine Officer (PQO). Hence, in 1971 Exotech suggested that other crash impact experience be reviewed for possible application. In response, the PQO requested the White Sands Missile Range (WSMR) in New Mexico to supply whatever pertinent data had been developed there<sup>(3)</sup>.

## ANALYSIS OF ROCKET/PROJECTILE IMPACT DATA

The WSMR reviewed available data obtained from rocket and projectile impact tests and selected unclassified data representative of a wide range of impact conditions. These data were provided by WSMR to Dr. Henry J. Moore of the U.S. Geological Survey who analyzed<sup>(4)</sup> them with regard to spacecraft microbial release. Dr. Moore's results corroborate the earlier analysis which showed

Figure 1.  
PRODUCT OF FRACTURE RATIO,  $f$ , AND  
SURVIVAL PROBABILITY,  $g$ , VS VELOCITY





that release is dependent primarily upon impact velocity and secondarily upon the properties of the surface.

This conclusion is borne out in the presentation of Figure 2 which displays the impact results observed as a function of both target density and impact velocity. The lesser effect of target density is illustrated in the low degree of slope of the lines separating the observation categories. The major categorization factor is seen to be impact velocity.

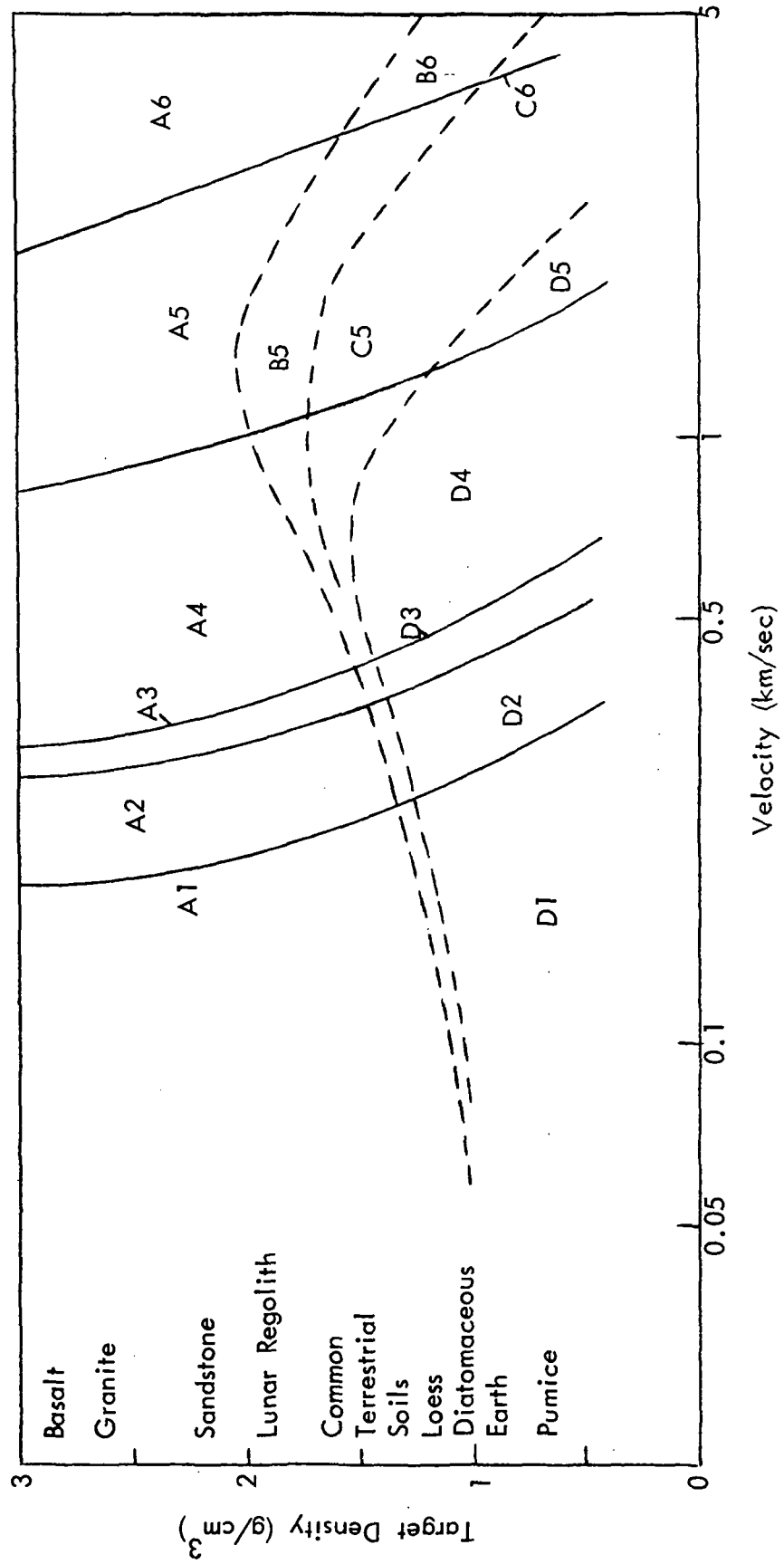
These test results divide into two broad groups separated at an impact velocity of about 350 m/sec. Below this value there is structural deformation and stripping of appendages — mechanisms conducive to the release of internal and mated surface contamination. Velocities above 350 m/sec, however, are necessary to effect fracturing and material breakup. These are the impact mechanisms necessary to release encapsulated contamination. Hence, we can regard 350 m/sec as an approximate lower velocity limit for the release of buried burden.

Dr. Moore's results were studied to determine their influence upon the earlier postulated relationship between microbial release and impact velocity. The purpose of this report is to review the impact of Dr. Moore's results upon currently-used release parameter values.

To provide a basis for comparison of Dr. Moore's results with earlier experimental and analytical data, fracture ratios were developed from Dr. Moore's data:

| Velocity m/sec | Fracture Ratio, $f$ ,<br>in meter <sup>-1</sup> |
|----------------|-------------------------------------------------|
| 0 - 220        | 1                                               |
| 300 - 1200     | 10 to 10,000                                    |
| 900 - 3000     | 1000 to 100,000                                 |

Figure 2.





Fracture ratio values were derived from Dr. Moore's narrative descriptions and a review of photographs of the impact fragments. These data are plotted in Figure 3 with the Boeing pellet impact data for reference. The range of fracture ratios shown is attributable to differences in the surface properties, the more dense target surfaces producing higher values.

Only two of the WSMR's four target density groups are shown. These are for the more dense surface materials whose densities ranged from  $1.0 \text{ gm/cm}^3$  to  $3.0 \text{ gm/cm}^3$ . The highest density group (referred to as A), is qualified as follows:

"Less than 10% of the spacecraft and its components remain buried beneath a crater made upon impact and they either rebound or are ejected with various degrees of destruction."

For the next most dense group B, the qualification applied is as follows:

"10 to 50% of the spacecraft and its components remain buried beneath the crater made upon impact and they are either intact or deformed to various degrees."

The remaining two groups gave fracture ratios ranging from zero (no fracturing) to those of group B.

A comparison with the plastic-pellet derived data, presented earlier, indicates that a somewhat less conservative (less fracturing for a given velocity) posture can be taken in the case of buried contamination.

The effect of these findings is discussed in the next section.

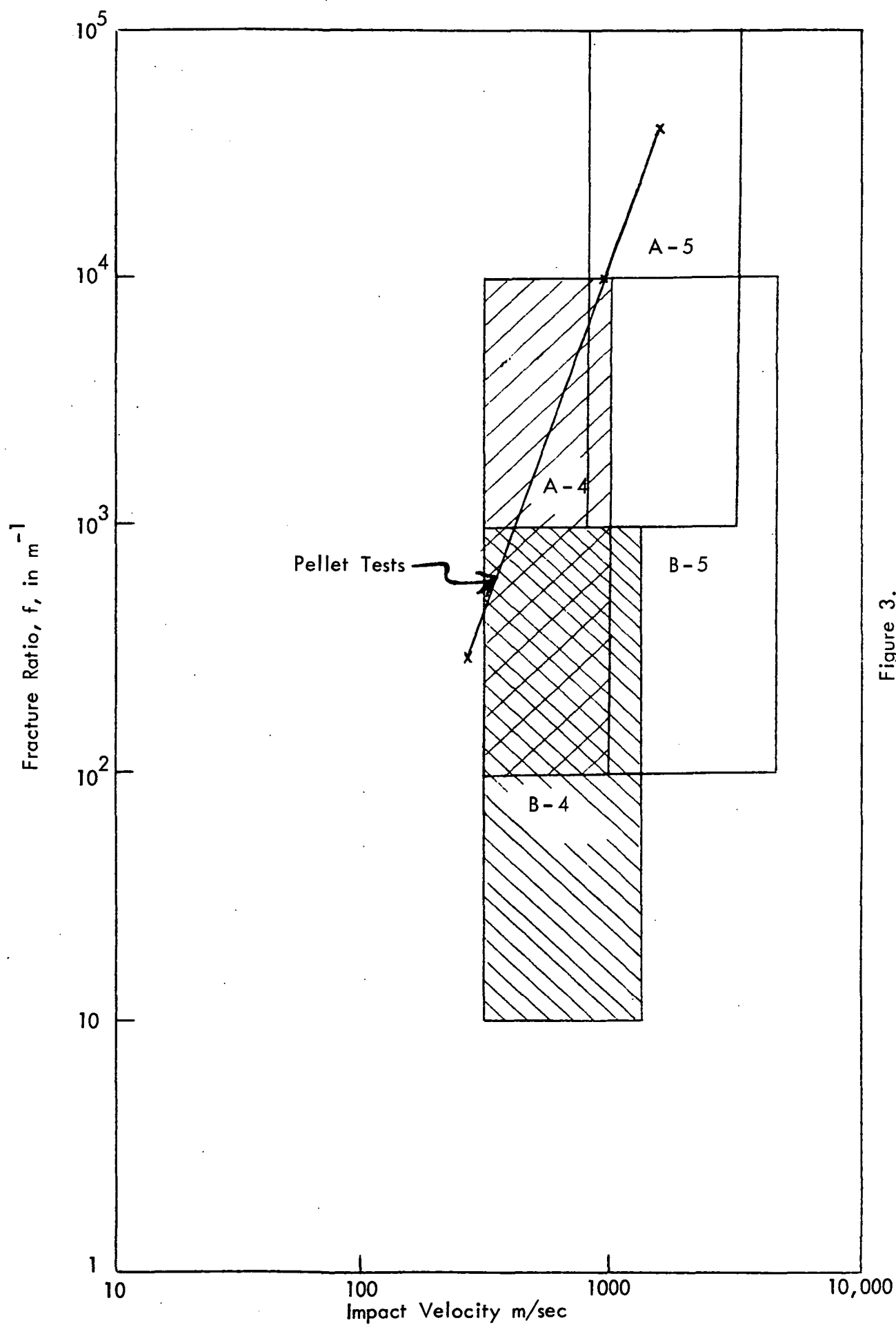


Figure 3.  
COMPARISON OF FRACTURE RATIO - IMPACT VELOCITY RELATIONSHIPS



## RESULTS

The pertinent analysis used in the derivation of the currently-used release parameters is presented in Interim Report TR72-12<sup>(5)</sup>. The approach used was to bound the factors which influence the probability of microbial release, and to separate those which are sensitive in the determination of the release probability value from those which are relatively insensitive. The latter group was later evaluated with less concern for developing an accurate value than for providing a numerical limit bounding all reasonably expected values.

In the case of encapsulated burden, a maximum numerical limit was defined for the Fracture Factor with the result that release by erosion became the dominant factor for Martian landers, given the postulated atmospheric conditions. In this limitation process, two conditions were assumed to prevail, viz.;

1. A low probability of crash landing — The probability that the spacecraft would crash land on the planet from any cause was stipulated at less than 1 chance in 1000.
2. A low probability of high velocity impact — The probability that the impact velocity would be greater than 300 m/sec was stipulated to be 4.4 orders of magnitude smaller than the total probability of crash landing.

If these two conditions are satisfied, the magnitude of the Fracture Factor is of little importance, and the slight reduction which the WSMR data could substantiate would not influence the value of the probability of release.



Since the two underlying conditions enumerated above appear to be reasonable assumptions (based upon data received from the Viking Project as reported in TR 72-12), a change in the currently-used encapsulated release parameters does not appear warranted. Should these two conditions not prevail, however, further analysis is recommended for which the WSMR data and Dr. Moore's analysis provide a valuable data base.

In the case of mated surface contamination, accidental impact is a potent release mechanism. The WSMR data corroborates other impact test results which show that the velocity region in which mated burden can be released extends from as low as 10 to several thousand meters per second. The most significant part of this range is below 500 meters per second where impact energies are insufficient to produce noticeable kill. The defense of a small likelihood of planetary contamination from this source rests almost entirely on a small probability of occurrence of a crash landing. The WSMR data lends no support to this determination; these data are valuable, however, in adding detail to material deformation projections.

## CONCLUSIONS

There is no justification at present for modifying release prediction formulations or revising release parameter values based upon WSMR impact data.

Dr. Moore's data should be reserved as a basis for future impact research, should flight projects be unable to apply current release methodology and attendant assumptions.

As space flight experience is gained, particularly with planetary landers, these results should be reviewed to assure their applicability.



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