SimSpace: Teachers’ notes

Contents

What is SimSpace? ........................................................................................................................................3

Overview ..................................................................................................................................................3

Aim of the game .....................................................................................................................................3

Learning opportunities ............................................................................................................................3

Curriculum mapping ...............................................................................................................................4

Playing the game – a walkthrough .......................................................................................................5

The interface ........................................................................................................................................7

Step-by-step walkthrough .......................................................................................................................7

Attack tips .............................................................................................................................................13

Attack options .....................................................................................................................................13

How to score points ...............................................................................................................................14

How to win ..........................................................................................................................................14

SimSpace gameplay checklist .............................................................................................................15

Using SimSpace in the classroom .........................................................................................................16

Self-directed gameplay .........................................................................................................................16

Directed gameplay ...............................................................................................................................16

Considerations .......................................................................................................................................16

Lesson ideas .........................................................................................................................................17

Introducing the game .............................................................................................................................17

Playing the game ..................................................................................................................................17
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions and ideas for further activities</td>
<td>18</td>
</tr>
<tr>
<td>Useful weblinks</td>
<td>19</td>
</tr>
<tr>
<td>Handout: Introduction to NEOs</td>
<td>20</td>
</tr>
<tr>
<td>Handout: Stuff in our skies</td>
<td>22</td>
</tr>
<tr>
<td>Handout: Asteroids &amp; comets</td>
<td>23</td>
</tr>
<tr>
<td>Handout: SimSpace checklist</td>
<td>25</td>
</tr>
<tr>
<td>Handout: Attack tips</td>
<td>26</td>
</tr>
<tr>
<td>Handout: SimSpace – The interface</td>
<td>27</td>
</tr>
</tbody>
</table>
What is SimSpace?

Overview
SimSpace is a game-based learning resource where players take on the role of space scientists, scouting the skies for Near Earth Objects (NEOs) that may pose a risk to life on Earth. The premise is that planet Earth is overdue a major impact from an asteroid or comet, and players are leading the effort to detect any NEOs heading our way.

It’s a game of increasing tension, as players are faced with evaluating many collision candidates, trying all the time to collect more data to establish the level of threat more precisely. The game is based around realistic data collection and modelling tools, tracking with a telescope, modelling the object’s orbit and predicting its impact. Players can estimate the size and energy of the NEO using its brightness, and take the decision whether they need to strike with nuclear weapons. All this has to be done against the clock. 30 years pass in 12 minutes and if the killer comet or asteroid goes undetected, planet earth will be wiped out!

SimSpace can be played in small groups, by individuals or used in a whole class setting and is accompanied by comprehensive teacher support resources, handouts and suggested lesson ideas.

Aim of the game
The aim of the game is to detect which NEOs are going to cause regional or global catastrophes and destroy them, before they destroy Earth. Students will need at least two or three attempts to get near to completing the task successfully. The idea behind game-based learning is to learn by experimentation and trying things out, getting feedback along the way (usually losing the game) until you work out strategies to win. In SimSpace, you can only win by demonstrating scientific skills and applying the concepts – which is why it can act as an effective learning vehicle.

Learning opportunities
Learning comes from playing the game, with students discovering the learning points for themselves by drawing conclusions from their gameplay experience. SimSpace can be used as a jump off point for a whole range of learning activities when used in conjunction with some of the ideas and resources outlined in this guide. The table on the next page offers a few ideas and there are further suggestions in the ‘Using SimSpace in the classroom’ section at the end of this document.
<table>
<thead>
<tr>
<th>Learning points</th>
<th>How the game illustrates this</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarities and differences between comets and asteroids</td>
<td>On the IMPACT PREDICTOR tool, comets and asteroids have different scales for converting brightness to mass. Since comets are icy and lighter in colour, a given brightness corresponds to a smaller mass than an equally bright asteroid.</td>
</tr>
<tr>
<td>Shape of orbit of objects around the Sun</td>
<td>The IMPACT PREDICTOR tool shows the elliptical shape, and how the path of a NEO gradually intersects with that of the Earth.</td>
</tr>
<tr>
<td>Effect of NEO hitting Earth, kinetic energy, depends on mass and speed</td>
<td>The IMPACT PREDICTOR asks pupils to input the NEO mass, and uses this to calculate the kinetic energy and then animates the predicted impact.</td>
</tr>
<tr>
<td>Some astronomical quantities can only be measured indirectly</td>
<td>The mass of a NEO can only be deduced by measuring its brightness, and using a conversion scale (a graph) that relates brightness to mass.</td>
</tr>
<tr>
<td>The risks of a global catastrophe</td>
<td>Of the many NEOs detected, only a few will be identified as on a collision course. An even smaller number would be large enough to cause a catastrophe.</td>
</tr>
<tr>
<td>Uncertainty over the position and course of a NEO’s orbit changes over time</td>
<td>Before the NEO is tracked, its size and closest approach date is roughly estimated (this explains why NEOs sometimes disappear from a list that has been filtered – as their data changes). The more information collected, the clearer the risk level.</td>
</tr>
<tr>
<td>Measuring risk using the Torino scale, based on evidence</td>
<td>Using the ‘SET RISK LEVEL’ tool with the colour scale (white = zero, to red = extreme) several times for the same NEO shows how the risk can increase/decrease as new information is collected.</td>
</tr>
</tbody>
</table>

**Curriculum mapping**

SimSpace is mapped to the following National Curriculum objectives:

14-16: How Science Works
- Applications and implications of science: ‘risk’ and ‘how uncertainties in scientific knowledge change over time’.
- Communication skills: ‘analysing, interpreting, applying ideas’, and ‘using qualitative and quantitative approaches’.

14-16 Breadth of Study
- Environment, Earth and Universe: the solar system is part of the Universe.

The game directly addresses learning objectives in the following GCSE specifications:

**Edexcel**

**Twenty First Century Science**
- Core: P1 – The Earth in the Universe: ‘probability of an asteroid hitting the Earth’.

**Gateway**
- Core: P2 – Living for the future: ‘Threats to Earth – asteroid collision’.
Use of the game as a learning resource can support and develop the following **Thinking Skills**:
- Information processing: sort, classify, compare/contrast.
- Reasoning skills: draw inferences, make judgments.

**Playing the game – a walkthrough**

SimSpace is a realistic simulation that is significantly speeded up (30 years passes by in 12 minutes) and so presents a fairly steep learning curve. It is recommended that teachers play the game a couple of times, introducing it in the classroom.

This section presents a walkthrough of how to play the game and a gameplay checklist that will act as a crib sheet/reminder of the steps you need to go through once you are familiar with the game.

SimSpace starts with a short opening animation.

60 million years ago, an asteroid hit the Earth and wiped out the dinosaurs

Our only defence is to watch for Near Earth Objects ... This is your mission.
The game opens with the ‘Getting Started’ help screen. This offers help on the steps you need to go through – as well as tabs for help with other tools/aspects of the game. While ‘Help’ is open the simulation/game is paused. Close the window to start the game.
The interface

The whole game is played within the same window. The interface diagram below explains all of the features and functions available. This diagram is also available as a printable handout for students.

**EARTH STATE**
This shows the current state of the Earth.

**TOOLS**
These tools enable the player to track NEOs and predict the orbit and impact of each NEO as well as classify the risk level of each and attack if appropriate. Tools become available as the player goes through the steps in sequence. To use the attack tool you must be a professor.

**NEO details**
NEO details are presented here. To deal with a particular NEO, click to select. NEOs are initially shown as green before the risk is classified by the player.

**NEO Filters**
These controls enable you to filter the list of NEOs by closest approach (CA) date, distance, speed and diameter. For example, you can only choose to view NEOs that have a CA date of less than 20 years.

**SCIENTIST LEVEL**
This shows what level of scientist you currently are. There are three levels: Scientist, Senior Scientist and Professor. You need to be a Senior Scientist to set a NEO to a direct hit classification or a Professor to set a definite threat classification and launch an attack.

**HELP**
Offers general help on the steps you need to go through to play the game and on how to use each specific tool. The game is paused while the help screen is open.

**QUIT**
This quits the game.

**DATE**
This shows the current date. 30 years pass in 12 minutes so each second is equal to one month.

**NEWS**
News items, such as promotions and any asteroid hits, are shown here.

**NEO tabs**
Sort the NEOs by: closest approach (CA) date, distance, speed, size, type and risk level; or by NEOs which have already been tracked, orbit predicted or impact predicted.

---

**Step-by-step walkthrough**

**STEP ONE: Tracking NEOs**

The first step is to use the telescope to track any new NEOs that have recently been identified.

To do this, click the TRACKING button on the left-hand side. Select each NEO in turn and then click the ‘Track NEO’ button. You can track up to four NEOs simultaneously.

Once the NEO has been tracked it shows as ‘Complete’ in the list.
STEP TWO: Orbit prediction – probability ellipse

The second step is to use the ORBIT PREDICTOR tool.

Watch the ‘Probability ellipse’ get smaller. If the Earth is outside the ellipse then the NEO will miss. If it is inside then there is a chance that the NEO will hit.

STEP THREE: Classification – set risk levels

If the ‘probability ellipse’ shows that the NEO will miss, then you can set the Risk Level of that NEO to white (ZERO RISK OF COLLISION).

If the ‘probability ellipse’ shows the Earth inside the ellipse then set the Risk Level of that NEO to yellow (SIGNIFICANT RISK OF COLLISION. WATCH CLOSELY).

To earn points and be promoted you will need to correctly classify a number of NEOs. Once a NEO has been classified as Zero Risk you can forget about it and concentrate on any that present a significant risk.
To see which NEOs present the most significant risk, return to the NEO FILTER screen and sort by Closest Approach (CA) date using the tabs at the top of the screen or the filter at the bottom of the screen.

**TIP**

The game begins on 1/1/2010 and lasts 30 years so any NEOs with a CA date beyond 2040 do not present any danger within the simulation. Obviously in real life they would be a concern!

**STEP FOUR: Orbit prediction – graphical prediction**

If there are any NEOs with a close CA date that have been identified as yellow (significant risk) – then these should be further investigated using the orbit prediction tool.

Return to the ORBIT PREDICTOR tool. Use the controls to fast forward the simulation to just before the CA date.

The ‘Closest Approach Distance’ will change from TBC to a number (shown as 4 here). If this is any number other than zero then the NEO will miss Earth, posing no threat. You can reclassify the NEO as white – 0 threat. If the number is 0 then this indicates a hit. Mark the NEO as orange and go to the IMPACT PREDICTOR tool.

**TIP**

To review the Closest Approach Date the speed on the timeline must be set to the slowest setting to get a reading.
STEP FIVE: Impact prediction

The IMPACT PREDICTOR TOOL is the most complicated part of the game as it involves a number of processes. The tool is used to find out the effect and impact of the NEO.

Firstly, you need to determine the brightness of the NEO. Move the crosshair over the graphic of the comet or asteroid and then click the mouse.

This will give you a figure for the brightness (shown here as 7).

Secondly you need to calculate the mass of the NEO by reading the brightness-mass graph.

To access the graph, click the ‘Conversion Scale’ tab on the left-hand side of the window. Then select the appropriate conversion scale either ‘comet’ or ‘asteroid’.
Thirdly you need to estimate the mass of the NEO from the log graph. To do this:
- Look on the brightness (y) axis to find the brightness of the current NEO (in this example it is 7).
- Look horizontally until you reach the curve of dots.
- Look down to the X axis and estimate the mass (it’s $7 \times 10^7$ kg in this example).

Type in the mass of the NEO as you calculated it from the graph and then click the SIMULATE IMPACT button to view the impact animation. Here the impact is fairly small and local.

**TIP**

It’s a good idea to explain logarithmic graphs and the scientific notation used on it to players before they use the IMPACT PREDICTOR TOOL.
STEP SIX: Attack

After completing the IMPACT PREDICTION you should reclassify the NEO as a definite risk (red) - Local, Regional or Global - and then make a decision as to whether you want to attack.

TIP

Although a local risk would be a concern in reality, in the game it has little impact on the Earth and you may decide that there are more pressing NEOs that need to be dealt with than this one.

If the NEO poses a regional or global threat then you definitely need to launch an attack.

The ATTACK tool will destroy a NEO or change its path so that it is no longer headed directly for Earth.

You need to decide which method of attack you want to use:

- Nuclear Direct hit
- Nuclear side impact
- Spaceship collision

Each of these methods has pros and cons, so you will need to weigh up which is best in the current circumstances.
**Attack tips**

**Launching attacks:**
- There is a 25% chance that a nuclear missile will explode on the launch pad. Any explosion will result in the loss of 25% Earth state.
- Spaceships don’t explode on take-off, and therefore won’t cause any damage to the Earth.

**If a NEO hits Earth:**
- Level 8 NEOs will cause Local damage, meaning the loss of 25% Earth state.
- Level 9 NEOs will cause Regional damage, meaning the loss of 50% Earth state.
- Level 10 NEOs will cause Global damage, meaning the loss of 100% Earth state.

**To attack a level 8, 9 or 10 NEO the following has to be true**

**For asteroids:**
- The CA distance has to be 0.
- The CA date has to be less than 20 years away.
- The asteroid has a diameter greater than or equal to 10 metres.

**For comets:**
- The CA distance has to be 0.
- The CA date has to be less than 20 years away.
- The comet has a diameter greater than or equal to 20 metres.

**Attack options**
Choosing the right type of attack is vital.

**Nuclear direct hit attacks will succeed if:**
- The NEO is an asteroid less than 7,500 metres in diameter.
- The NEO is a comet less than 15,000 metres in diameter.

**Nuclear side impact attacks will succeed if:**
- The NEO has a CA date over 2 years.

**Spaceship collision will succeed if:**
- The NEO has a CA date over 10 years.
- The NEO is an asteroid less than 7,500 metres in diameter.
- The NEO is a comet less than 15,000 metres in diameter.

If your first attack is unsuccessful, try again using a different weapon.
How to score points

Points are awarded firstly for classifying and marking NEOs correctly, either as no risk to Earth (white) or as a significant risk (yellow). Later, once further investigations have been undertaken, points are awarded for re-classifying a NEO as a direct hit or as a definite threat to life on Earth either Locally, Regionally or Globally. Further points are awarded for destroying, either partially or completely, or diverting a NEO so it is less of, or no longer a risk to Earth.

<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>POINTS</th>
<th>LEVEL REQ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctly classifying and marking NEO correctly as WHITE - ZERO RISK OF COLLISION</td>
<td>1 point</td>
<td>Scientist</td>
</tr>
<tr>
<td>Correctly classifying and marking NEO correctly as YELLOW - SIGNIFICANT RISK OF COLLISION. WATCH CLOSELY</td>
<td>2 points</td>
<td>Scientist</td>
</tr>
<tr>
<td>Correctly classifying and marking NEO correctly as ORANGE - DIRECT HIT. MAY THREATEN LIFE ON EARTH. CRITICAL SITUATION</td>
<td>3 points</td>
<td>Senior Scientist</td>
</tr>
<tr>
<td>Correctly classifying and marking NEO correctly as RED - DEFINITE THREAT – LOCAL, REGIONAL OR GLOBAL</td>
<td>4 points</td>
<td>Professor</td>
</tr>
<tr>
<td>Partially destroying NEO (Regional devastation)</td>
<td>4 points</td>
<td>Professor</td>
</tr>
<tr>
<td>Partially destroying NEO (Local destruction)</td>
<td>6 points</td>
<td>Professor</td>
</tr>
<tr>
<td>Successfully destroying/diverting NEO</td>
<td>10 points</td>
<td>Professor</td>
</tr>
</tbody>
</table>

Players are only able to mark NEOs as white or yellow as a Scientist. As a Senior Scientist, players can also classify NEOs as orange (direct hit). To classify a NEO as red – or to launch an attack on a NEO, players must be working as a Professor.

To be promoted from Scientist to Senior Scientist players must earn 10 points. To be promoted from Senior Scientist to Professor, players must earn 20 points.

How to win

During the simulation the order in which the NEOs appear in the list is random. However, in each game there will always be one NEO that will cause devastation on a global scale (which will end the game if it is not destroyed) and two regional catastrophe NEOs which each reduce ‘Earth State’ to 50% if they hit. You need to detect these, and then strike them before their ‘CA date’ to complete the game successfully. If ‘Earth State’ is reduced to 0% then it is game over. In the game a 50% ‘Earth State’ is considered a partial success.
**SimSpace gameplay checklist**

The checklist is a step-by-step reminder of the steps you need to go through to successfully play (and hopefully complete) the game. There is a handout version for students at the end of this document.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **1.** | The game automatically loads the ‘Help’ menu at the start, close this to begin playing the game.  
**TIP** – the game is paused when ‘Help’ is open. |
| **2.** | As NEOs begin to appear on the radar start to track them by clicking on them, then select TRACKING and ‘Track NEO’.  
**TIP** – you can track up to four NEOs at a time. |
| **3.** | Sort NEOs by CA date – deal with those that are most imminent. |
| **4.** | Run Orbit Prediction tool on any NEOs with close CA dates. Use the ‘Probability ellipse’ to see if there is any risk of a hit. |
| **5.** | Classify NEOs as yellow if the Orbit Prediction tool shows a hit. Classify NEOs as white if there is no risk.  
**TIP** - to gain enough points to be promoted to Professor ensure that you continue to track, orbit predict and classify any new NEOs. Once you’ve gained Professor Status you can just concentrate on the NEOs that have the closest CA dates. |
| **6.** | Deal with any NEOs that have the closest approach (CA) date and that have been classified as yellow (significant risk). |
| **7.** | Run the graphical prediction element of the Orbit Prediction tool to get an exact ‘Closest Approach Distance’. Do this by speeding up the timescale, then as you get close to the CA date, view the simulation at normal speed. |
| **8.** | If the ‘Closest Approach Distance’ is 1 or above, reclassify as no risk (white).  
If the ‘Closest Approach Distance’ is 0 then reclassify the NEO as orange (direct hit). |
| **9.** | Use the Impact Prediction tool to measure the brightness of the NEO, estimate its mass and run the impact simulation.  
**TIP** - there are several processes to go through here so don’t forget to follow the on-screen instruction. |
| **10.** | Reclassify the risk to Earth as a Definite Threat (red) – Local, Regional or Global. |
| **11.** | Launch an attack – assessing the pros and cons of each – Nuclear Direct Hit, Nuclear Side Impact or a Spaceship Collision. |
Using SimSpace in the classroom

SimSpace is designed to be integrated into lessons but can also be used as an individual learning resource. This section aims to help teachers to find the most appropriate way to integrate the game into their teaching and learning.

There are two main ways in which the game can be played by students, ensuring the game meets the differentiation needs of classes or groups, as well as teacher confidence in using the game as part of a lesson. These are self-directed or directed gameplay.

Self-directed gameplay
Let students play the game individually, in pairs or in small groups as a self exploratory project. They play the game as they choose to, developing their own hypotheses and strategies and playing these out. Students may decide to jump in and play the game without a strategy and see how successful they are or they may review the help files to devise a plan before they start. The principle behind this approach is to allow students to experiment, to come to their own conclusions and then to follow this up with some related and more structured learning activities.

Directed gameplay
The teacher can take more control of the game, giving students direct instructions about what to do in each step of the simulation. This approach uses the game more as a teaching aid than as a learner-centred game. Teachers are able to select particular learning points they want to make.

Teachers could also play the game as a whole class activity, using an interactive whiteboard or projector, commenting on actions and game feedback and asking students to suggest different approaches or to attempt to explain results.

Considerations
In integrating the game into lessons, teachers should consider:

- How much introductory or contextual information to present to students before they play the game.
- How groups of students are organised and how much direction or in-situ guidance they are given as they play the game.
- What research tools students are given access to as they play the game, e.g. access to the internet or accompanying handouts, or if they are given any supporting resources at all.
- How extensive or prescribed to make the writing and recording of students’ approaches to the game and the ensuing results. After students have played the game, teachers will need to decide how much time to spend on sharing the results and strategies from groups of students and how best to facilitate this.
**Lesson ideas**

As well requiring two or three attempts to learn how to play the game, SimSpace also contains a lot of physics ideas and concepts that are likely to be new to students and you may want to consider spreading the use of the game over more than one lesson.

**Introducing the game**

You could introduce the game through the context of ‘what killed the dinosaurs?’ – using the popular asteroid theory, or the film ‘Deep Impact’ (links below). What would happen if a huge asteroid or comet was on collision course with Earth? Could we stop it? How would we detect the object in time? And how would we know if it is going to wipe us out or just burn up in the atmosphere? How likely is it that an asteroid would wipe out planet Earth? Is there a real risk? These are the questions that SimSpace answers by getting pupils to simulate the process from NEO detection to a nuclear strike.

Alternatively, you could use the ‘Keeping an eye on Space Rocks’ multimedia presentation from NASA – [www.jpl.nasa.gov/multimedia/neo/spaceRocks.html](http://www.jpl.nasa.gov/multimedia/neo/spaceRocks.html) – which offers a really good introduction to NEOs, or use the ‘Introduction to NEOs’ handout included at the end of the document.

It is a good idea to give pupils a quick tour of the game – pointing out all the ‘tools’ they will use, and explaining the sequence of actions to take in order to identify a NEO as a threat, or rule it out. There are a couple of handouts available that will support students in playing the game – a diagram of the interface, showing all the tools and features, and a checklist that describes the steps you need to go through in playing the game.

The tools are:

- Tracking tool – collect telescope observations, to use in modelling orbits.
- Orbit tool – to ‘play’ a simulation of the orbit to see if it will hit Earth.
- Impact tool – to estimate the size of the impact, and whether to strike.
- Attack tool – to launch a nuclear or other attack to destroy major threats.

There are extensive help files within the game that explain how to use all the tools.

**Playing the game**

Organise for students to play the game in twos or threes, depending on the number of machines you have. Although the game runs quite fast, and benefits from one person on the controls, playing as a team will provoke discussion and dialogue between students about what is happening and the best course of action to take, which is really valuable.

Allow them to play through the simulation at least twice – the maximum length of a game is 12 minutes without any pauses (looking at help screens).
When all groups have played the game through at least twice stop them and get together as a whole class. To turn the experience of playing into learning requires pupils to reflect on what they did in the ‘virtual world’ and apply this to real world understanding. Working as a whole group, discuss each team’s results/successes/failures, and each team’s strategies for playing – what worked/what didn’t. Did they manage to identify the NEOs that were the biggest threats to Earth? How easy/difficult was it? What was their ‘Earth State’ at the end of the game? Discuss the risks of a global catastrophe, such as a comet hitting the Earth (taking into account the consequences, the chance of it occurring and any uncertainties).

This will generate discussion about the key curriculum objectives like risk, uncertainty and the properties of comets and asteroids and their orbits. At this stage you might want to have the game running on a projector or whiteboard, and stop it to illustrate learning points.

An extension activity for those pupils who manage to win could be to work up an explanation of their strategy using scientific concepts, or to research the authenticity of the data in the game. How many NEOs are currently being tracked? Are there equal numbers of asteroids and comets? How often does a NEO come along that poses a real threat (orange or red on the Torino scale) to Earth?

Below there is a set of questions, provoked by the game, which may form the basis of further investigation, exploration or activities.

**Questions and ideas for further activities**

- Are there any dangers in using nuclear weapons to attack a NEO, especially when the attack is not 100% successful?
- What should be considered in terms of ethics around attacking NEOs? Weighing up pros and cons? Are there situations when it’s okay to put some people’s lives at risk?
- What’s the difference between a comet and asteroid? Do they need to be treated differently? Are there more of one than the other? Where do they come from? What can they tell us?
- Investigate the different theories around extinction of the dinosaurs.
- In the game, you still ‘Win’ even though 50% of the Earth has been destroyed? What would the world look like if this was a reality? Would you still consider it winning?
- As well as tracking and cataloguing NEOs, the NEO community argue that there should be continuous research into new weapons/methods of diverting a NEO should there be real risk. Investigate what ideas have already been suggested. Get students to work as teams to devise and pitch new ideas to the rest of the group.
- What is the current data on NEOs?
- What, where and when was the last asteroid strike?
### Useful weblinks

<table>
<thead>
<tr>
<th>Issue</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK International space centre website</td>
<td><a href="http://www.spacecentre.co.uk/Page.aspx/180/EXPLORE_NEOs">www.spacecentre.co.uk/Page.aspx/180/EXPLORE_NEOs</a></td>
</tr>
<tr>
<td>Comprehensive section on NEOs which would make a good introduction to the topic.</td>
<td></td>
</tr>
<tr>
<td>A multimedia introduction to NEOs from the Jet Propulsion Laboratory at NASA. A good introduction resource.</td>
<td></td>
</tr>
<tr>
<td>Portal and community website – Space.com</td>
<td><a href="http://www.space.com/">www.space.com/</a></td>
</tr>
<tr>
<td>The Catalina Sky Survey project.</td>
<td><a href="http://www.lpl.arizona.edu/css/">www.lpl.arizona.edu/css/</a></td>
</tr>
<tr>
<td>Rocks from Space – NEO page</td>
<td><a href="http://rocksfromspace.open.ac.uk/NEOs_detail.htm">http://rocksfromspace.open.ac.uk/NEOs_detail.htm</a></td>
</tr>
<tr>
<td>Open University’s website on the solar system.</td>
<td></td>
</tr>
<tr>
<td>IAU Minor Planet Center in Massachusetts, USA.</td>
<td><a href="http://www.cfa.harvard.edu/iau/mpc.html">www.cfa.harvard.edu/iau/mpc.html</a></td>
</tr>
<tr>
<td>Real list of data of potential future Earth impact events that the JPL Sentry System has detected based on currently available observations.</td>
<td><a href="http://neo.jpl.nasa.gov/risk/">http://neo.jpl.nasa.gov/risk/</a></td>
</tr>
<tr>
<td>Excellent introduction to NEOs and the threat they pose to our planet.</td>
<td><a href="http://pan-starrs.ifa.hawaii.edu/public/asteroid-threat/asteroid_threat.html">http://pan-starrs.ifa.hawaii.edu/public/asteroid-threat/asteroid_threat.html</a></td>
</tr>
<tr>
<td>Theory of an asteroid impact responsible for extinction of the dinosaurs.</td>
<td><a href="http://www.dinosaurfact.net/extinction/breaking_asteroid.php">www.dinosaurfact.net/extinction/breaking_asteroid.php</a></td>
</tr>
<tr>
<td>Short summaries of some theories of dinosaur extinction.</td>
<td><a href="http://web.ukonline.co.uk/a.buckley/dino.htm">http://web.ukonline.co.uk/a.buckley/dino.htm</a></td>
</tr>
</tbody>
</table>
Handout: Introduction to NEOs

Over the past 50 years scientists have discovered that asteroids and comets have collided with the Earth throughout its 4.5 billion year history. The impact of these Near Earth Objects (NEOs) with our planet can be catastrophic and still represents a natural hazard today.

What are NEOs?
A NEO is any asteroid or comet whose orbit around the Sun brings it close to Earth’s orbit. The official definition of ‘close’ in this situation is 45 million kilometres. Asteroids and comets are the left over building blocks from when the planets formed, 4.5 billion years ago.

Asteroids are made of rocky materials similar to those of the four inner planets; Mercury, Venus, Earth and Mars. Comets are mostly made of ice and frozen gases. (See handout on the differences between comets and asteroids). When NEOs are nudged by the gravity of massive objects like planets, their orbits can be changed causing them to head inwards towards Earth.

Most asteroids and comets have remained largely unaltered since their formation. Therefore they are like a natural time capsule and can reveal a lot about the conditions present when the Solar System was first born.

Is anyone on the lookout?
There are now several dedicated search programmes looking for NEOs. The most successful in recent years has been the Catalina Sky Survey. In the first half of 2008, the Catalina Sky Survey accounted for 70% of newly discovered near Earth asteroids (www.lpl.arizona.edu/css/). When a NEO is first detected, it may only have been observed for a few minutes or hours of its orbit. Therefore, there is a lot of uncertainty about the track the object will actually take around the Sun. There is a lot of investigation to calculate the many potential orbits that the object could be on. If any of these ‘virtual’ orbits bring an asteroid within 750,000 kilometres of the Earth’s orbit at some point in the future, it is classified as a Potentially Hazardous Asteroid (PHA).

This investigative work is carried out by a worldwide network of professional and amateur astronomers collectively known as the NEO Community. The results of these observations are fed into the process of calculating the risks posed by NEOs.
Are there many NEOs out there?

In 1900 there were only 21 known NEOs, all but one of which were comets.

By 1990 the number of NEOs detected had risen to 170, the majority of which were asteroids.

As of July 2009 there were 6,321 NEOs known. Of these, 1,060 were classified as Potentially Hazardous Asteroids.

There are far more small NEOs than large. On a global scale it is the large NEOs, with diameters greater than 1 kilometre, which pose the biggest threat. There are estimated to be around 1,000 such NEOs. As of July 2009 astronomers had detected 783 of these large objects.

When new observations of a NEO are made, they are submitted to the Minor Planet Centre (MPC) in Massachusetts in the USA (www.cfa.harvard.edu/iau/mpc.html).

There are two independent centres that use these observations to calculate the risk of any future impacts. One is based in the USA (http://neo.jpl.nasa.gov/risk/) the other in Italy (http://newton.dm.unipi.it/neodys/index.php?pc=4.0).

TORINO Scale

The Torino Impact Hazard Scale is a simple tool for communicating the risk posed by a NEO (see separate handout).

The information in this handout is an edited version of the NEO pages on the National Space Centre’s website. For more information see: www.spacecentre.co.uk/Page.aspx/183/WHAT_ARE_NEOs_/
Handout: Stuff in our skies

- About 2,000 objects massive enough (1 km diameter) to cause global catastrophe are known to cross Earth’s orbit. Such an impacting object would wipe out 25% of humanity.
- About 10,000 objects of 500 m size cross Earth’s orbit.
- About 300,000 objects of 100 m size cross Earth’s orbit.
- About 150 million objects of 10 m size cross Earth’s orbit.
- Some 70% of potential impactors are asteroids; the rest are comets.
- About 50% of the Earth-crossing asteroids most likely are extinct or dormant comets.

FREQUENCY OF IMPACTORS:

Pea size meteoroids - 10 per hour
Walnut size - 1 per hour
Grapefruit size - 1 every 10 hours
Basketball size - 1 per month
50 m rock that would destroy an area the size of New Jersey - 1 per 100 years
1 km asteroid - 1 per 100,000 years
2 km asteroid - 1 per 500,000 years
A ‘nemesis’ parabolic comet impactor would give us only a 6-month warning

Above information from: [http://web.ukonline.co.uk/a.buckley/dino.htm](http://web.ukonline.co.uk/a.buckley/dino.htm)
(Originally from the Anglo-Australian Observatory’s research astronomer Duncan Steel’s book Rouge Asteroids and Doomsday Comets).
Handout:
Asteroids & comets

<table>
<thead>
<tr>
<th>ASTEROIDS</th>
<th>COMETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>made up of metals and rocky material</td>
<td>made up of ice, dust and rocky material</td>
</tr>
<tr>
<td>formed early in the history of the solar system about 4.5 billion years ago</td>
<td>formed early in the history of the solar system about 4.5 billion years ago</td>
</tr>
<tr>
<td>formed in the warmer inner solar system between the orbits of Mars and Jupiter</td>
<td>formed in the cold outer planetary system far from the sun where ices would not melt</td>
</tr>
<tr>
<td>inactive body of matter</td>
<td>can be inactive or active object</td>
</tr>
</tbody>
</table>

What is the difference between an asteroid, comet, meteoroid, meteor and meteorite?

<table>
<thead>
<tr>
<th>Asteroid</th>
<th>A relatively small, inactive body, composed of rock, carbon or metal, which is orbiting the Sun.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comet</td>
<td>A relatively small, sometimes active object, which is composed of dirt and ices. Comets are characterised by dust and gas tails when in proximity to the Sun. Far from the Sun it is difficult to distinguish an asteroid from a comet.</td>
</tr>
<tr>
<td>Meteoroid</td>
<td>A small particle from an asteroid or comet orbiting he Sun.</td>
</tr>
<tr>
<td>Meteor</td>
<td>A meteoroid that is observed as it burns up in the Earth's atmosphere - a shooting star.</td>
</tr>
<tr>
<td>Meteorite</td>
<td>A meteoroid that survives its passage through the Earth's atmosphere and impacts the Earth's surface.</td>
</tr>
</tbody>
</table>

Reference: [www.nearearthobjects.co.uk/](http://www.nearearthobjects.co.uk/)
# Handout: Torino scale

The Torino Impact Hazard Scale

<table>
<thead>
<tr>
<th>No Hazard (White Zone)</th>
<th>0</th>
<th>The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (Green Zone)</td>
<td>1</td>
<td>A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.</td>
</tr>
<tr>
<td>Meriting Attention by Astronomers (Yellow Zone)</td>
<td>2</td>
<td>A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of localized destruction. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of regional devastation. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.</td>
</tr>
<tr>
<td>Threatening (Orange Zone)</td>
<td>5</td>
<td>A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether or not a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether or not a collision will occur.</td>
</tr>
<tr>
<td>Certain Collisions (Red Zone)</td>
<td>8</td>
<td>A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several 1000 years.</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.</td>
</tr>
</tbody>
</table>
The checklist is a step-by-step reminder of the steps you need to go through to successfully play (and hopefully complete) the game.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| 1. | The game automatically loads the ‘Help’ menu at the start, close this to begin playing the game.  
**TIP** – the game is paused when ‘Help’ is open. |
| 2. | As NEOs begin to appear on the radar start to track them by clicking on them, then select TRACKING and ‘Track NEO’.  
**TIP** – you can track up to four NEOs at a time. |
| 3. | Sort NEOs by CA date – deal with those that are most imminent. |
| 4. | Run Orbit Prediction tool on any NEOs with close CA dates. Use the ‘Probability ellipse’ to see if there is any risk of a hit. |
| 5. | Classify NEOs as yellow if the Orbit Prediction tool shows a hit. Classify NEOs as white if there is no risk.  
**TIP** - to gain enough points to be promoted to Professor ensure that you continue to track, orbit predict and classify any new NEOs. Once you’ve gained Professor Status you can just concentrate on the NEOs that have the closest CA dates. |
| 6. | Deal with any NEOs that have the closest approach (CA) date and that have been classified as yellow (significant risk). |
| 7. | Run the graphical prediction element of the Orbit Prediction tool to get an exact ‘Closest Approach Distance’. Do this by speeding up the timescale, then as you get close to the CA date, view the simulation at normal speed. |
| 8. | If the ‘Closest Approach Distance’ is 1 or above, reclassify as no risk (white).  
If the ‘Closest Approach Distance’ is 0 then reclassify the NEO as orange (direct hit). |
| 9. | Use the Impact Prediction tool to measure the brightness of the NEO, estimate its mass and run the impact simulation.  
**TIP** - there are several processes to go through here so don’t forget to follow the on-screen instruction. |
| 10. | Reclassify the risk to Earth as a Definite Threat (red) – Local, Regional or Global. |
| 11. | Launch an attack – assessing the pros and cons of each – Nuclear Direct Hit, Nuclear Side Impact or a Spaceship Collision. |
General information

Launching attacks:
There is a 25% chance that a nuclear missile will explode on the launch pad. Any explosion will result in the loss of 25% Earth state.
Spaceships don’t explode on take-off, and therefore won’t cause any damage to the Earth.

If a NEO hits Earth:
Level 8 NEOs will cause Local damage, meaning the loss of 25% Earth state.
Level 9 NEOs will cause Regional damage, meaning the loss of 50% Earth state.
Level 10 NEOs will cause Global damage, meaning the loss of 100% Earth state.

To attack a level 8, 9 or 10 NEO the following has to be true

<table>
<thead>
<tr>
<th>For asteroids:</th>
<th>For comets:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The CA distance has to be 0.</td>
<td></td>
</tr>
<tr>
<td>The CA date has to be less than 20 years away.</td>
<td></td>
</tr>
<tr>
<td>The asteroid has a diameter greater than or equal to 10 metres.</td>
<td></td>
</tr>
<tr>
<td>The CA distance has to be 0.</td>
<td></td>
</tr>
<tr>
<td>The CA date has to be less than 20 years away.</td>
<td></td>
</tr>
<tr>
<td>The comet has a diameter greater than or equal to 20 metres.</td>
<td></td>
</tr>
</tbody>
</table>

Attack options
Choosing the right type of attack is vital.

<table>
<thead>
<tr>
<th>Nuclear direct hit attacks will succeed if:</th>
<th>Nuclear side impact attacks will succeed if:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The NEO is a comet less than 15,000 metres in diameter.</td>
<td></td>
</tr>
<tr>
<td>The NEO is an asteroid less than 7,500 metres in diameter.</td>
<td></td>
</tr>
<tr>
<td>The NEO has a CA date over 2 years.</td>
<td></td>
</tr>
<tr>
<td>The NEO has a CA date over 10 years.</td>
<td></td>
</tr>
<tr>
<td>Spaceship collision will succeed if:</td>
<td>The NEO is an asteroid less than 7,500 metres in diameter.</td>
</tr>
<tr>
<td>The NEO is a comet less than 15,000 metres in diameter.</td>
<td></td>
</tr>
</tbody>
</table>
Handout:
SimSpace – The interface

The whole game is played within the same window. The interface diagram below explains all of the features and functions available.

**EARTH STATE**
This shows the current state of the Earth.

**TOOLS**
These tools enable the player to track NEOs and predict the orbit and impact of each NEO as well as classify the risk level of each and attack if appropriate. Tools become available as the player goes through the steps in sequence. To use the attack tool you must be a professor.

**NEO details**
NEO details are presented here. To deal with a particular NEO, click to select. NEOs are initially shown as green before the risk is classified by the player.

**NEO Filters**
These controls enable you to filter the list of NEOs by closest approach (CA) date, distance, speed and diameter. For example, you can only choose to view NEOs that have a CA date of less than 20 years.

**SCIENTIST LEVEL**
This shows what level of scientist you currently are. There are three levels: Scientist, Senior Scientist and Professor. You need to be a Senior Scientist to set a NEO to a direct hit classification or a Professor to set a definite threat classification and launch an attack.

**HELP**
Offers general help on the steps you need to go through to play the game and on how to use each specific tool. The game is paused while the help screen is open.

**DATE**
This shows the current date. 30 years pass in 12 minutes so each second is equal to one month.

**NEWS**
News items, such as promotions and any asteroid hits, are shown here.

**NEO tabs**
Sort the NEOs by: closest approach (CA) date, distance, speed, size, type and risk level; or by NEOs which have already been tracked, orbit predicted or impact predicted.

**QUIT**
This quits the game.