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Negotiating Uncertainty: Asteroids, Risk and the Media

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ABSTRACT

Natural scientists often appear in the news media as key actors in the management of risk. This paper examines the way in which a small group of astronomers and planetary scientists have constructed asteroids as risky objects and have attempted to control the media representation of the issue. It shows how scientists negotiate the uncertainties inherent in claims about distant objects and future events by drawing on quantitative risk assessments even when these are inapplicable or misleading. Although the asteroid scientists worry that media coverage undermines their authority, journalists typically accept the scientists' framing of the issue. The asteroid impact threat reveals the implicit assumptions which can shape natural scientists' public discourse and the tensions which arise when scientists' quantitative uncertainty claims are re-presented in the news media.

Keywords: asteroids, impact threat, astronomy, risk, uncertainty, science journalism, media, science news

Introduction

Over the past two decades, British newspapers have periodically announced the end of the world. Playful headlines such as “The End is Nigh” and “Armageddon Outta Here!” are followed a few days later by reports that there’s no danger after all: “PHEW. The end of the world has been cancelled” (Britten, 1998; Wickham, 2002; *Evening Standard*, 1998).

These stories, and others like them appearing in news media around the world, deal with the possibility that an asteroid or comet may one day collide with the Earth causing global destruction. The threat posed by near-Earth objects (NEOs) has been actively promoted by a group of astronomers and planetary scientists since the late 1980s. Construing asteroids and comets as risky objects, the NEO scientists have lobbied politicians and written popular books calling for dedicated sky surveys to identify potentially hazardous asteroids. Yet despite their own efforts to draw the public’s attention to the issue, the scientists have worried about the way in which the impact threat is reported in the news media, especially in the UK. After each episode of media coverage, they have attempted to find new ways of controlling the representation of asteroids as a risk. At the heart of their concerns has been the question of how they can manage uncertain knowledge about asteroids whilst retaining their authority as scientists.

This paper examines the tensions which arise when natural scientists position themselves in the public arena as experts on risk by looking at the ways in which the NEO scientists have constructed asteroids as a risk, their struggles to control the media representation of the issue, and the assumptions on which their evolving communication strategy has been based. Since it was reports in the UK press which most concerned the scientists, it is on these that this paper focuses.

Social theorist Ulrich Beck (2000, xii) has used comet impacts to illustrate how modern society has moved away from a preoccupation with natural risks: “We are no longer talking about comets crashing to earth or accidents with a greater or lesser degree of probability occurring.” In his *Risk Society*, Beck (1992) argues that our current phase of modernisation is defined by the replacement of localised, natural

hazards with global, technological risks. Yet the demarcation between natural and technological risks is not as clear cut as Beck seems to imply. Debates about the probabilities of “natural” risks are as characteristic of the risk society as are controversies about industrial risks. As this paper shows, even astronomers – the scientists whose objects of study are furthest removed from the products of industrialisation – can be active participants in the discourses of risk. We *are* still talking about comets (and asteroids) crashing to Earth, but we are doing so in a new way. “Natural” risks such as the impact threat are, like industrial risks, constructed through scientific discourses made available through technological developments. The impact threat has all the characteristics of one of Beck’s “risks of modernisation”: it is global, unlimited in time, and invisible until made visible by science.

Sociologists of science have examined the ways in which scientists construct and manage risk. Scholars such as Brian Wynne argue that risk is context dependent and that scientific risk assessments constrain discourse by rendering risk the object of quantitative analyses and by imposing a strict demarcation of risk from ethics and political values (e.g., Wynne, 2001). The issue of risk is closely related to how uncertainties within scientific knowledge are negotiated. Constructivist analyses of scientific uncertainty argue that uncertainty is not simply an absence of knowledge or an aspect of underlying reality, but something which is actively constructed and managed (Pinch, 1981; Campbell, 1985; Star, 1985; Stocking and Holstein, 1993; Zehr, 1999). Holly Stocking (1998: 168), for instance, using the term “ignorance” to cover uncertainties, errors, absences of knowledge and other forms of non-knowing, argues that ignorance, like knowledge, is “a construction embedded in diverse social interests and commitments.”

The authority of science emerges as a key issue shaped by uncertainty claims. Although uncertainty can potentially undermine scientific authority in public science settings, it is often used to enhance it (Campbell, 1985; Zehr, 1999). In a study of scientific policy advisors, Shackley and Wynne (1996) find that scientists manage uncertainties flexibly to facilitate their interactions with policy-makers at the same time as maintaining their authority. Uncertainty can also serve to demarcate science and the public. In a study of policy advice on the risk from mobile phones, Stilgoe (2007) finds that uncertainty and public concerns are co-produced – the judgement

about what forms of uncertainty are appropriate also entails a judgement about which, if any, public concerns are relevant.

In the news media, too, uncertainty can offer a means through which scientific authority can be negotiated. Zehr (2000) finds that uncertainty, constructed through news values such as controversy and novelty, provided a frame for newspaper coverage of global warming. The way in which uncertainty was managed served to position scientists as the providers of authoritative knowledge and the public as misinformed. However, journalists and scientists may construct uncertainty in conflicting ways. Stocking (1999) argues that scientists often make ignorance claims to support particular actions but that such claims can be appropriated and modified by the news media to serve their, typically different, interests. This modification of uncertainty claims often leads scientists to complain that the media coverage of risk is sensationalist and aberrant (Dunwoody and Peters, 1992). As this paper shows, even when journalists uncritically reproduce scientists' own uncertainty claims, scientists can construe news reports as undermining their credibility and can respond by seeking further control over public discourse.

Constructing asteroids as a risk

The idea that asteroid impacts could pose a threat to human civilisation first became the subject of scientific analysis at a conference held in Snowmass, Colorado in 1981. However, the topic received little further attention until 1989, when a NASA press release predicting that the close approach of an asteroid known as 1989FC would be a “near-miss” (NASA, 1989) attracted widespread media coverage. In response, the US Congress directed NASA to organise two workshops on the issue.¹ Later that year, a talk by planetary scientist Clark Chapman and astronomer David Morrison at a meeting of the American Geophysical Union stimulated further media coverage.

Chapman and Morrison's assessment of the asteroid impact threat would be highly influential over the following years. They had just written a popular book discussing a variety of planetary disasters, including asteroid impacts. In their final chapter they presented the findings of the 1981 Snowmass workshop. They reported that the

workshop participants had concluded that: “each year civilization is threatened with destruction with a probability of about 1 in 300,000. That’s about 1 chance in 6000 of such an impact happening during a person’s lifetime (taking 50 years as a lifetime)” (Chapman and Morrison, 1989: 279). Acknowledging that this was a crude estimate, the authors suggested that the chances could be as high as 1 in 200 per lifetime or as low as 1 in 20,000. They went on to compare this risk with a number of everyday risks, finding that, for example, the chance of experiencing a civilization-destroying impact was about 300 times greater than the chance of dying from botulism poisoning or about 1/60th of the chance of dying in a car accident (Chapman and Morrison, 1989: 283).

The media coverage of the American Geophysical Union meeting repeated Chapman and Morrison’s claims. The Associated Press reported that:

Conservatively assuming a 50-year human lifespan, that means any person has about a one-in-6,000 chance of being killed by an asteroid during their lifetime, compared with an American’s one-in-20,000 chance of dying on a plane crash or one-in-50,000 chance of being killed by a tornado. (Siegel, 1989.)

Some newspapers condensed the statistics further. For example, a report in the *Seattle Times* (1989) began: “It is three times more likely you will be killed by an asteroid than in an airplane crash, two scientists say.”

In January 1994, Chapman and Morrison brought the argument of their popular book to a scientific audience in a widely-cited review article in *Nature*. By explicitly labelling asteroid impacts as a “risk” and “hazard” and by predicting the human and social consequences of an impact, they once again configured asteroids as risky objects of human import. They also presented a refined and more detailed version of the statistical analysis presented in their popular book. Now, in “assessing the hazard”, as the subtitle of the paper put it, they framed their analysis more clearly within a technical risk assessment discourse which served to position scientists as those best placed to judge the significance of the threat and what should be done about it.

Assuming that the human population is spread evenly across the planet, Chapman and Morrison estimated the number of deaths that different size impacts would cause and,

dividing this by the estimated average time interval between impacts, they obtained a table of “world deaths per year” for each class of impact (Chapman and Morrison, 1994: 36). They found that intermediate-sized objects at the threshold for global catastrophe posed the greatest hazard. As in their popular book, they computed “the odds that you will die as the result of the impact of a comet or asteroid near the threshold”, this time obtaining the figure of 1 in 20,000 (Chapman and Morrison, 1994: 36). Once again, they compared this risk to other more widely-recognised risks such as car accidents (more likely), aircraft crashes (equally likely) or food poisoning (much less likely).

The more familiar risks with which the asteroid impact threat was found to be comparable are subject to technological controls with which society attempts to mitigate against the risk. Thus Chapman and Morrison noted that: “By the straight odds of being killed, the impact threat is as serious as some hazards that most people take very seriously and that governments spend appreciable money to mitigate” (Chapman and Morrison, 1994: 37). Their statistical assessment of risk therefore located asteroids within discourses of health and safety, insurance, and technological intervention. In a paper published the same year, Greg Canavan, a scientist at the Los Alamos National Laboratory, used a similar approach in a cost-benefit assessment of asteroid detection and interception systems to estimate the annual economic loss due to asteroid impacts (Canavan, 1994).

Chapman and Morrison’s paper acknowledged a number of uncertainties. Predicting the physical consequences of an impact of given energy involves uncertainties in the physical and chemical effects of impacts, in climatic modelling, and in the biological and ecological responses to impacts. The correlation of impact energy to asteroid diameter further depends on assumptions about the speed and angle of impact and the composition and density of the asteroid – properties which cannot be measured directly by astronomical means. Estimates of the average time intervals between impacts are also uncertain, being derived from estimates of the total population of each class of asteroid which are in turn deduced from the lunar cratering record or extrapolated from the observed populations.

Chapman and Morrison managed these uncertainties through a range of rhetorical devices which served to reify their statistical estimates. For instance, a graph showing the average annual fatalities against impact energy delimited uncertainty within known bounds shown as a shaded area on the graph. Rather than a set of contestable assumptions and unknowns, non-knowing became an ordered quantity which can be bounded and subjected to numerical analysis. This approach also obscured their implicit assumptions about social systems. Central to Chapman and Morrison's analysis was the identification of the threshold impact energy which would lead to a global catastrophe. This they defined in terms of the number of human deaths, something which depends on the robustness of agriculture and, as they noted, on such factors as whether there are stores of food and on how economic, social and political structures would cope with such an event (Chapman and Morrison, 1994: 35). By containing the uncertainties in their estimate of the threshold energy within a quantified range, Chapman and Morrison transformed unknowable and politically-dependent factors about the nature of society into known uncertainties associated with physical attributes and arising from gaps in knowledge which could be addressed in future research. Their comparative table of death rates from various causes further reduced the uncertainties and assumptions about asteroid impacts to statistical statements equivalent to empirically-collected data on other causes of death.

In the years following Chapman and Morrison's *Nature* article, their quantification of the risk of dying from an asteroid impact was repeated in a range of texts, including official reports and popular books authored by scientists (e.g.: Atkinson, 2000; Near Earth Object Science Definition Team, 2003; Lewis, 1997; Steel, 1995, 2000; Verschuur, 1996). However, despite their own popularising efforts, the NEO scientists began to see the public communication of the impact threat as a problem. The 1989 press reports of the impact threat had covered the issue on the scientists' terms, reproducing Chapman and Morrison's risk assessment in much the same form as they had themselves presented it. But as dedicated sky surveys began to identify particular asteroids which might pose a risk, both journalists and scientists now had to negotiate the uncertainties attached to specific predictions.

Asteroid 1997 XF11

Having constructed asteroids as a risk, astronomers began to assess the probability of an impact whenever a new near-Earth asteroid was discovered. In most cases, the impact probability is zero but in some cases the possibility of an impact cannot be ruled out on the basis of the initial observations, which are usually made over a very limited period of time. Rather than give a precisely defined path, the initial orbit calculations delineate a region in space – known as the “uncertainty region” – where the asteroid is most likely to be. If this region overlaps with the orbit of Earth, then there is some chance of an impact. As more observational data is factored into the calculations, the uncertainty region shrinks and the possibility of impact is usually ruled out.

The calculation of an asteroid orbit with a possible impact solution became the subject of widespread news reports in 1998. The way in which both scientists and journalists managed the uncertainties involved in this case became a cause of concern amongst the NEO community for years to come. On 11th March, Brian Marsden, Director of the Minor Planet Center, the clearing house for observations of asteroids, released a circular on behalf of the International Astronomical Union (IAU) with details of new observations of an asteroid called 1997 XF11. The asteroid had been discovered the previous year and had been identified as a potentially hazardous asteroid requiring further observation. The initial orbit calculations indicated that the asteroid would make a close pass of Earth – closer than the distance to the moon – at 6.30pm GMT on 26th October 2028.

The circular was accompanied by a press information sheet posted on the web in which Marsden explained the significance of the new results: “Recent orbit computations indicate it is virtually certain that it will pass within the Moon’s distance of the Earth a little more than 30 years from now” (Marsden, 1998a). Whilst noting that there was “still some uncertainty to the computation” and that the chance of an actual collision was small, Marsden stated that “one is not entirely out of the question.” In the circular, he explained that these details were being released “in the hope that further observations will allow refinement of the 2028 miss distance” (Marsden, 1998b).

Refining the orbit calculations did not necessarily require waiting for telescope time since asteroids are often recorded unnoticed on astronomical photographs taken for other purposes. Scientists at NASA immediately carried out a search for XF11 on earlier photographs and the additional data they found enabled them to generate a more accurate estimate of the asteroid's orbit. The amended calculations showed that the closest the asteroid would get was twenty times further away than previously thought. However, even before the earlier photographs were found, two NASA scientists had run a different set of calculations to estimate the asteroid's impact probability. They found there was no chance of a collision with Earth. On 12th March, NASA issued a press release stating that: "Asteroid XF11 will pass well beyond the Moon's distance from Earth in October 2028 with a zero probability of impacting the planet" (Jet Propulsion Laboratory, 1998). On the same day, the IAU amended their press information sheet and released another circular with the updated calculations.

In terms of the science, there was nothing remarkable about this sequence of events except, perhaps, the speed at which the new calculations were carried out. However, Marsden's statements of 11th March had framed the original prediction in terms of certainty. Even whilst noting the uncertainty in the calculations and calling for further data to remove that uncertainty, Marsden was claiming that a very close passage was "virtually certain". The prediction of a certain close approach and possible, albeit unlikely, collision meant that the announcement could readily be converted into a news story. The IAU statement was reported by the Reuters and Associated Press news agencies on 11th March and the story hit the front pages of newspapers around the world over the following few days. All four of the UK national broadsheets (the *Times*, the *Guardian*, the *Independent* and the *Daily Telegraph*) carried the story on their front pages, as did the *New York Times* in the US. The *Washington Post*, the *Wall Street Journal* and many local and mass market newspapers carried the story on their inside pages. Over two days, the London *Times* carried as many as seven articles and a cartoon relating to XF11; the *Guardian* carried five pieces.

Even though the first stories in the UK papers went to press the day after the calculations were revised, journalists emphasised the possibility of an impact. Thus

the front page of the *Times* announced that: “Apocalypse could be just 30 years away” (Hawkes, 1998a). The catastrophic consequences of an impact were described and given authority by attributing them to various experts. Towards the end of its story, for example, the *Guardian*, like many other UK newspapers, quoted a Los Alamos scientist saying: “It scares me. It really does. An object this big hitting the Earth has the potential of killing many, many people” (Radford, 1998a).

The conversion of the (by then ruled out) possibility of impact into a definite event was reinforced by reference to the precise timing of the close approach. For instance, the *Times* headline read: “6.30pm, October 26, 2028: could this be the deadline for the Apocalypse?” (Hawkes, 1998a). In a journalistic context, the precision of astronomical calculations, even those based on insufficient data, provided the specificity required for newsworthiness. For the astronomer, a precise time is a data point in a computation. For the journalist, precise timing denotes a news event. By re-signifying a time coordinate as a date for the diary, the journalists worked to create a newsworthy disaster event out of a computerised data run.

Even though they interpreted the closeness of approach of the asteroid as evidence of the possibility of a direct hit, most UK newspapers were careful to avoid definite statements about an impact. Thus the *Times* headline posed a question rather than make a firm statement and the *Telegraph* headline stated that: “Asteroid *may* spell doom for human civilisation” (Irwin, 1998; italics added). The *Guardian* noted that the predictions could mean a near-miss rather than a hit: “a mile-wide asteroid called 1997 XF11 could miss the planet by about 26,000 miles” (Radford, 1998a). The reports were hedged with conditional qualifiers – “*If it hits...*”, “October 26, 2028 *could* be our last day” (Irwin, 1998; Buie, 1998; italics added). The stories included various statements about the uncertainty of the calculations, with the *Times* noting that the margin of error was 180,000 miles, six times the most likely distance of closest approach (Hawkes, 1998b). Even the mass-market *Sun* newspaper, whilst humorously exploiting the precision of the possible impact time, qualified this with a caution from an authoritative figure reassuring readers that there would, in fact, be no impact:

Put a date in your diary, folks. 2028 Thurs, Oct 26 5.30 tea time world ends.

THE giant asteroid will be a spectacular sight - but won't hit us, telly astronomer Patrick Moore predicted last night. (*Sun*, 1998a)

Of the four UK broadsheets, all but the *Guardian* also included references to the calculations from NASA. Indeed, the *Independent* (Arthur, 1998) used the NASA figures to frame the whole story, stressing from the start that the original calculations had been challenged within a few hours of their announcement.

As in 1989, journalists managed the uncertainty inherent in impact predictions by quoting probability statistics. On 12th March, the *Washington Post* reported that NASA planetary scientist, Kevin Zahnle, put the odds of a collision with Earth at 1 in 1000 (Sawyer, 1998). The next day, the *New York Times* put the odds higher, reporting that physicist Edward Teller thought there was little more than 1 percent chance the asteroid would hit Earth (Browne, 1998). Other scientists would later say that even Zahnle's figure was wrong, but it was repeated in many British newspapers without being attributed to Zahnle and without noting that these odds had not been verified by any other scientists (e.g.: Britten, 1998; Buie, 1998; Cookson, 1998; Dowdney, 1998; Ham, 1998; *Sun*, 1998b). Journalistically, the specificity of the 1 in 1000 odds, like the precision of the time of impact, served to construct an impact as a scientifically-verified fact.

Some reports also reproduced statistics and comparisons similar to those in Chapman and Morrison's paper. For instance, the *Guardian* noted that "US scientists have put the chance of death by asteroid as roughly the same as death by aircraft crash" (Radford, 1998a) and the *Daily Telegraph* (1998) stated that "The chance of being killed, directly or indirectly, by a meteorite is greater than that of wild animals, fireworks, terrorist bombs and airline hijackings". Reporting probabilities such as these converted possible future scenarios into concrete facts located within the bounds of the known and the commonplace.

For the newspapers, therefore, the XF11 story was newsworthy because it could be framed as a time-specific disaster event circumscribed and legitimised by quantitative science. Despite the specificity required for event-led reporting, journalists were still able to stress the uncertainty of the observations and to introduce balance in the form

of scientists with alternative predictions. Nevertheless, because the news stories foregrounded the possibility of impact, NEO scientists were concerned about the reporting. On 14th March, the IAU therefore issued a statement announcing that “contrary to preliminary reports, there is no danger of [XF11] colliding with the Earth in 2028” (Morrison, 1998a). Although some of the newspapers had already mentioned the NASA calculations in their reports of 13th March, the “retraction” of 14th March led to another flurry of stories in the UK press. The *Times*, giving details of the process through which the orbit calculation was revised, framed this latest development as an example of science working successfully. “Nobody got it wrong”, the story emphasised (Hawkes, 1998c). By contrast, the *Guardian* humorously presented the story as an example of science going wrong: “Astronomers yesterday admitted they had got the end of the world slightly wrong” (Radford, 1998b).

From the start the newspapers had mentioned the uncertainty of the orbit calculations and their stories about the re-calculation tended to be lower profile and were sometimes framed as successful science. Even so, the scientists saw the XF11 media coverage as a fiasco. In the IAU statement of 14th March, Morrison (1998a) had argued that: “For better or for worse, the astronomers who carry out these searches and orbit calculations work in the public eye. The idea that a threatening asteroid could be kept secret (or that anyone would want to keep it secret) is ludicrous.” Thinking over the “significance of the XF11 scare” again a few days later, he worried about astronomers being accused of “crying wolf or of being unreliable sources of information” and concluded that:

I believe that everyone agrees that in similar future cases, we should take more time to check the orbit and look for other observations before any announcements are made to the press. (Morrison, 1998b)

Clark Chapman (1998a) blamed Brian Marsden. Chapman criticised Marsden’s practice of checking the validity of new observations submitted to the Minor Planet Center before circulating them to other astronomers. Even allowing for the limitations of the original data, Chapman claimed that Marsden’s calculations were wrong and he would later describe Marsden’s announcement as “a wholly erroneous prediction that never should have been made in the first place” (Chapman, 1999). Other astronomers seemed to support Marsden, however, and Marsden himself continued to insist that

his calculations had been correct and that others had obtained similar results (Marsden 1998d). Yet despite disagreeing over who was to blame, Marsden, like Chapman and Morrison, thought that astronomers' communication practices were part of the problem. What had "gone wrong" with XF11, he suggested, was the readiness of some scientists to e-mail large numbers of people with spontaneous comments (Marsden, 1998c). He defended his own announcement of the initial calculations, however, as necessary to alert other astronomers to the need for more data.

Although much of their criticism of the XF11 affair centred on their own behaviour, the reason the NEO scientists thought XF11 mattered was because it had damaged the public image of NEO science. Marsden, for instance, worried that "initial concerns had been replaced by jokes about astronomers making mistakes" and that astronomers had been accused of "irresponsible" behaviour (Marsden 1998c). The inclusion in news reports of contradictory statements by the IAU and NASA – journalistically, a standard example of balance – was also thought to have been damaging, portraying an image of a community in conflict. For instance, anthropologist Benny Peiser (1998) thought that the XF11 affair had created "the impression of divisions and disagreement – if not incompetence – within the astronomical community."

Peiser was the moderator of the *Cambridge Conference Network*, an interdisciplinary e-mail discussion group for scientists, journalists and others interested in the impact threat and other global catastrophes. His e-mail list hosted extensive debates about the media coverage of the impact threat over the following years. XF11 was frequently cited by the NEO scientists as an example of what could go wrong with the public communication of the impact threat. Central to their concerns was the fact that they had been publicly revealed to have uncertain knowledge. In promoting asteroids as risky, astronomers had placed their incomplete knowledge of asteroids in the public domain. The uncertainties inherent in science-in-the-making thus became publicly visible in media reports. The scientists managed these uncertainties by configuring them as precise times and certain probabilities, but when re-presented in the context of balanced or humorous news reports, the scientists interpreted these same devices as problematic.

Hazard scales

For some scientists, the solution was to prevent any public communications about asteroid orbits until adequate data had been provided and all calculations had been checked and peer reviewed. To this end, a new peer review protocol for announcements of asteroid orbits was agreed by astronomers at a meeting in Houston a week after the XF11 incident. However, some felt that this would encourage “secret” science, leading to possible accusations of a cover-up, and argued that the public had a right to know if civilisation were in danger (e.g., McNaught, 1998; Steel, 1998b).

An alternative way of dealing with the public communication of the impact threat was suggested by MIT professor Richard Binzel. Binzel (1998) argued that rather than debate what had gone wrong with the media coverage of XF11, astronomers should be finding ways to ensure that future media coverage of the impact threat was better. Already in 1995, he had proposed a “hazard index” to facilitate “simple and efficient communication between astronomers and the public” (Binzel, 1997: 545). As in Chapman and Morrison’s analysis of the impact threat, Binzel’s index replaced uncertainties with apparently certain numerical statements. Binzel presented a revised version of his index at an asteroid workshop held in Torino, Italy in June 1999. Despite criticisms from some delegates, the workshop endorsed what now became known as the Torino Scale. On 22nd July, the IAU, NASA and MIT all issued press releases about the international endorsement of the scale. A year later, a more technical account of the scale appeared in *Planetary and Space Science*, one of the main journals in the field (Binzel, 2000).

In all three press releases and the journal paper, the scale was presented as a tool for improved risk communication. Binzel saw asteroid orbit calculations as a “risk communication challenge” and presented his scale as “a carefully considered and endorsed system for clear and efficient risk communication” (Binzel, 2000: 297, 298). The scale assigned to any observed asteroid a number from zero to ten, with zero indicating that it presented no risk of damage and ten representing a certain and catastrophic collision. Small asteroids of high impact probability score zero because they will cause little damage even if they do hit. A very large asteroid could score

higher, even if it was unlikely to hit, because it would cause a global catastrophe if it did. The numbering was supported by text describing the consequences of an impact on each point on the scale and by colour coding, with the higher numbers coded red down through orange to white for zero.

The Torino scale was compared to the Richter scale for measuring the magnitude of earthquakes. According to Binzel, a Richter-like scale would help the public assess the degree of anxiety to attach to a given asteroid. “If you tell a Californian that an earthquake registering one on the Richter scale was going to hit tomorrow, he would say, ‘So what?’ If you were talking about a six, that would be different” (NASA, 1999). The comparison was repeated in several of the news stories that followed the press releases (e.g.: McLean, 1999; *Guardian*, 1999; McKie, 1999).

In fact, the comparison between the Richter scale and the Torino scale goes only as far as assigning a number to an event. For astronomer Gerrit Verschuur (1998), this was an important feature of the Richter scale. It didn’t matter, he suggested, that people didn’t know what these numbers meant in terms of the energies involved, they were still able to judge how bad an earthquake was from its Richter scale number. Similarly, if the asteroid threat was summed up by a single number, people would be able to react appropriately even without understanding what the number represents technically.

There were, however, two essential differences between the Richter scale and the Torino scale. Firstly, as Binzel (2000: 300) noted in his journal paper, the Torino scale was a predictive scale. While the Richter scale expresses the amount of energy that has been released during an earthquake (an empirical measure), the Torino scale attempts to predict the energy that would be released *if* a given asteroid were to impact with the Earth (a theoretical construct). For at least one astronomer, Brian Marsden (1999a), this meant that any comparison between the Richter and Torino scales “really makes no sense.” Secondly, where the Richter scale expresses a single-valued quantity as a single number, the Torino scale combines two quantities – the possible energy of impact and the probability of impact – into a single number.

The combination of two quantities into a single integer value requires a decision about where the boundaries of each category should lie. Binzel anchored his categories by reference to Chapman and Morrison's annual impact probabilities for impacts of given energies, which he suggested offered a "natural basis" for category one on the scale. Category 10 was set at those impacts which would be equivalent to the impact which is thought to have caused the extinction of the dinosaurs. The rest of the categories, Binzel (2000: 299, 300) acknowledged, were "non-unique" and "subjective".

Because the impact probability is essentially an expression of uncertainty in the determination of the orbit and because the energy of impact must be deduced from the diameter and composition of the asteroid (quantities which can only be measured indirectly and with some difficulty),² the position of an asteroid on the Torino scale changes as astronomers refine their measurements of an asteroid. If, as was the case with XF11, the possibility of an impact with Earth is ruled out, the asteroid will move down to zero on the scale. Furthermore, because Binzel's choice of category boundaries meant that the high risk category 8 adjoined category 3 for asteroids with impact energies thought to be capable of causing local damage or category 0 for smaller impact energies, a small adjustment in the estimated energy or probability could lead to a very large change in an object's position on the Torino scale.

The adoption of the Torino scale by the IAU was met with objections from some in the NEO community. They raised questions about the process through which the scale had been endorsed and they criticised the scale itself. Often these criticisms were accompanied by suggestions for how to improve the scale (e.g. Marsden 1999b) or for alternative quantitative assessments (Marsden 2003b). French astronomer Alain Maury (2000) went much further than most in his criticisms of the Torino Scale, highlighting the uncertainties stemming from "insufficient astrometric observations" and "even lousier photometric observations" and the resulting problem of fluctuations in an asteroid's position on the scale as more data became available. Arguing that what the public really wanted to know was not a probability but whether or not a particular asteroid was actually going to impact, he proposed that asteroids be classified as either "perfectly harmless" or "not harmless at first sight" and that a short statement about the *improbability* of impact be issued for those asteroids which fell in

the latter category. Maury ironically named his proposal the “Maury Scale”. A few years later, Danish astronomer Leif Kahl Kristensen, made similar criticisms (Kristensen, 2003). Yet Maury and Kristensen were unusual in arguing against the need for numerical or colour-coded scales in favour of explanatory prose. Others felt that minor changes to the Torino Scale would suffice and proposed a new version of the scale with different descriptions for each category (Morrison et al, 2004: 361). Level 1 and 2 events were now said to pose “no cause for public attention or public concern” but were still considered to be of interest to astronomers.

Binzel (2000: 302) had presented his scale as a tool for public communication only and suggested that alternative “more sophisticated” metrics could be used for professional communication. One such scale, known as the Palermo scale, was proposed by Steven Chesley and co-authors (Chesley et al, 2002). Noting the shortcomings of a scale based on integer values arranged in a non-uniform manner, they presented a continuous logarithmic scale based on the notion of the “expected energy” (the product of the estimated impact energy and impact probability of a given asteroid) relative to the background hazard posed by the entire population of near-Earth asteroids in the time remaining until the potential impact. An asteroid with a positive rating on the Palermo scale would represent a risk of impact greater than the background risk. As with the Torino Scale, an asteroid’s position on the Palermo scale could change rapidly when further observations became available. The Palermo scale was adopted for use in computerised systems in Italy and the US which automatically prioritised which asteroids needed further monitoring or orbital analysis. In 2001, the IAU decided that the peer review protocol by then in place for dealing with possible impact solutions should be triggered by asteroids with a Palermo score greater than zero indicating an impact probability greater than the background hazard.

The Palermo scale was based on a complex mathematical assessment of the expected energy of an asteroid. However, conceptually the Palermo Scale was not particularly complex – a positive rating indicated that an asteroid posed a risk greater than the background hazard from the total population of asteroids of similar energy. The larger the positive value, the greater the risk. As was sometimes noted, a renormalisation and rounding up of the Palermo Scale could produce a zero-to-ten scale similar to the Torino scale. Yet the scientists assumed that the Torino Scale, with its less

mathematical derivation, was simpler than Palermo. In fact, the non-unique division of the Torino Scale meant that in some ways it was more, not less, obscure than the Palermo Scale.

Controlling public discourse

Despite the introduction of the Torino and Palermo scales, the impact threat continued to be reported regularly in the news media, appearing roughly once every year. Like XF11, many of the other “impact scares” led to extensive debate amongst astronomers about how best to handle the public communication of the threat. As they drew up peer review protocols and considered the merits of different hazard scales, the scientists implicitly drew on a set of assumptions about news audiences’ understanding of science, the power of numerical statements to control public discourse and the potential of the media to undermine scientists’ credibility.

Repeatedly, the scientists focussed on the lack of public understanding of science in general, and of probabilities in particular, as the central problem in communicating the impact threat. Clark Chapman and Brendan Mulligan (2002), for instance, wrote of “the low level of scientific comprehension by the public” and Chapman (2003) worried that “scientists’ understanding of the impact probabilities simply doesn’t get through to the public.” Astronomer Mark Kidger (2003) claimed that: “The whole business of NEOs and impacts works with numbers that are beyond the ability of most people to understand.”

When non-scientists failed to respond to reports of the impact risk in what the NEO scientists deemed to be the appropriate manner, the scientists frequently attributed this to the public’s misunderstanding of the issue. In one paper written jointly by Chapman, Morrison and risk scholar Paul Slovic, the authors reported a study which Slovic had conducted with 200 college students. The students gave varying interpretations of the statement: “Scientists say that a civilization-threatening asteroid impact can be expected every 300,000 to 1,000,000 years” (Morrison et al, 1994: 84). Rather than acknowledging the ambiguity of this statement (with its “expected”, rather than “average”, intervals between impacts), the authors referred to the students

as “confused”. Similarly, statements about public “alarm” in response to media “scares” (e.g., Chapman & Mulligan, 2002) implicitly attributed irrational responses to the public.

Since the public didn’t understand probabilities, the scientists concluded, some form of simplification was necessary. It was this that the Torino Scale was supposed to have provided. Binzel (2000: 297) had recommended his scale on the grounds that it was “a simple and efficient tool” for communicating with the public. As Gerrit Verschuur (1998) put it: “I fully appreciate that probabilities make little sense to most lay people, and that is why the use of some numerical scale makes sense.” Early criticism that the Torino Scale was *too* simple was accommodated through the introduction of the Palermo Scale for communication between researchers. The use of two separate scales implied a strict demarcation between what was deemed appropriate for use within the scientific community and what was deemed appropriate for external use. The demarcation was further reinforced in the revised version of the Torino Scale which stressed the difference between events meriting scientific attention and those meriting public attention. The proposals for a peer review protocol which would delay announcements of impact solutions until all calculations had been checked did likewise. In adopting such a position, the scientists were assuming that public science must be seen to be certain and that public displays of uncertainty were to be avoided. But journalists found little use for the Torino Scale. It could help make a story when a new high was reached (as did the Palermo Scale), but otherwise it added little to newsworthiness. A strict demarcation between science and public was not useful to journalists tasked with mediating scientific claims to public audiences.

Despite the Torino Scale being “absurd”, as one astrophysicist bluntly put it (Asher 2003), the attempt to reduce the uncertainties associated with an individual asteroid to a single number cohered with the quantitative risk assessments that the scientists had promoted since the 1980s. Even as criticisms of the media representation of asteroid impacts mounted, the way in which they were represented within the scientific community was rarely criticised. Yet even the use of the term “impact” to refer to orbit solutions of particular asteroids could be challenged. As NASA scientist Jon Giorgini (2000) noted:

“Impact” is an intrinsically biased/inflammatory word and not actually what the probability calculations refer to. The calculations address trajectory intersection. Claims of impact depend on object composition, fracture (in this case, rivet?) status, and a host of assumptions used in place of actual facts, many of which can’t be known.

The scientists’ probabilistic assessments of the impact threat were also problematic. In their influential 1994 analysis, Chapman and Morrison had used the technical discourse of probability statistics to hide assumptions about the vulnerability of social structures and to convert multiple uncertainties into certain knowledge. Yet their calculation of annual death rates from rare impacts involved sampling at intervals of just one year a phenomenon which only becomes statistically meaningful over intervals of hundreds of thousands of years. This was a form of sampling error. The fluctuations from one year to the next – from zero deaths in nearly all years to billions in a year of impact – far exceeded the size of the annual average.

Despite frequently referring to impacts as low frequency/high consequence events, NEO scientists failed to acknowledge that this meant that annual averages were statistically meaningless.³ Instead, by offering comparisons with such things as deaths from car crashes, they implied an equivalence between the impact risk and other death rates whose averages are statistically valid. When other scientists did criticise Chapman and Morrison’s comparisons, they did so by offering alternative comparisons – such as worldwide death rates from childhood diseases or smoking (Weissman, 1994; Sagan and Ostro, 1994) – rather than criticising the actuarial approach itself. Yet, like the comparison between the Torino Scale and the Richter Scale, these risk comparisons compared quantities derived from historical data – events which have actually happened – with those based on a predicted event (the destruction of human civilisation by an asteroid impact) that has never happened. As Chapman and Morrison (1994) admitted, there have never actually been any authenticated deaths from asteroid impacts.

In an email to the Cambridge Conference Network in the days after the XF11 affair, astronomer Duncan Steel (1998a) pushed the manipulation of statistics even further. After bemoaning the public’s “lack of understanding of probabilities” and their failure to take seriously impacts which occurred on average once every 50,000 or 500,000

years, he reasoned that car accidents, which are taken seriously, had a similar timescale:

Averaged over industrialized nations I believe that the car accident rates indicate a probability of dying that way of about one in 120. For the same nations the average life expectancy is about 80 years. Thus the timescale for dying in a car crash is of order $120 \times 80 \sim 10,000$ years.

In fact, for the US, approximately 39,000 fatalities in car crashes each year means there is the equivalent of one fatality every 13 minutes. This is the most meaningful measure for the timescale of deaths from car crashes. Since the “probability of dying” already factors in the average life expectancy, Steel’s figure is actually the time needed to kill the entire population through car crashes assuming the population to be otherwise static.⁴

The problems associated with the statistical framing of the impact threat mean that it should not be seen as a cognitive strategy to aid understanding. Rather, like the presumed demarcation between scientist and public, it functioned as a discursive strategy to aid the denotation of asteroids as risky and the positioning of NEO scientists as the appropriate experts to manage the risk. Among other things, this could help secure funding for NEO research. Some of the critics of the Torino Scale were explicit about funding being the core issue at stake. Astronomer Mark Kidger (1999) worried that with so few objects registering on the scale at all, media interest would fall off and the public might assume the problem had gone away. “The truth is that the problem still exists, will not go away, and can only get more serious if a reduced public profile of the issue leads to a serious reduction in funding for NEO programs.” He suggested that to maintain public interest the lower end of the scale should be expanded so that it registered more objects more frequently.

Another commentator, although not himself a NEO researcher, was even more explicit. Jens Kiefer-Olsen (2000) claimed that any impact scale “must serve primarily as a vehicle to extract funding from politicians. Hence the scale should produce a one-dimensional figure, namely the amount of \$\$\$ to be allocated immediately, or over a specific period.” Brian Marsden (2003a) thought that media exposure had indeed helped secure funds for NEO research and suggested that

without the XF11 coverage “NASA would have put less money into NEO searches than it now does (yes, there could yet be more!)”

Despite the scientists’ concerns about the quality of media reports on the impact threat, journalists rarely, if ever, challenged the claims made by the scientists and they accepted the statistical framing of the issue which the scientists promoted. Most journalists included statements about uncertainty in their news reports, their stories were derived from statements issued by scientific sources and they often quoted relevant experts or institutions. When revised data was released implying a downgraded risk for a specific asteroid, some news reports presented this as meaning that the scientists had made mistakes but most did not take this angle. Thus journalists were accepting of the NEO scientists claims and were willing to reproduce them in their reports.

However, the scientists’ attachment of specific numbers and dates to possible impact solutions enabled journalists to frame their stories in terms of certain knowledge. When later reports presented equally certain, but different, knowledge claims the scientists worried that they would lose credibility. As Clark Chapman (1998b) said after the XF11 affair: “All of us, not just the MPC [Minor Planet Centre], lost some credibility a few weeks ago when failures in the peer-review process at the MPC led to the XF11 scare.” Others, such as Italian astronomer Andrea Milani (1999), worried that delaying an announcement would also damage the researchers’ credibility.

If the people not belonging to the rather exclusive club of specialists of orbit determination get the impression that they are not being informed, on an issue as critical as the orbits of the NEO (and their close approaches to the Earth), the credibility of the scientific community as a whole could be undermined, and this is a more subtle but very dangerous version of the crying wolf story.

For many in the NEO community, journalists’ use of humour, especially in the UK newspapers, raised similar concerns. They persistently worried about what they called “the giggle factor” (Weissman, 1994: 1202; Morrison et al, 2004: 354). What for journalists was one means by which the speculative nature of the science could be signalled, was for the scientists an assault on their authority. Such reactions implicitly assumed that newspapers should properly be informative rather than entertaining and that the public interpreted what they read in newspapers literally and altered their

opinions of social actors such as scientists in response to what they read in individual news stories.

Conclusion

Most studies of the construction of uncertainty in public science have focussed on policy contexts. The asteroid impact threat offers an example of how scientists can actively construct risk and publicly manage the uncertainties in their knowledge even in a field not clearly positioned within a policy context. Indeed, the promotion of asteroids as risky objects can be seen as part of a strategy to secure increased funding by transforming asteroid research into a public policy concern.

Shackley and Wynne (1996) have argued that uncertainty claims function as boundary-ordering devices which can stabilise and maintain the boundary between scientists and policymakers at the same time as enabling interactions across the boundary. The absence of a prior public policy context for asteroid research meant that the uncertainty claims of the NEO scientists were often addressed, through the news media, to a wider public audience. In this context, the differing interests of the scientists (to establish their authority and gain public support) and the journalists (to entertain their audiences with newsworthy stories) meant that uncertainty claims failed to function successfully as boundary-ordering devices. However, in devising new hazard scales and communication protocols, the scientists persisted in their expectation that the quantification of uncertainty would serve their interests by controlling public discourse.

As in policy-based studies of scientific uncertainty, authority emerges as a key feature of the negotiation of the uncertainties of asteroid impacts. The NEO scientists attempted to position themselves as authoritative purveyors of knowledge by transforming non-knowing (indeterminacies in orbit predictions and asteroid properties, unknown social factors, etc.) into quantitative assessments of uncertainty. Journalists were accepting of this transformation. News reports often reproduced the scientists' uncertainty claims uncritically, as others have found of science reporting more generally (e.g., Nelkin, 1995).

Despite their uncritical approach, the journalists managed uncertainty in different ways than did the NEO scientists. They drew on three key devices. Firstly, they recontextualised the scientists' statistical statements through juxtaposition with scenarios of future impacts. These provided the specific events required of news reports. Although the scientists presented similar scenarios in their own popular writings (Mellor, 2007), they objected to the perceived certainty conveyed when such scenarios were attached to specific possibilities. Secondly, journalists were able to signal uncertainty through the use of conditionals and through caveats placed low in a story. To the scientists, such unobtrusive devices were overwhelmed by the foregrounding of possible future events. Thirdly, journalists signalled uncertainty more prominently through the use of humour and the reporting of differing predictions. The scientists interpreted these as challenges to their authority and credibility.

The different representational practices used by the scientists and journalists were grounded in different assumptions about the public audience. As Stilgoe (2007) found, the construction of scientific authority and credibility through uncertainty claims also entails the construction of the public. When revising their representations of uncertainty, the NEO scientists repeatedly construed the public as ignorant and easily scared. By contrast, the journalists' use of humour implied that their readership would get the joke and understood that an impact was highly unlikely. The use of humour thus assumed an audience capable of decoding ironic headlines as expressions of uncertainty. The scientists' failure to acknowledge such capability on the part of the public encouraged their own (mis)reading of humour as an assault on their credibility.

The question for the media coverage of risk is not so much whether reporting emphasises certainty or uncertainty but how precisely the dynamic between the two is handled (c.f. Stocking, 1999). The asteroid impact threat reveals the complexities of this dynamic, both in terms of the repeated work scientists put into controlling the public representation of uncertainty, and the layered means through which journalists are able to denote both certainty and uncertainty simultaneously.

Friedman et al (1996) have suggested that responsible journalism about risk issues should include the reporting of risk statistics and risk comparisons. The analysis presented here shows that even if journalists do faithfully report such figures, scientists continue to complain about the media coverage. More importantly, the flawed nature of many of the scientists' numerical assessments shows that such reporting fails to provide the critical questioning one might reasonably expect of responsible journalism. This suggests that the framing of issues as amenable to quantitative risk assessments can itself be problematic.

This study shows that certainty and uncertainty are inextricably interwoven. Their co-production is accomplished in different ways by different discursive communities. Scientists use quantitative assessments, even those which are technically inappropriate, to replace uncertainty with "certainty *about* uncertainty" (Shackley and Wynne, 1996: 281). Such assessments can be developed as overt communication strategies aimed at controlling public discourse in order to assert the scientists' authority and promote the significance of their specialism. Journalists reproduce and recontextualise these assessments, reinforcing their certainty even at the same time as they signal their speculative and uncertain nature through devices such as humour and balance. Scientists' responses to these journalistic devices, however, can draw on assumptions about the media audience which, far from resolving the perceived problem, further entrench the discursive gap between the two communities.

Notes

¹ The workshops drew on a growing evidential base – including observations of asteroid populations and the cratering rates of other planets, geological evidence of past impacts on Earth and new mathematical techniques for analysing asteroid orbits – which all showed that future impacts on Earth were possible although infrequent over anything less than geological timescales. This paper does not dispute that evidence, but examines how this *possibility* came to be configured as a *risk* to human civilisation. For a more detailed discussion of the history of the promotion of the impact threat, see Mellor (2007).

² The acute nature of these uncertainties is illustrated by two objects (2000 SG344 and 2001 GP2) which appear on tables of potential impactors but which may, in fact, be man-made space debris (Chesley et al, 2002: 429).

³ An exception is Brian Marsden (1997, 54) who briefly noted in one paper that collisions of global concern “are so potentially devastating and so infrequent that it is in fact inappropriate to consider them statistically.”

⁴ Since life expectancy is measured in years, Steel’s product of the inverse of the “probability of dying” times average life expectancy (i.e. his 120×80) can only have units of years if the probability is dimensionless rather than being an annual measure. This means that the probability must already factor in the average life expectancy. For example, for the US, number of car deaths per year = 39,000; total population = 300,000,000; average life expectancy = 80 years. So (number killed each year/total population) $\times$ average life expectancy = $1/96$, which is the same order of magnitude as Steel’s figure of $1/120$ for all industrialized nations. Thus Steel’s “probability of dying” = (number killed each year/total population) $\times$ average life expectancy. Hence average life expectancy/probability of dying = total population/number killed each year = number of years to kill total population.

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