CASE STUDY

Title

Micrometeoroid Impact, Damage and Shielding Activity – The Open University

Summary

The Open University run a curricular activity on the impact, damage and shielding of micrometeoroids using a remotely operated optical microscope. The *Damage Equations* are used to approximate the crater depth or maximum thickness of material that will be perforated caused by an impactor on a surface. The activity can be conducted with the microscope itself or using provided measurement data. The activity is intended for independent study and takes students roughly 3 hours to complete.

Aims/Objectives

The purpose of the case study is to highlight the importance of designing for damage mitigation from micrometeoroids. Students investigate the effects of micrometeoroid impact of different sizes on spacecraft materials and a method for reducing the mass of protective shielding. Using the remote optical microscope gives students the opportunity to engage practically with the subject.

What was the context / background?

The activity described is an element of the Space Science module taught at the Open University as part of the MSc 'Space Science and Technology' programme. The module is made up of 5 parts; the first part is a basic introduction and the other 4 parts are case studies on past space missions. The micrometeoroid impact activity is a part of the Apollo 11 case study. The activity is run through the Open Science Laboratory - a platform bringing interactive practical science to students where the internet is available. The remote optical microscope must be booked in advance and is available to Open University students on STEM modules and approved users outside the Open University subject to an arrangement with the lab director.

Micrometeoroids present a hazard to spacecraft and astronauts. Cratering events occur at hypervelocity i.e. greater than speed of sound in the target material. The impact energy is transferred to localised volume of the target, resulting in very high shock pressures that result in vaporisation, melting and fracture of the target depending on the material and impact conditions. The craters investigated in this activity were created using the Open University's All Angle Light Gas Gun (ALGG) that can propel projectiles up to 4mm in diameter to speeds up to 7km/s.

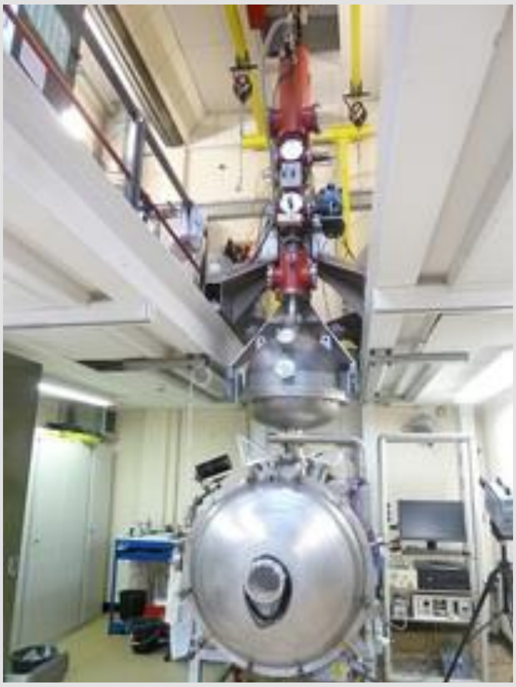

Figure 1: Open University's All Angle Light Gas Gun (ALGG) [Image credit: Open University]

How was it organised and who was involved?

This was a staff-led curricular activity with a focus on student independent learning. The process we went through to implement this was:

- Gas gun used to create impact crater in aluminium block and aluminium Whipple shield [Note: This does not need to be done for other Universities looking to use this activity as the data has already been collected]
- Students given access to the activity sheet and required to read through the material.
- [Optional step] Students log in to the OpenScience Laboratory to book a slot on the remote optical microscope.
    - To make enquiries regarding booking the remote optical microscope for students not enrolled on an Open University STEM course, please contact: openstemlabs@open.ac.uk
- Optical microscope used to measure the dimensions of the impact crater [Note: This is an optional step as a data sheet is provided with all the measurements].
- Activity sheet contains several problem questions to answer using data obtained from the remote optical microscope.
- Answers are provided for the students to mark their own work.

What resources did you need?

The level of resources required for this activity depend on whether the students undertake the crater measurements themselves via the remote optical microscope or use provided measurement data.

Resources needed:

Option 1 – using the remote optical microscope to measure the craters

- Fortescue, P., Stark, J. and Swinerd, G. (2011). Spacecraft systems engineering (4^{th} edition). Chichester: Wiley. ISBN: 978-0-470-75012-4
- Activity sheet
- Answer sheet
- Access to remote optical microscope
    - To make enquiries regarding booking the remote optical microscope for students not enrolled on an Open University STEM course, please contact: openstemlabs@open.ac.uk
    - Use of the remote optical microscope comes with a financial cost.
- Support from lecturer and post-graduates for students that are struggling to get the correct answers.

Option 2 – using the measurements in the measurement data folder

- Fortescue, P., Stark, J. and Swinerd, G. (2011). Spacecraft systems engineering (4th edition). Chichester: Wiley. ISBN: 978-0-470-75012-4
- Activity sheet
- Answer sheet
- Support from lecturer and post-graduates for students that are struggling to get the correct answers.

Describe the activity

Most cratering events in space are hypervelocity impacts; i.e. impacts that occur at speeds that exceed the speed of sound in the target material (a few km/s). The energy of the impacting particle is initially transferred to a localized volume of the target, causing very high shock pressures (tens of GPa) that result in vaporization, melting and fracture of the target, depending on the material and impact conditions. Impacts into ductile materials produce relatively uniform craters (Figure 2a) from melting of the target, whereas in brittle materials larger scale cracks and spallation damage also occur (Figure 2b).

The activity is made up of 4 stages:

1. Background reading
2. Measurement
3. Calculation and Analysis

Figure 2: Hypervelocity impact in a) metal and b) glass [Image credit: Open University]

1. **Background reading (Exercise 1)**

- Students are recommended to read Section 8.6 of Spacecraft Systems Engineering by Fortescue, Swinerd and Stark and the ESA Space Debris page.
- Students are also recommended to read through the activity sheet before going any further.

2. **Measurement (Exercise 2)**

- Students must book onto the remote optical microscope via the OpenScience Laboratory portal.
- Measurements are made of the crater on the solid block of aluminium and the aluminium Whipple shield, respectively.
- This step is optional for those that do not want to use the remote optical microscope. Measurement data is available to skip this step.

3. **Calculation and Analysis (Exercise 3)**

- Measurement data is used to compare calculated crater depths with measured crater depths and comment on any discrepancies between the values.
- Penetration limits are calculated and discussed.
- Penetration impact is calculated for a micrometeoroid that has penetrated the surface.
- Students must identify the benefit of the Whipple shield over the solid block.

Further detail on the activity may be found by looking at the Activity Sheet and Answer Sheet attached.

Thematic Categories (tick any that apply to your case study)

Method		Topic	
Online Text and Notes	☒	Orbits and Trajectories	☐
Assessment Materials	☐	Rocket Propulsion	☐
Video and Audio Lectures	☐	AOCS/ADCS	☐
Lecture Slides	☐	Payloads	☐
Curricula	☐	Power	☐
Video and Audio Clips	☐	Communications	☐
Recommended textbooks	☐	On Board Data Handling	☐
Useful software	☐	Systems	☐
Worksheets and Projects	☒	Mechanical	☒
Simulations	☐	Thermal	☐
Tutors' Guides	☐	Astronomy	☐
	☐	Earth Observation	☐
	☐	History of Spaceflight	☐
	☐	Other	☐

Contact Details

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