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Studies of hypervelocity impact phenomena as applied to the protection of spacecraft operating in the MMOD environment

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Abstract

In keeping with the tradition of the Hypervelocity Impact Society, this paper is a written version of the keynote address I presented at the start of 2015 Hypervelocity Impact Symposium as the recipient of the Society's Distinguished Scientist Award. It covers the highlights of my nearly 30 year career working in the area of hypervelocity impact phenomenology, mainly as it is applied to the protection of humans and spacecraft that work an operate in the micrometeoroid and orbital debris (MMOD) environment.

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Keywords: Spacecraft protection, MMOD, hypervelocity impact

1. Introduction

I am deeply grateful to the Hypervelocity Impact Society, its Awards Committee, and the Board of Directors for selecting to receive the Society's Distinguished Scientist Award at the 2015 Hypervelocity Impact Symposium (HVIS2015). I am humbled when I read the list of the names of previous award recipients, and honored to be included in this distinguished group.

This paper is a written version of the keynote address I presented at the start of HVIS2015. In keeping with tradition, it covers the highlights of my nearly 30 year career working in the area of hypervelocity impact phenomenology, mainly as it is applied to the protection of humans and spacecraft that work an operate in the micrometeoroid and orbital debris (MMOD) environment. Over these past 30 or so years I have been fortunate enough

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to work with many talented and gifted graduate students, scientists, engineers, analysts, and modelers, and it is only thanks to their keen insights and assistance that I have been able to accomplish what I have. Special acknowledgements are due, however, to the following individuals:

- Roy Taylor and Miria Finckenor (formerly and currently at the NASA Marshall Space Flight Center, respectively), who gave my career the jump-start it needed when I was a new Assistant Professor at the University of Alabama in Huntsville;
- Joel Williamsen (formerly at the NASA Marshall Space Flight Center and currently with the Institute for Defense Analyses), who has had the burden of working with me for many of these past 30 years on a variety of topics related to space debris;
- Dave Jerome (formerly at Eglin Air Force Base), who introduced me to DoD aspects of hypervelocity impact phenomenologies and studies;
- Klaus Thoma, Frank Schafer, and Robin Putzar (currently at the Ernst Mach Institute), who were kind enough to welcome me to the Fraunhofer Ernst Mach Institute for 7 months as a Humboldt Research Awardee and to give me a much-needed break from my academic administration duties;
- Steve Scott and Mike Squire (currently at the NASA Engineering Safety Center), who have asked me to serve on several NESC Technical Committees, thereby broadening my appreciation of the needs of NASA and its contractors when dealing with the problem of space debris;
- Martin Ratliff (currently at the NASA Jet Propulsion Laboratory), who introduced me to the world of robotic spacecraft and who keeps reminding me that robotic spacecraft have different needs and requirements that human rated spacecraft; and,
- Charlie Anderson, Lalit Chhabildas, and everyone else with whom I have had the pleasure of working as a member of the Hypervelocity Impact Society and who also served as my mentors over the span of my career.

In looking back, it is apparent that the work that I have done has always been about increasing the safety of human space operations. Specifically, whether through data analysis and empirical model development or through modelling efforts that led to suggested possible modifications to ‘standard’ ballistic limit equations for thin multi-wall systems, the primary focus of the work has always been to gain a deeper understanding of the phenomenology involved in high speed impacts so that we can better protect our astronauts and our spacecraft against the hazards and risks posed by MMOD impacts. My career thus far can be thought of as having three phases:

- The early years, as a newly minted Assistant Professor at the UAH, when I spent a lot of time analyzing and making sense of the reams of data that were generated at NASA/MSFC under the Phase B and C/D test programs that supported the development the international space station,
- The middle years, when I ventured to develop analytical models of the various phenomena that occur during a hypervelocity impact, and
- Recent years, when I have be lucky enough to a work on a much wider variety of problems, as well as serving on several NRC/NAE and NESC technical committees.

These phases overlap, of course, and the activities and knowledge gained in one supported the activities and exercises in the other. However, another common thread throughout my work is that I have tended to work in areas or on topics were just outside the more mainstream activities related to high speed impact testing and spacecraft protection. For example, while the majority of the analysis was being performed on normal impact test data obtained using spherical aluminum projectiles, I was intrigued by and directed my energies towards the study of oblique impacts, non-spherical, and non-aluminum projectiles. These activities naturally gave rise to studies on the kind of hole (not simply whether or not there was a hole) in a pressure wall, what happens within a module following a penetrating impact, and characterizing ricochet debris, among others.

In the next few sections I will attempt to summarize the more salient points that have come out of these various studies. In order to understand the context of my work, it is important to first lay out just what exactly constituted the mainstream of testing and analysis work in the area of hypervelocity impact and spacecraft protection in the time period beginning with the late 1980s. It is my hope that future generations of rocket scientists will be able to continue and expand upon these studies as we continue to unravel all the wonder and mysteries associated with these highly energetic phenomena.