

# **14th Hypervelocity Impact Symposium (HVIS 2017)**

Procedia Engineering Volume 204

Canterbury, United Kingdom  
24 – 28 April 2017

**Editor:**

**Mark J. Burchell**

ISBN: 978-1-5108-5004-0

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© by Elsevier B.V.  
All rights reserved.

Printed by Curran Associates, Inc. (2017)

For permission requests, please contact Elsevier B.V.  
at the address below.

Elsevier B.V.  
Radarweg 29  
Amsterdam 1043 NX  
The Netherlands

Phone: +31 20 485 3911  
Fax: +31 20 485 2457

<http://www.elsevierpublishingsolutions.com/contact.asp>

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2633  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

# TABLE OF CONTENTS

<b>PREFACE</b> .....	1
<i>Mark J. Burchell</i>	
<b>STUDIES OF HYPERVELOCITY IMPACT PHENOMENA AS APPLIED TO THE PROTECTION OF SPACECRAFT OPERATING IN THE MMOD ENVIRONMENT</b> .....	4
<i>William P. Schonberg</i>	
<b>HOW LABORATORY HYPERVELOCITY IMPACT EXPERIMENTS HAVE HELPED US TO UNDERSTAND COMET DUST SAMPLES: A BRIEF REVIEW</b> .....	43
<i>A T Kearsley</i>	
<b>THE HIGH-VELOCITY IMPACT OF DYNEEMA® AND SPECTRA® LAMINATES: IMPLEMENTATION OF A SIMPLE THERMAL SOFTENING MODEL</b> .....	51
<i>S. Austin, A. D. Brown, J. P. Escobedo, H. Wang, H. Kleine, P. J. Hazell</i>	
<b>SMOOTH PARTICLE HYDRODYNAMICS GPU-ACCELERATION TOOL FOR ASTEROID FRAGMENTATION SIMULATION</b> .....	59
<i>Sergey K. Buruchenko, Christoph M. Schäfer, Thomas I. Maindl</i>	
<b>AN IMPROVED CONTACT ALGORITHM FOR MULTI-MATERIAL ARBITRARY LAGRANGIAN-EULERIAN HYDROCODES IN THREE-DIMENSIONS</b> .....	67
<i>Kenneth C. Walls, David L. Littlefield</i>	
<b>SIMULATING HYPERVELOCITY IMPACT PHENOMENA WITH DISCRETE ELEMENTS</b> .....	75
<i>Erkai Watson, Martin O. Steinhauser</i>	
<b>EFFECT OF HONEYCOMB CORE UNDER HYPERVELOCITY IMPACT: NUMERICAL SIMULATION AND ENGINEERING MODEL</b> .....	83
<i>Hong Chen, Alessandro Francesconi, Sen Liu, Shengwei Lan</i>	
<b>COMPUTER MODELING OF PROCESS OF PROJECTILE'S PENETRATION INTO DISCRETE-ELEMENT ARMOR PANEL</b> .....	92
<i>V. Kartuzov, I. Kartuzov, O. Mikhailov</i>	
<b>ANALYSIS OF METAL MATRIX COMPOSITE (MMC) APPLIED ARMOR SYSTEM</b> .....	100
<i>Minhyung Lee, Sangwon Park, Ilguk Jo, Sangkwan Lee</i>	
<b>BEHIND ARMOR EFFECTS OF EXTENDING ROD TECHNOLOGY</b> .....	108
<i>Brett R. Sorensen</i>	
<b>MODELING IMPACT OUTCOMES FOR THE DOUBLE ASTEROID REDIRECTION TEST (DART) MISSION</b> .....	116
<i>A. M. Stickle, E. S. G. Rainey, M. Bruck Syal, J. M. Owen, P. Miller, O. S. Barnouin, C. M. Ernst</i>	
<b>CALCULATING THE MOMENTUM ENHANCEMENT FACTOR FOR ASTEROID DEFLECTION STUDIES</b> .....	124
<i>Tamra Heberling, Galen Gisler, Catherine Plesko, Robert Weaver</i>	
<b>MOMENTUM ENHANCEMENT DUE TO HYPERVELOCITY IMPACTS INTO PUMICE</b> .....	130
<i>James D. Walker, Sidney Chocron, Donald J. Grosch, Daniel D. Durda, Kevin R. Housen</i>	
<b>STUDY OF THE EFFECTS OF PROJECTILE SHAPE IN THE ASTEROID ORBIT CHANGE BY SPACECRAFT IMPACT</b> .....	138
<i>Masaya Ikeda, Masashi Tanaka, Daisuke Yokoo, Takao Koura, Yasuhiro Akahoshi</i>	
<b>HYPERVELOCITY IMPACT CRATERING OF CHONDRITIC METEORITES: IMPLICATIONS FOR ASTEROID RECOIL</b> .....	146
<i>G. J. Flynn, D. D. Durda, E. B. Patmore, S. J. Jack, M. J. Molesky, B. A. May, M. M. Strait, R. J. Macke</i>	
<b>HYPERVELOCITY IMPACT ON PUMICE: SCALE EFFECTS ON EXPERIMENTS AND SIMULATIONS</b> .....	154
<i>Sidney Chocron, James D. Walker, Donald J. Grosch, Alexander J. Carpenter, Daniel D. Durda, Kevin R. Housen</i>	
<b>ENERGY BASED DISTRIBUTION FOR MULTI-LAYER FRAGMENTATION</b> .....	162
<i>Justin C Sweitzer</i>	
<b>FRAGMENT TRACKING IN HYPERVELOCITY IMPACT EXPERIMENTS</b> .....	170
<i>Erkai Watson, Max Gulde, Stefan Hiermaier</i>	
<b>CHARACTERIZING IN-FLIGHT TEMPERATURE OF EXPLOSIVELY FORMED PROJECTILES IN CTH</b> .....	178
<i>N. S. Helminiak, P. Sable, E. Harstad, A. Gullerud, J. Hollenshead, E. S. Hertel</i>	
<b>STATISTICAL STRENGTH MEASUREMENTS OF STEEL AS APPLIED TO COMPUTATIONAL STATISTICALLY COMPENSATED FRACTURE AND FRAGMENTATION CALCULATIONS</b> .....	186
<i>Michael V. Hopson, Susan L. Bartyczak, Christine M. Scott</i>	

<b>A STUDY OF THE EFFECT OF ASPECT RATIO ON FRAGMENTATION OF EXPLOSIVELY DRIVEN CYLINDERS</b> .....	194
<i>Tom De Vuyst, Rade Vignjevic, James C. Campbell, Andreas Klavzar, Marina Seidl</i>	
<b>COUPLED EULER-LAGRANGE SIMULATIONS OF METAL FRAGMENTATION IN PIPE BOMB CONFIGURATIONS</b> .....	202
<i>Arne Gullerud, Jeromy Hollenshead</i>	
<b>THE HYPERVELOCITY IMPACT FACILITY AT THE UNIVERSITY OF KENT: RECENT UPGRADES AND SPECIALIZED CAPABILITIES</b> .....	208
<i>R. Hibbert, M. J. Cole, M. C. Price, M. J. Burchell</i>	
<b>INVESTIGATING THE VELOCITY ENVELOPE OF LASER-DRIVEN MICRO-FLYERS FOR HYPERVELOCITY IMPACT EXPERIMENTS</b> .....	215
<i>Debjoy Mallick, Matt Shaeffer, Steven Dean, Kt Ramesh</i>	
<b>FRAGMENT IMPACT MODELING AND EXPERIMENTAL RESULTS FOR INSENSITIVE MUNITIONS COMPLIANCE OF A 120MM WARHEAD</b> .....	223
<i>Kevin T. Miers, Nausheen M. Al-Shehab, Daniel L. Prillaman</i>	
<b>HYDROCODE SIMULATIONS OF LIQUID FILLED CHANNELS FOR UNDERSTANDING EROSION IN SHAPED CHARGE JET PENETRATION</b> .....	231
<i>W. Casey Uhlig, Matthew J. Coppinger</i>	
<b>FAILURE MECHANISMS OF NI-H<sub>2</sub> AND LI-ION BATTERIES UNDER HYPERVELOCITY IMPACTS</b> .....	239
<i>J. E. Miller, F. Lyons, E. L. Christiansen, D. M. Lear</i>	
<b>TOWARDS PREDICTIVE TRANSFERABLE SIMULATIONS OF CERAMIC FAILURE IN BALLISTIC EVENTS</b> .....	247
<i>Andrew L. Tonge, Brian E. Schuster</i>	
<b>STRESS-WAVE PROPAGATION AND DAMAGE FORMATION ASSOCIATED WITH HYPERVELOCITY PENETRATION INTO POLYCARBONATE</b> .....	255
<i>N. Kawai, Y. Kuroda, M. Nagano, S. Hasegawa, E. Sato</i>	
<b>MODELING OF HYPERVELOCITY IMPACT OF SANDWICHED OPEN CELL ALUMINUM FOAM</b> .....	262
<i>Xiaotian Zhang, Ruiqing Wang, Q. M. Li</i>	
<b>EJECTA FROM LPSO-TYPE MAGNESIUM ALLOY TARGETS IN HYPERVELOCITY IMPACT EXPERIMENTS</b> .....	270
<i>Masahiro Nishida, Funiya Kodama, Koichi Hayashi, Yasuhiro Akahoshi, Kazuyuki Hokamoto, Tsuyoshi Mayama, Michiaki Yamasaki, Yoshihito Kawamura</i>	
<b>TIME-RESOLVED MEASUREMENT OF DEFORMATION OF METAL PLATES DUE TO HIGH-VELOCITY IMPACTS</b> .....	276
<i>Phillip Jannotti, Robert Doney, Brian Schuster</i>	
<b>NUMERICAL SIMULATION OF HIGH-VELOCITY PROJECTILE INTERACTIONS WITH GROUPS OF SPACED RODS AND PLATES</b> .....	284
<i>Alexander V. Gerasimov, Sergey V. Pashkov</i>	
<b>MODELING AND EXPERIMENTAL FRAGMENT IMPACT TESTING OF THE XM25</b> .....	292
<i>Nausheen Al-Shehab, Steven Doremus, Kevin Miers, Benjamin Wong, Jacek Foltynski, Arthur Daniels</i>	
<b>HYPERVELOCITY IMPACTS IN THE LABORATORY ON HOT ROCK TARGETS</b> .....	300
<i>A. J. W. Morris, M. J. Burchell</i>	
<b>SHAPE EFFECT ANALYSIS OF ALUMINUM PROJECTILE IMPACT ON WHIPPLE SHIELDS</b> .....	308
<i>M. J. Carrasquilla, J. E. Miller</i>	
<b>COMPARISON OF LASER ABLATION EFFECTS TO HYPERVELOCITY IMPACT AND DEBRIS DARKENING</b> .....	315
<i>Gouri Radhakrishnan, Paul M. Adams, Christopher J. Panetta, Diana R. Alaan</i>	
<b>DISCHARGE ON SOLAR ARRAY COUPON BY DEBRIS IMPACT</b> .....	323
<i>Shogo Tagami, Mariela Rojas Quesada, Takao Koura, Yasuhiro Akahoshi</i>	
<b>COMPARISON OF CRATER BEHAVIOR OF WATER ICE BY LOW AND HIGH DENSITY PROJECTILES UNDER HYPERVELOCITY IMPACT</b> .....	329
<i>Lan Sheng-Wei, Liu Sen, Qin Jin-Gui, Ren Lei-Sheng, Huang Jie</i>	
<b>ZERO TO 1,600 M/S IN 40 MICRONS: SENSITIVE PULSE SHAPING FOR MATERIALS CHARACTERIZATION ON Z</b> .....	337
<i>Andrew J. Porwitzky, Christopher T. Seagle, Brian J. Jensen</i>	
<b>A HYPERVELOCITY IMPACT FACILITY OPTIMISED FOR THE DYNAMIC STUDY OF HIGH PRESSURE SHOCK COMPRESSION</b> .....	344
<i>T. J. Ringrose, H. W. Doyle, P. S. Foster, M. Betney, J. W. Skidmore, T. Edwards, B. Tully, J. R. Parkin, N. Hawker</i>	

<b>A MESOSCALE-BASED HOMOGENIZATION STUDY OF SAND USING THE DISCRETE ELEMENT METHOD .....</b>	<b>352</b>
<i>Gerald Pekmezi, David Littlefield</i>	
<b>CORRELATION BETWEEN HOT SPOTS AND 3-D DEFECT STRUCTURE IN SINGLE AND POLYCRYSTALLINE HIGH-EXPLOSIVE MATERIALS.....</b>	<b>360</b>
<i>Cameron Hawkins, Oliver Tschauer, Zachary Fussell, Jesse Smith</i>	
<b>EULERIAN HYDROCODE ESTIMATES OF RICHTMYER-MESHKOV INSTABILITY GROWTH AND ARREST.....</b>	<b>367</b>
<i>S. P. Rojas, E. N. Harstad, R. G. Schmitt</i>	
<b>CHARACTERIZING IN-FLIGHT TEMPERATURE OF SHAPED CHARGE PENETRATORS IN CTH.....</b>	<b>375</b>
<i>P. Sable, N. S. Helminiak, A. Gullerud, E. Harstad, J. Hollenshead, E. S. Hertel</i>	
<b>LINKING THE EQUATION OF STATE FOR FIBER-REINFORCED COMPOSITES TO THOSE OF THE INDIVIDUAL FIBER AND MATRIX CONSTITUENTS.....</b>	<b>383</b>
<i>Alexander J. Carpenter, Sidney Chocron, Charles E. Anderson Jr.</i>	
<b>HYPERVELOCITY IMPACT TESTING OF MATERIALS FOR ADDITIVE CONSTRUCTION: APPLICATIONS ON EARTH, THE MOON, AND MARS .....</b>	<b>390</b>
<i>Erick Ordonez, Jennifer Edmunson, Michael Fiske, Eric Christiansen, Joshua Miller, Bruce (Alan) Davis, Jon Read, Mallory Johnston, John Fikes</i>	
<b>ATOMISTIC SIMULATIONS OF ELASTIC-PLASTIC DEFORMATION IN NICKEL SINGLE CRYSTAL UNDER SHOCK LOADING.....</b>	<b>397</b>
<i>Liu Hai, Huang Jie, Zhou Zhi-Xuan, Ma Zhao-Xia</i>	
<b>IMPACT-INDUCED COMPACTION OF PRIMITIVE SOLAR SYSTEM SOLIDS: THE NEED FOR MESOSCALE MODELLING AND EXPERIMENTS .....</b>	<b>405</b>
<i>Thomas M. Davison, James G. Derrick, Gareth S. Collins, Philip A. Bland, Michael E. Rutherford, David J. Chapman, Daniel E. Eakins</i>	
<b>RAMAN IDENTIFICATION OF OLIVINE GRAINS IN FINE GRAINED MINERAL ASSEMBLAGES FIRED INTO AEROGEL .....</b>	<b>413</b>
<i>Jamie E. Wickham-Eade, Mark J. Burchell, Mark C. Price, Leon J. Hicks, Jane L. Macarthur, John C. Bridges</i>	
<b>THE ROLE OF TARGET HETEROGENEITY IN IMPACT CRATER FORMATION: NUMERICAL RESULTS .....</b>	<b>421</b>
<i>Hannah C. M. Susorney, Olivier S. Barnouin, Angela M. Stickle, Carolyn M. Ernst, David A. Crawford, Mark J. Cintala</i>	
<b>PRIMARY STUDY ON SHIELDING PERFORMANCE OF AEROGEL/FIBERGLASS COMPOSITE STUFFED IN THERMAL INSULATION SHIELD .....</b>	<b>429</b>
<i>Li Jing, Jiang Lin, Wen Xuezhong, Huang Jie, Luo Qing, Huang Xuegang, Liu Sen</i>	
<b>CHALLENGES OF DEBRIS-IMPACT RISK ASSESSMENT FOR ROBOTIC SPACECRAFT.....</b>	<b>437</b>
<i>James Chinn, Martin Ratliff</i>	
<b>RE-EXAMINATION OF ELECTRICAL FAILURE RISK ON SATELLITE'S POWER HARNESSES CAUSED BY SPACE DEBRIS IMPACTS: SIMULTANEOUS MEASUREMENTS OF SUSTAINED DISCHARGE AND PLASMA DENSITY.....</b>	<b>445</b>
<i>Takayuki Hirai, Masumi Higashide, Hirohisa Kurosaki, Shirou Kawakita, Sunao Hasegawa, Yuki Mando, Shota Yamaguchi, Koji Tanaka</i>	
<b>EXPERIMENTAL AND NUMERICAL STUDY OF SUBMILLIMETER-SIZED HYPERVELOCITY IMPACTS ON HONEYCOMB SANDWICH STRUCTURES .....</b>	<b>452</b>
<i>P. Deconinck, H. Abdulhamid, P-L Hérel, J. Mespoulet, C. PUILLET</i>	
<b>ORION EXPLORATION FLIGHT TEST POST-FLIGHT INSPECTION AND ANALYSIS.....</b>	<b>460</b>
<i>J. E. Miller, E. L. Berger, W. E. Bohl, E. L. Christiansen, B. A. Davis, K. D. Deighton, P. A. Enriquez, M. A. Garcia, J. L. Hyde, O. M. Oliveras</i>	
<b>CONSIDERING THE GAP EFFECT AND SHAPE DETAIL FOR A WIRE PROBE ANTENNA SUBJECTED TO HYPER-VELOCITY IMPACTS.....</b>	<b>468</b>
<i>Kumi Nitta, Masumi Higashide, Atsuhiko Takeba, Masahide Katayama</i>	
<b>HYPERVELOCITY IMPACT TESTING OF A PRESSURIZED COMPOSITE OVERWRAPPED PRESSURE VESSEL AND COMPARISON TO NUMERICAL ANALYSIS.....</b>	<b>476</b>
<i>M. A. Garcia, B. A. Davis, J. E. Miller</i>	
<b>INTRODUCING MANUFACTURING FEATURES INTO NUMERICAL MODELING OF HYPERVELOCITY IMPACT DAMAGE OF COMPOSITE PRESSURE VESSELS.....</b>	<b>484</b>
<i>Aleksandr Cherniaev, Igor Telichev</i>	
<b>HYPERVELOCITY IMPACT IN LOW EARTH ORBIT: FINDING SUBTLE IMPACTOR SIGNATURES ON THE HUBBLE SPACE TELESCOPE.....</b>	<b>492</b>
<i>A T Kearsley, J L Colaux, D K Ross, P J Wozniakiewicz, L Gerlach, P Anz-Meador, T Griffin, B Reed, J Opiela, V V Palitsin, G W Grime, R P Webb, C Jeynes, J Spratt, T Salge, M J Cole, M C Price, M J Burchell</i>	

<b>ORBITAL DEBRIS MOMENTUM TRANSFER IN SATELLITE SHIELDS FOLLOWING HYPERVELOCITY IMPACT, AND ITS APPLICATION TO ENVIRONMENT VALIDATION.....</b>	<b>500</b>
<i>Joel Williamsen, Steven Evans</i>	
<b>EXPERIMENTAL STUDY OF HYPERVELOCITY IMPACTS ON SPACE SHIELDS ABOVE 8 KM/S.....</b>	<b>508</b>
<i>J. Mespoulet, P-L Hérel, H. Abdulhamid, P. Deconinck, C. Pullet</i>	
<b>BALLISTIC LIMIT EQUATIONS FOR NON-ALUMINUM PROJECTILES IMPACTING DUAL- WALL SPACECRAFT SYSTEMS.....</b>	<b>516</b>
<i>William P. Schonberg, J. Martin Ratliff</i>	
<b>Author Index</b>	