Colliding Worlds:

Asteroid Research and the Legitimisation of War in Space

ABSTRACT

Over the past twenty years a small group of astronomers and planetary scientists have actively promoted the idea that an asteroid might collide with the Earth and destroy civilisation. Despite concerns about placing weapons in space, the asteroid scientists repeatedly met with scientists from the Strategic Defense Initiative to discuss mitigation technologies. This paper examines the narrative context in which asteroids were constructed as a threat and astronomy was reconfigured as an interventionist science. I argue that conceptualising asteroids through narratives of technological salvation invoked a 'narrative imperative' which drew the astronomers towards the militaristic endings that their stories demanded. Impact-threat science thus demonstrates both the ways in which scientific research can be framed by fictional narratives and the ideological ends which such narratives can serve.

Keywords: asteroid impacts, defence science, military, SDI, astronomy, science fiction, narrative.

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Since the late 1980s, a small group of astronomers and planetary scientists have repeatedly warned of the threat of an asteroid impacting with Earth and causing global destruction. They foretell a large impact causing global fires, the failure of the world's agriculture and the end of human civilisation. But, these scientists assure us, we live at a unique moment in history when we have the technological means to avert disaster. They call for support for dedicated astronomical surveys of near-Earth objects to provide early warning of an impactor and they have regularly met with defence scientists to discuss new technologies to deflect any incoming asteroids.

The scientists who have promoted the asteroid impact threat have done so by invoking narratives of technological salvation – stories which, like the Strategic Defense Initiative (SDI), promised security through a superweapon in space. The asteroid impact threat can therefore be located within the broader cultural history of fantasies about security and power which Bruce Franklin (1988) has argued is inextricably linked to the century-old idea that a new superweapon could deliver world peace. Howard McCurdy (1997: 78-82), in his study of the ways in which the US space programme was shaped by popular culture, has suggested that the promotion of the impact threat can be seen as the completion of Cold War fantasies which had used a politics of fear to justify space exploration. McCurdy highlights the alignment between the promotion of the impact threat and works of fiction. In this paper, I consider the reconceptualisation of asteroid science which this alignment entailed.

It is beyond the scope of this paper to give a complete history of the science of planetary impacts. My focus is on how a group of scientists moved from seeing impacts as significant events in Earth history to seeing them as threatening events in the human future – a move from historical to futurological narratives. Nor is there space to give a full account of the empirical developments which were used to support the construal of asteroids as a threat. Rather, I wish to make the case that these empirical developments were given meaning within a specific narrative context which drew civilian astronomers into contact with defence scientists, especially those working on SDI.

A number of studies (e.g., Dennis, 1994; DeVorkin, 1992; Forman, 1987; Kevles, 1990; Leslie, 1993; McDougall, 1985) have revealed the ways in which US research

programmes and nominally-civilian scientific institutions originated in military programmes.¹ One aim of this paper is to demonstrate how the boundary between civilian and military science is blurred not just institutionally, but also at a fundamental conceptual level. The civilian scientists discussed here followed different working practices and traded in different forms of expertise than did the defence scientists. They were typically astronomers or planetary scientists who worked for NASA or on NASA-funded research programmes at universities and private institutes. They saw themselves as distinct from the defence scientists who were typically physicists and engineers working on new weapons systems or other technologies of national security at the Los Alamos and Lawrence Livermore National Laboratories or at armed services institutions.² Yet the two groups came to share an interest in asteroids and with that, a set of assumptions about the nature of human society, the role of technology and our place in outer space. As they came into contact, their differing backgrounds meant they disagreed over a number of issues, yet both sides pursued the collaboration despite the tensions.

Many studies of the interaction between military and civilian science have focussed on sources of funding and shared technologies.³ Important as these are, they fail to capture fully the dynamic between the two communities. In particular, a cynical picture of scientists simply pursuing sources of funding on any terms cannot reveal the far-reaching ways in which civilian research can become entrenched in particular patterns of thinking which are supportive of militaristic programmes. For military/civilian collaborations to be sustained, civilian scientists need to share with their counterparts in the defence sector an understanding of the overall trajectory of their research. For shared technologies to be developed, they need first to be imagined. Military/civilian interactions are therefore predicated on, and mediated through, a shared technoscientific imaginary. Despite expressing concerns about the motives and methods of the weapons scientists, the civilian scientists who promoted the asteroid impact threat drew on narratives which configured a human role in space in a similar way to SDI. These narratives helped make asteroids conceivable as a threat, yet they also served to make acceptable, and even necessary, the idea of space-based weaponry. Despite their disagreements, at the level of their shared narratives the discourses of the civilian and defence scientists were mutually supportive.

Several studies of the role of narrative in the production of scientific knowledge have

identified it as a means of generating coherence in science which both enables and constrains further research (O'Hara, 1992; Haraway, 1989; Rouse, 1996; Brown, 1998). Richard Harvey Brown is the most explicit about what constitutes a narrative, defining it as 'an accounting of events or actions temporally that explains them causally or motivationally' (Brown, 1998: 98). Brown's definition of narrative fits with that of narrative theorists such as Mieke Bal (1997) who have stressed that narrative entails not a random unfolding of events but a sequenced ordering involving a transition from one state to another brought about or experienced by actors. One implication of this is the fundamental role of causality and agency. Another is that a narrative beginning always anticipates an ending – a resolution or closure to the events which have been set in motion. Historian Hayden White (1981: 23) has argued that the tendency to present history as narrative 'arises out of a desire to have real events display the coherence, integrity, fullness, and closure of an image or life that is and can only be imaginary'. He finds that narrative closure involves a passage from one moral order to another. 'Where, in any account of reality, narrativity is present, we can be sure that morality or a moralizing impulse is present too' (White, 1981: 22). In this sense, narrative is inherently teleological and ideological. The inexorable movement of a narrative toward a predetermined end ensures that its many assumptions go unchallenged.

An analytical approach to the interaction between military and civilian science which recognises the ideological function of narrative can help side-step some of the difficulties associated with the distortionist thesis often attributed to Paul Forman's (1987) landmark paper on the military basis of US post-war physics. Forman has been criticised for implying that without military patronage, physics would have followed an ideal direction unaffected by outside interests (e.g., Kevles, 1990). By looking at what sorts of narratives scientists draw on, we can avoid Forman's supposed idealism. The question is not so much whether science has been distorted, but through which of many possible stories a research programme has been articulated. To ask which stories have been invoked is to ask which ideologies have implicitly been accepted. And to ask that is to allow that, on ideological grounds, some stories are preferable to others.

Because narratives are shared within a research community, they are not always explicitly articulated in texts. Technical papers are most likely to hide the fundamental assumptions

that underpin a research area. However, literature addressed to wider audiences is often more explicit. Grey literature, such as policy reports or review articles, and popularisations written by scientists are therefore useful sources for identifying the narrative context in which a science is framed, traces of which may also be found in technical papers. Whilst always remembering that such accounts are written with particular persuasive or marketing goals in mind, these texts nonetheless reveal what, to the scientist-author, is both thinkable and compelling.

In what follows, I draw on this full range of texts, from technical papers to popularisations, to show that the scientists promoting the impact threat have repeatedly turned to narratives of technological salvation which imagined the ultimate superweapon – a space-based planetary defence system which would protect the Earth from the cosmic enemy. I begin with a brief overview of earlier conceptions of asteroids before outlining the events through which asteroids were promoted as a threat and examining the narrative context in which this occurred. I finish by arguing that the narration of the impact threat entailed a reconceptualisation of asteroids, space and astronomy and invoked a 'narrative imperative' which helped legitimise the militarisation of space.

Classical Asteroids

From the discovery of the first asteroid by Guiseppe Piazzi in 1801, these small solar system bodies had been easily accommodated within the Newtonian scheme. Piazzi's discovery had appeared to confirm the predictions of the Titius-Bode law, a numerical formulation based on the observed distances of the known planets which shared with Newtonian dynamics a conception of space as a predictable mathematical realm (Nieto, 1972). The orbits of the first two asteroids were successfully computed by Carl Friedrich Gauss and it was on the basis of this work that Gauss (1809) produced his definitive mathematical treatise on orbit determination. Asteroids, as the alternative name 'minor planets' suggests, followed planet-like orbits, moving predictably through a geometrically-abstracted space. Throughout the nineteenth century asteroids were regarded as remnants of a fragmented planet or, later, of the bodies from which the planets formed. Their significance as objects of study was defended on the grounds of what they could reveal

about the solar system past. Thus asteroids were conceptualised through grand narratives of cosmic origins.

Through the first half of the twentieth century, a number of asteroids were discovered with orbits approaching, or crossing, that of Earth. The focus in this period was on taxonomy – identifying different families of asteroid on the basis of similarity of orbit or chemical composition – and on the relation of asteroids to other solar system bodies, especially comets, or to meteorites found on Earth. In the post-War decades, planetary astronomy flourished under US state patronage (Doel, 1996; Tatarewicz, 1990) and by the 1970s the increasing number of physical studies of asteroids had helped to position asteroid research as a recognisable speciality. The institutionalisation of the field was marked by the first international asteroid conference, held at Tucson, Arizona in 1971 and by the publication of the proceedings edited by University of Arizona astronomer Tom Gehrels (1971). A second conference was held eight years later and was accompanied by the publication of a state-of-the-field volume, *Asteroids*, again edited by Gehrels (1979) and running to some thousand pages. *Asteroids* was the fifth volume in an annual Space Science Series of source books mapping the current understanding of an area of space science. Consolidating the sense of an active and growing field, the series would include three more volumes focussed on asteroids in later years: *Asteroids II* (Binzel et al, 1989), *Hazards due to Comets and Asteroids* (Gehrels, 1994), and *Asteroids III* (Bottke et al, 2002a).

In his introductory chapter to *Asteroids*, Gehrels stated that the major problems to be addressed in future work were 'the origin and evolution of the asteroids and the identification of the meteorite parent bodies' (Gehrels, 1979: 17). However, during the following decade asteroids also took on a further meaning as signifiers not only of planetary evolution but also of the evolution of life on Earth. In 1980, Luis Alvarez and his co-workers (1980) published geochemical evidence which they claimed showed that the extinction of the dinosaurs was contemporary with the impact of a large asteroid.⁴ The possibility that asteroid or comet collisions could affect evolution had been suggested in some earlier papers (Öpik, 1958; Urey, 1973), but it was only now that the idea was considered extensively by astronomers and palaeontologists. With the discovery of a convincing impact crater (Hildebrand et al, 1991), growing numbers of known near-Earth

asteroids and the increasing knowledge from planetary probes of the impact histories of other planets (Shoemaker, 1983), many scientists came to accept the idea that an asteroid impact had played some role in the dinosaur extinction and possibly in other mass extinctions as well (Albritton, 1989; Glen, 1994b).

The recognition that impacts were a force in Earth history helped draw asteroids into the catastrophic discourse popularly associated with comets.⁵ Whilst asteroids have relatively small orbits inclined close to the planetary plane, long-period comets have highly elongated orbits oriented in all directions making them difficult to observe. Traditionally, the unexpected apparition of comets had been associated with Earthly calamities (Schechner Genuth, 1997) – a tradition which asteroids had not shared up to this point. A number of nineteenth and early-twentieth century writers had explored the possibility of a cometary encounter in works of fiction and popular science.⁶ The catastrophes conjured by these writers were typically attributed to the passage of the Earth through the cloud of gas and dust in the comet's tail rather than to the impact of a solid body. The impact-extinction thesis, by contrast, configured both comets and asteroids as potential solid impactors. However, the difficulties observing long-period comets much in advance of their arrival near Earth ensured that it would be asteroids, rather than comets, which would figure most prominently in the promotion of impacts as a threat.

Classical asteroid science had dealt in the prediction of eternal truths and the recounting of cosmic history. Asteroid orbits had demonstrated the Newtonian order of the Solar System and were accommodated within narratives of origins that reinforced the timeless generalities of Newtonianism. But once impact-extinction theory had drawn asteroids into the history of terrestrial evolution, they came to be identified with contingent events and with timelines that had both beginnings and endings. In this context, the predictive goal of physical science could be re-oriented towards future contingencies. The growing empirical evidence that supported the view of impacts as a significant force in geological history did not itself determine a view of asteroids as signifiers of the human future. That required asteroids to be located within a new set of stories. During the 1980s, a few astronomers began to resignify asteroids in this way but for some years they had only limited success in converting others to their view of asteroids as a threat. Taking a prophetic turn, these scientists began telling stories about the future of human civilisation and how space

technologies could save the world.

Doug Davis (2001) has argued that the idea that the extinction of the dinosaurs was caused by an impact drew the study of the planetary past into the networks of Cold War science. Participants in the impact-extinction controversy debated the relevance of Carl Sagan's nuclear winter calculations, drew on studies of bomb cratering and invoked the models and metaphors of total-war fighting. As astronomers began to take the prophetic turn, they extended the conceptual alignment between impact science and the culture of total war into the study of the planetary future.

The Prophetic Turn

Since the 1930s, asteroid collision rates had been understood well enough for some astronomers to have recognised the possibility of future impacts with Earth, but they had not dwelt on this possibility or framed their work in terms of human consequences.⁷ In 1967, a predicted close approach by the asteroid Icarus prompted a student exercise at MIT into how to prevent an imagined impact. The findings were published (Kleiman, 1979) but were not pursued beyond the classroom or the popular press. It was only in 1980, when Luis Alvarez and others examined the possibility of future impacts as part of an attempt to formulate a new vision for NASA, that asteroids began to be constructed as a threat by the research community (Chapman and Morrison, 1989: 276). The following year, NASA sponsored a workshop at Snowmass, Colorado on the consequences of asteroid impacts.⁸ In addition to questions about how best to detect near-Earth asteroids – the traditional observational domain of astronomy – the workshop also considered questions about the vulnerability of society if agriculture were to be wiped out for a year, the instability of social and economic structures in the aftermath of an impact, and how to deflect or destroy a potential impactor, a question already anticipated in Alvarez's analysis. Such questions firmly located asteroids within the sphere of human action.

The workshop also brought astronomers into direct contact with defence scientists. According to the astronomer Tom Gehrels, who presented details of his new Spacewatch asteroid survey to the workshop, already at this time astronomers recognised that the

energies involved in deflecting an asteroid would require nuclear weapons and they therefore asked 'the people familiar with nuclear engineering to take an interest in these problems' (Gehrels, 2001). In fact, some of the defence scientists were quick to do just that. Unlike many of the civilian scientists who were slow to pursue the impact threat, one of the defence scientists at the Lawrence Livermore National Laboratory wrote a report on the asteroid threat as early as 1984 and impacts with Earth were a favourite topic of conversation among Lowell Wood's group at the lab at this time (Broad, 1985: 107, 190).

Wood was one of Edward Teller's protégés at Livermore and, like Teller, he was one of the most active proponents of a space-based missile defence system, an idea endorsed by Reagan in his famous Star Wars speech of 1983 and officially launched as the Strategic Defense Initiative two years later. Wood and Teller both met regularly with officials in the Reagan administration to brief them on the work of Wood's group and on the potential of nuclear-powered x-ray lasers to form a defence shield. In 1987, after the failures of the x-ray laser project became apparent, Wood and Teller began to promote 'Brilliant Pebbles', a space-based system of small autonomous kinetic-energy weapons (Broad, 1992; FitzGerald, 2000). The idea had been suggested to them by Los Alamos physicist Greg Canavan, one of the other defence scientists to take an interest in the asteroid impact threat. Canavan (1994: 1183) would later acknowledge the close relation between Brilliant Pebbles and systems for destroying small Earth-threatening asteroids, noting that Brilliant Pebbles' destruction mechanism, sensors and propulsion system could all be utilised for asteroid mitigation.

Despite the defence scientists' interest in the asteroid impact threat, civilian scientists did little to pursue the idea through most of the 1980s. Even a provocative popular book by UK astronomers Victor Clube and Bill Napier (1982), in which they claimed that ancient myths had been inspired by catastrophic impacts, concentrated on past events and only hinted at asteroids as a future hazard. One civilian scientist who did articulate the threat more explicitly was retired Harvard astronomer Fred Whipple.⁹ In his popular book, *The Mystery of Comets*, Whipple warned that '*asteroids and comets have, and will, strike the Earth, causing serious if not catastrophic devastation*' (Whipple, 1985: 245, italics in original). He concluded:

Protection of the Earth from undesirable impacting bodies is not just a science fiction project for some improbable future. The cost might be comparable to, even smaller than, the world's current military expenditures. We could choose to do it now. We could choose to protect ourselves from asteroids and comets rather than from each other. (Whipple, 1985: 249)

Yet Whipple's warning failed to provoke any technical or institutional response. Even at the end of the decade, the state-of-the-field volume *Asteroids II* (Binzel et al. 1989) included only the briefest mentions of the impact threat.¹⁰

By this time, however, more persistent efforts by two scientists were having some success in drawing attention to the threat of an asteroid impact. In 1988, Clark Chapman, a planetary scientist at the Planetary Science Institute in Arizona, and NASA astronomer David Morrison submitted an abstract about the impact threat for a conference. Fuelling a sense of marginalisation that continued for many years despite their later success in promoting the impact threat, the abstract was initially rejected. After the authors objected, the abstract was accepted, but for a poster presentation rather than an oral paper (Chapman, 1998).

Perhaps in response to the perceived dismissal of their ideas by the scientific community, Chapman and Morrison, like Whipple and Clube and Napier, decided to present their ideas in a popular book, *Cosmic Catastrophes*, the last chapter of which included a summary of the Snowmass workshop. The book considered a number of possible planetary disasters, but concluded that 'the greatest hazard of all is that civilization could be entirely destroyed any day by the unexpected impact of an asteroid or comet' (Chapman and Morrison, 1989: 275).

Configuring the present as the peripetia in the narrative of human evolution, Chapman and Morrison claimed that:

In just the last couple of decades . . . our cultural evolution has enabled us to become aware of the nature of the threat that doomed the dinosaurs, and could doom us, as well. And we may even have the technological prowess to save ourselves from what until now could only be thought of as an act of God. (Chapman and Morrison, 1989: 275-6)

This appeal to technological salvation would characterise the promotion of the asteroid threat throughout the following decade.

Around the same time as *Cosmic Catastrophes* was published, NASA issued a press release stating that an asteroid then known as 1989FC had had a near-miss with Earth but had gone undetected until after its closest approach.¹¹ The press release led to widespread media coverage (for example, Leary, 1989; Wright, 1989; Johnson, 1989; Will, 1989). Chapman and Morrison were invited to discuss the issue at two scientific meetings that year and, in the first policy move, Morrison was invited to discuss the impact threat with the Space Caucus of the House of Representatives (Chapman, 1998).

The following year, the American Institute of Aeronautics and Astronautics (AIAA), the professional organisation representing aerospace engineers, produced a position paper recommending that studies should be conducted into how to increase the detection rate of potential impactors and, noting the usefulness of SDI technologies in this regard, to devise ways of deflecting them (Tagliaferri, 1990). In response, Congress instructed NASA to conduct two workshop studies – one on the detection of asteroids and one on their deflection.¹² These influential workshops helped consolidate the view of asteroids as threatening bodies.

The Detection Workshop, chaired by David Morrison, took the form of a committee of 24 civilian scientists, the majority of whom were based in the US but with six members from other countries including one from the USSR. The committee met formally three times, the first meeting being held alongside a NASA-sponsored conference on near-Earth asteroids at San Juan Capistrano in California in July 1991. The committee's report reviewed the impact threat as already elaborated at the Snowmass workshop and proposed a network of new ground-based telescopes, named the 'Spaceguard Survey', to increase the detection rate of near-Earth asteroids. The report identified objects of greater than 1km in diameter as posing the greatest threat since an impact with such an object could cause 'global environmental damage and mass mortality' (Morrison, 1992: 103). These larger objects would also be relatively easy to observe compared to the more numerous small asteroids.

After the Detection Workshop had completed its study, the Interception Workshop was

convened at the Los Alamos National Laboratory. The majority of the workshop participants were defence scientists, although civilian scientists such as Morrison and Chapman were also present. In preparation for the workshop, Lowell Wood had provided participants with an analysis he had written in 1990 which argued that the greatest threat was posed by small objects which impacted with Earth relatively frequently and could cause local damage (Chapman, 1998). With his Lawrence Livermore colleague Rod Hyde, Wood argued that all near-Earth objects greater than 100m diameter were worth intercepting (Canavan et al. 1994). This contradicted the findings of the Detection Workshop.

In arguing over which size of asteroid posed the greatest threat, both the civilian and defence scientists emphasised the relevance of their own expertise and facilities. Despite appeals to population statistics and impact energies, the size of object identified as of most interest was, for both sides, a flexible notion dependent on current interests. A decade later, after the Spaceguard survey had catalogued over half of the near-Earth asteroids over 1km and none had been found to be on a collision course with Earth (Morrison et al, 2002: 740), the civilian scientists began to argue that the greatest threat was now posed by objects a few hundred metres in diameter.¹³ The magnitude of the threat was not so much a property of the asteroids, but of the scientists' lack of knowledge about their trajectories – something which could always be addressed by supporting their studies.

The size of asteroid posing the greatest threat was just one of several points of contention between the civilian and defence scientists. In their own histories of the impact threat, the civilian scientists repeatedly drew attention to these disagreements, rhetorically creating a distance between the two groups even as they worked together to promote the new conception of asteroids as a threat demanding a technological response. Clark Chapman (1998), for instance, reported that there were tensions over calls for a nuclear defence even as early as the Snowmass workshop. He attributed the delay in publishing the report of the workshop to objections raised by planetary scientist George Wetherill who was concerned that calls for the placing of nuclear explosives in space might destabilise US/Soviet relations.

Similarly, astronomer Duncan Steel (1995: 234) recalled that the members of the

Detection Committee had been 'outraged' by a paper presented at the San Juan Capistrano conference by Nicholas Colella, a Lawrence Livermore scientist who had called for the development of a multi-million dollar satellite-based detection system, and that Lowell Wood had been 'roundly booed' after criticising NASA space missions in an after-dinner speech. Steel said that he found the Interception Workshop 'very interesting and stimulating', but that it was also 'bizarre in that some of the presentations paid little regard to the laws of physics and less to any laws of economic reality' (Steel, 1995: 232). According to Steel, some of the talks were 'wildly in error' and David Morrison had complained that the defence scientists lived in a 'parallel universe' and that they seemed to draw on science fiction rather than the laws of physics (Steel, 1995: 234-5). They did indeed draw on science fiction, but, as we will see, so too did the civilian scientists.

Dismissing the defence scientists helped the civilian scientists reinforce their identity as a separate community. But the disagreements also touched on questions of principle, such as whether mitigation measures of any sort should be deployed. These concerns were later articulated most clearly, and most forcefully, by the Cornell astronomer Carl Sagan, an active campaigner against nuclear weapons who had been one of the scientists to propose the nuclear winter scenario a decade earlier (Turco et al. 1983). Sagan highlighted what has since become known as the 'deflection dilemma'. Whilst agreeing that there was a need for a detection programme, Sagan argued that investigating deflection mechanisms was premature, not just because there would be time enough to develop such technologies once the need arose, but also because such technologies would be open to misuse and as such would pose a greater risk than the asteroids themselves (Sagan, 1992; Sagan and Ostro, 1994a).

Other scientists, whilst still insisting on the significance of the threat and on the need for detection surveys, agreed with Sagan that mitigation systems should not be developed unless a potential impactor was identified.¹⁴ Others argued against the deployment of a mitigation system for more pragmatic reasons. In the first peer-reviewed journal article on the subject, Thomas Ahrens and Alan Harris (1992) of the California Institute of Technology argued that because the relevant technologies would change rapidly in the coming years, it would be inappropriate to do more than outline possible strategies. However, they also suggested that SDI technologies such as Boeing's Lightweight

Exoatmospheric Projectile might be used to deflect small asteroids.

In the following years, civilian and defence scientists continued to meet despite their differences. In 1993, Stuart Nozette and Pete Worden of the Ballistic Missile Defense Office (BMDO, formerly the Strategic Defense Initiative Office) organised a workshop on the impact threat as part of the Erice series of international seminars dedicated to nuclear war and planetary emergencies.¹⁵ In the same year, an international conference was held at Tucson, Arizona leading to the publication of *Hazards due to Comets and Asteroids* (Gehrels, 1994), a volume in the Space Science Series containing 47 peer-reviewed papers by 120 collaborating authors. The publication of this volume was supported by the BMDO and the Los Alamos National Laboratory, as well as the University of Arizona. In an attempt to negotiate the differences between the two groups, the volume included collaborative papers by David Morrison and Edward Teller (1994) and by Greg Canavan and Carl Sagan and others (Harris et al. 1994). Yet disagreements remained. Whilst some of the civilian scientists were cautious about calling for nuclear explosives to be placed in space, noting the political and legal barriers to such an action, the defence scientists continued to argue that nuclear explosives were mandatory and Edward Teller went so far as to call for experimentation to begin at once (Morrison and Teller, 1994: 1142; statement attributed to Teller alone).¹⁶

Further joint meetings were held in 1994 at Air Force Space Command in Colorado Springs and at Chelyabinsk-70, the Russian nuclear weapons lab, with follow up meetings there and in the Ukraine in subsequent years. A Planetary Defense Workshop was held at Lawrence Livermore in 1995; a NASA-sponsored workshop on mitigation was held near Washington in 2002; and a Planetary Defense Conference was held in California in 2004.¹⁷

Congress also continued to take an interest in the issue. In 1994 it directed NASA to draw up a ten-year programme to catalogue all near-Earth asteroids larger than 1km. In response, NASA established the Near-Earth Object Survey Working Group, chaired by Eugene Shoemaker of the Lowell Observatory, which proposed a dedicated survey with \$24 million start-up costs over a five-year period and \$3.5 million annual operational costs in subsequent years (Shoemaker, 1995). Members of the Working Group later accused

NASA of passing the proposal to Congress with a cover letter effectively rejecting their recommendations.¹⁸ However, NASA did promise enhanced funding for existing surveys and in 1998 it set up a dedicated Near-Earth Object Programme Office with a budget of \$3 million, about 14% of the Planetary Astronomy Program total budget and twice the previous annual expenditure on near-Earth objects (Cherry, 1998). The office was to co-ordinate the US contribution to the Spaceguard Survey through two projects: the NEAT programme which had started in 1995 using a US Air Force surveillance telescope (Helin et al. 1997: 9), and LINEAR, launched in 1998 at MIT's Lincoln laboratory, which again used a US Air Force telescope.¹⁹ In addition, NASA approved rendezvous missions to asteroids, including the NEAR-Shoemaker mission that visited the near-Earth asteroid Eros in 2001.

The US military also planned asteroid rendezvous missions during the 1990s. In 1991, the Department of Defense approved the BMDO's Clementine mission to map the surface of the moon and the near-Earth asteroid Geographos as a way of testing SDI vehicles and sensors from the Brilliant Pebbles programme.²⁰ The spacecraft was launched in 1994 and reached the moon successfully but was unable to proceed to the asteroid. In 1995, another Clementine mission was planned to further test a new space vehicle and sensor technology. Clementine II was to fire autonomous microsatellite impactors at asteroids with the scientific rationale of providing information about asteroid composition.²¹ The mission was vetoed by the Clinton administration in 1997, but NASA's Deep Impact mission, initiated in 1999, took up the idea of an impact experiment with an autonomous microsatellite, though this time the target was a comet rather than an asteroid. Deep Impact fired a 500kg projectile at Comet Tempel 1 on 4th July 2005.

In addition to the rendezvous missions, various organisations conducted studies into possible planetary defence systems. In 1996, a US Air Force study (Urias, 1996) was completed under the umbrella of '2025', a project aimed at considering how the US could maintain future dominance in air and space. The study recommended the deployment of a three-tier planetary defence system by 2025. Despite calling for international co-operation on the issue, the study proposed a command system which would allow the US to unilaterally lead mitigation efforts and suggested that 'it will likely become necessary to selectively renegotiate existing treaties that currently prohibit testing and using weapons in

space' (Urias, 1996: 15).

Other groups proposed similar mitigation systems. At a conference at Chelyabinsk-70 in 1996, representatives of the Russian aerospace industry unveiled 'Space Shield', a planetary defence system consisting of space-based surveillance units and ground- and space-based interceptor missiles (Morrison, 1996). A few years later, a study for NASA's Institute for Advanced Concepts proposed SHIELD, a system of space-based 'Sentries' that would search for near-Earth objects and ground- and space-based 'Soldiers' to deflect any threatening objects (Gold, 1999).

By 2002, the notion that asteroids were threatening objects had become commonplace among asteroid scientists, as evidenced by *Asteroids III*, the third volume of the University of Arizona Space Science Series to present a state-of-the-field overview of all aspects of asteroid science. As well as acknowledging the continued importance of asteroids in reconstructing solar system history, the editors of the volume noted that: 'A second and perhaps more practical reason to study asteroids has to do with the fact that some of these bodies are capable of striking Earth with enough energy to produce severe or possibly catastrophic damage to our civilization' (Bottke et al. 2002b: 4). Unlike the previous two volumes, a number of contributions to this volume, dealing with a range of physical issues, were now justified on the grounds of the impact threat (e.g., Asphaug et al. 2002; Binzel et al. 2002; Burbine et al. 2002; Zappalà et al. 2002).

Despite what one paper referred to as a 'beneficent funding environment' (Jedicke, 2002: 83), many promoters of the impact threat still felt that resources were insufficient, governmental responses inadequate and media representations often inaccurate. But asteroids were now firmly located within the human sphere and the possibility of acting was accepted, regardless of which actions were, or were not, taken. The impact threat was now regularly discussed by scientists, politicians and journalists. An international organisation, the Spaceguard Foundation, had been set up to 'promote and co-ordinate' surveys and studies, including the creation of a 'Spaceguard System'.²² There was an extensive technical literature on the subject and numerous scientific conferences had met to consider the issue. The detection of potentially hazardous objects was explicitly funded by NASA, and the cataloguing of objects larger than 1km in diameter was 50% complete

(Stokes et al. 2002: 46). There had been Congressional Hearings on planetary defence; the US National Academy of Sciences had granted the highest priority to the detection of near-Earth objects; the British Government had set up a Task Force on near-Earth objects (Atkinson, 2000); the Parliamentary Assembly of the Council of Europe had passed a resolution calling for the detection of potentially hazardous asteroids; and the UN's Vienna Declaration on Space and Human Development had called for the international co-ordination of activities related to near-Earth objects.²³

Narratives of Technological Salvation

Despite their disagreements over technical details and funding priorities, both civilian and defence scientists appealed to narratives of technological salvation. In his study of the superweapon in the American imagination, Bruce Franklin (1988) has shown how a century-long tradition of future-war fiction shaped an apocalyptic ideology in which American technological genius was to put an end to all war and fulfil America's manifest destiny. Franklin argues that this cultural fantasising has been materially significant in producing actual superweapons and developing defence policy. As David Seed (1999) has also shown, SDI was made imaginable, and was explicitly defended, by science fiction writers. The impact-threat scientists took this cultural fantasising a step further as they attempted to establish the reality of that threat. It was now nature, rather than any human foe, which was configured as the warring enemy whose technological defeat would bring Earthly harmony.

Until the 1970s, most science fiction stories about asteroids imagined them as objects to be exploited for their mineral wealth.²⁴ Scientists' writings would occasionally reflect this interest.²⁵ Indeed, the only paper in the 1979 volume *Asteroids* to allude to a future impact of an asteroid with Earth was framed in terms of the exploitation of asteroids. In a bizarre paper, which had been rejected for an earlier publication after being judged 'outrageously innovative' and 'premature', Samuel Herrick (1979) proposed that portions of the asteroid Geographos could be targeted at specific points on the Earth to produce 'constructive' effects, such as the excavation of a new Central American canal to join the Atlantic and Pacific Oceans.

However, by the time of Herrick's technical fantasy, science fiction writers had begun to explore the more destructive consequences of an asteroid impacting with Earth. Most notably, Arthur C. Clarke, in his 1973 novel *Rendezvous with Rama*, described an asteroid impact in 2077. In the novel, a detection survey called 'Spaceguard' is established in response to the impact and the rest of the story deals with the investigation of what actually turns out to be an alien spacecraft that is detected by the Spaceguard survey some 60 years later. Clarke developed the Spaceguard idea further in another novel, *Hammer of God*, in 1993 after writing a short story on the same theme for *Time* magazine the previous year.

Clarke's impact novels were well regarded by the scientists promoting the impact threat and were cited in some of their peer-reviewed papers and policy documents as well as in their popular books. For instance, in their influential paper in *Nature*, Chapman and Morrison (1994: 38) introduced the idea of deflecting a possible impactor with a reference to *Hammer of God*, noting that: 'Just such a scenario . . . is the theme of a recent novel' (see also Morrison et al, 1994: 84; Atkinson, 2000: 36). Indeed, the scientists named their own international survey the Spaceguard Survey and their promotional organisation the Spaceguard Foundation in tribute to Clarke, as they acknowledged in their technical papers (e.g., Milani et al. 2002: 55). Clarke became a Trustee Member of Spaceguard, and he was a personal friend of Duncan Steel and Tom Gehrels, and wrote the foreword for one of Steel's popular books on the impact threat and the afterword for another one (Gehrels, 1988: 236; Steel, 1995, 2000a). As Clarke himself remarked in the acknowledgements for one of his novels, 'the strands of fact and fiction are becoming inextricably entwined' (Clarke, 1995: 247).

Also mentioned by the scientists was Larry Niven and Jerry Pournelle's *Lucifer's Hammer*. This 1977 novel is essentially a survivalist tale about the aftermath of a comet impact. In the lawless devastation following the impact, a former Senator sets up a community which attempts to re-establish a civilised, technologised society. This predominantly white community is attacked by various predominantly black violent gangs, one of which has turned to cannibalism as an initiation rite. Despite its racism, which always went unacknowledged in the scientists' comments, they praised this novel in their

popular books. For instance, planetary scientist John Lewis (1997: 151) stated that no novel had better visualised the effects of ocean impacts, and Steel cited it as an example of 'good science fiction' based on 'real science' (Steel, 2000a: 124). Acknowledging limits to the expertise of natural scientists, Clark Chapman and David Morrison (1989: 279) suggested that 'estimating sociological responses to catastrophe are more nearly in the purview of science-fiction writers, like Jerry Pournelle and Larry Niven, who addressed these matters in *Lucifer's Hammer*' (see also Morrison et al. 2004: 378). Like Clarke, Niven had direct contact with the scientists promoting the impact threat, attending the 2004 Planetary Defense Conference in California.

Despite their very different political affinities, Clarke, Niven and Pournelle all portrayed technology as a force for good. With his proposal for a Spaceguard survey in *Rendezvous with Rama* and with the action of *Hammer of God* based on board a research space vessel charged with deflecting the incoming asteroid, Clarke's impact novels promoted salvation through technology. Despite his earlier criticisms of SDI, in 1992 Clarke gave 'two faint cheers for Son-of-SDI', given certain provisos, because the technology might be needed to deflect an asteroid (Clarke, 1992: 12). Niven and Pournelle also promoted an ideology of technological salvation in their novel, despite setting *Lucifer's Hammer* in the technologically compromised aftermath of an impact. The story's denouement has the Senator's group defending a nuclear power station, which they see as offering the means to recover civilisation – a civilisation fully attainable only through its technological artefacts. In this, as in other impact narratives, technology offers not the source of destruction but the means of salvation.

In addition to referring to these novels, the scientists studying the impact threat also acknowledged film treatments of the asteroid impact threat – including the 1979 film *Meteor* and the 1998 films *Deep Impact* and *Armageddon*. For instance, a paper in the journal *Space Policy* includes a general reference to 'novels and Hollywood films' (Garshnek et al. 2000: 218) and NASA's Deep Impact probe shares its name with the film. The report of the UK's Task Force on near-Earth objects lists the release of all three films, as well as the publication of Clarke's *Rendezvous with Rama*, as significant events in a chronology of the understanding of asteroids and comets (Atkinson, 2000: 36-7). These films were themselves influenced by the scientific work of the day. *Meteor* was inspired

by the 1967 student project at MIT (Kleiman, 1979) and the 1998 films used scientists as consultants (Davis, 2001). As David Kirby (2003) has argued, as well as enabling film studios to claim that their films are scientifically accurate, such consultancy work provides scientists with opportunities to promote a particular version of reality.

The scientists also used narrative to present the impact threat in their own writings. The popular books written by the asteroid scientists often included narrative accounts of particular asteroid impacts that are hard to distinguish from the accounts found in fictional texts. For instance, in his popular book *Rain of Fire and Ice*, planetary scientist John Lewis described the approach of an asteroid as seen from ships in the North Atlantic sea-lanes just off England.²⁶ The following lines give a flavour of the narrativised style through which he establishes a causally-connected sequence of events: '[The] crews, watching the brilliant fireball approaching them almost head-on, are at first dazzled by the light, but the vastly brighter flare of the final explosion literally burns out their eyes. Ships . . . fill with smoke as they careen on, unpiloted, into hell' (Lewis, 1997: 195-6). This is one of several scenarios which, Lewis says, are narrative accounts of computer simulations 'just as they came off the computer' (Lewis, 1997: 188).

However much Lewis might wish to credit his computer with the authorship of these narratives, by naming real places, fixing times, establishing a causal sequence of events and alluding to proto-characters, he converts the generalised predictions of collision statistics and asteroid properties into concrete narrative scenarios familiar to his readers. Through such narration, the data of a speculative science becomes a realistic and immediate threat. Technical reports of similar computer simulations, whilst lacking the colour of Lewis's popular account, allude to similar narrative scenarios. For instance, a conference paper by two Los Alamos scientists combines the particularity of place with the immediacy of the present tense: 'The East Coast of the United States is hit very hard by the surge. . . . Delaware, Long Island, and all of Maryland below the Piedmont Plateau are completely inundated as are all coastal cities in this area' (Hills and Mader, 1995; see also Hills and Goda, 1999). Like Lewis's narratives, this is an account of events that have not happened – events which are construed out of computer models of possible kinetic energies, rock densities and atmospheric resistance applied to real locations in a possible future present.

Despite their own use of the narrative form and their explicit references to works of science fiction, the asteroid scientists expressed concerns about the proximity of their science to science fiction. They frequently complained of a 'giggle factor' (Morrison et al. 2004: 354; Verschuur, 1996: vi; Lewis, 1997: 220; Ailor, 2004: 6) and would insist on a clear separation between 'science fact' and 'science fiction' (Steel, 1995: 2, 247; Kring, 2000: 169). This double strategy of appealing to science fiction while creating distance from it is also found in popularisations of other areas of science. As I have argued elsewhere (Mellor, 2003), this appeal to science fiction should not simply be dismissed as a popular hook aimed to draw readers into the 'real' science. As noted above, in the case of impact-threat science, although the references to science fiction are more common in popular accounts, they can also be found in some peer-reviewed papers and policy documents. The means of framing a text, be it popular or technical, is not some innocent bolt-on device but fundamentally structures how we conceptualise the subject. Articulating a science of asteroids necessarily involves *imagining* asteroids. The asteroid scientists' references to fictional narratives suggest that the technoscientific imaginary on which they drew was shared with, and informed by, the narratives of science fiction.

Like the civilian scientists, the US defence scientists interested in the impact threat also worked in a community influenced by science fiction. Indeed, in some sectors of the military planning community, including those in which the promoters of SDI moved, explicit links with science fiction authors were cultivated regularly. As Chris Hables Gray (1994) has noted, 'militaristic science fiction and military policy coexist in the same discourse system to a surprising degree' (see also Franklin, 1988; James, 1994: 200). The Air Force Academy held annual 'Nexus' conferences on science fiction and military policy, and other conferences, such as the 'Futurist' conferences, also brought together military policy-makers and science fiction authors. At one typical conference held in 1985 at Ohio Air Force base, the authors present included prominent proponents of SDI such as Jerry Pournelle (Seed, 1999: 192). Pournelle was director of 'organisational support' for the Heritage Foundation's High Frontier project, which campaigned for SDI, and he was chair of a panel which in 1984 had published the pro-SDI tract, *Mutually Assured Survival* (Gray, 1994). He was also, for many years, the editor of the annual anthology series *There Will Be War!* which mixed pro-war science fiction stories with pro-SDI non-fiction to

claim that war was inevitable.

The scientists promoting and working on SDI weapons were avid consumers of science fiction and some had direct links to science fiction authors. Rod Hyde, one of the Lawrence Livermore scientists who studied the impact threat, belonged to the Citizen's Advisory Council on National Space Policy, an organisation founded by Pournelle (Broad, 1985: 141). Another Lawrence Livermore scientist included references to works by Pournelle, Niven and other science fiction authors in his doctoral thesis on the X-ray laser. In an interview with journalist William Broad, he explained that he turned to such authors for ideas about his own work. 'Writers of science fiction are supposed to look into the future. So I started looking to see what they had in mind for the X-ray lasers' (Broad, 1985: 120).

Such links were part of a broader futures planning culture within the military that relied heavily on fictional constructs. Gray (1994) argues that standard military practices such as war gaming and scenario construction are works of military fiction and that this fiction-making is both directly and indirectly influenced by the ideas of pro-war science fiction authors. The 1996 US Air Force study into the asteroid impact threat is an example of such fiction making. The study was part of a futures planning exercise which considered several possible 'alternate futures' for the year 2025, drawing on a 'concepts database' which included such science-fictional ideas as 'force shields' and 'gravity manipulation'. The authors of the study noted the science fiction provenance of these ideas, at one point referring directly to *Star Trek*, but they took the ideas seriously nonetheless. They noted, with some understatement, that gravity manipulation was an 'undeveloped technology', but made no such comment about other speculative technologies such as solar sails, mass drivers, or biological 'eaters' which were supposed to munch their way through the threatening comet or asteroid (Urias, 1996: 41-54).

The Narrative Imperative

The asteroid impact threat was thus articulated within a narrative context that was closely aligned to science fiction and was shared by both civilian scientists and defence experts.

As Veronica Hollinger (2000: 216-7) has noted, traditional science fiction is driven by an Aristotelian plot characterised by 'a valorization of the logic of cause and effect'. Impact narratives conformed to this traditional narrative logic: asteroids and scientists act by causing a series of events to unfold, from the approach of an asteroid and recognition of the threat through attempts at technological mitigation to resolution in salvation. These narratives configured asteroids as acting agents in human affairs and brought to asteroid science a structure in which human agents (and their technological proxies) solve the problem posed in the narrative and in so doing achieve closure. Allusions to impact narratives implied a direction and human-centredness to events which, once the narratives had been evoked, could not easily be suppressed. Despite their attempts to distance themselves from the weapons scientists, the civilian scientists experienced a 'narrative imperative' which drew them towards the same technologised ends as those promoting SDI.

A sense of narrative agency was evoked even in texts that were not primarily narrativel. Crucially, asteroids were no longer seen as signifiers of the mathematically-exacting Newtonian system, distant objects moving through the empty backdrop of space. Rather, they were configured as proximate beasts, acting subjects that could turn against humanity at any moment. Thus in their many popular books on the subject, the scientists described asteroids as belonging to a 'menagerie' or a 'cosmic zoo' (Steel, 2000a: 120); they were 'menacing' (Kring, 2000: 171) and had 'teeth' (Clube and Napier, 1990: 154); they were 'global killers' (Lewis, 1997: 209) which could unleash 'ferocious assaults' (Steel, 1995: 247) on the Earth; they were the 'enemy' (Steel, 2000a: 153). Likewise, in their paper in *Nature*, Chapman and Morrison (1994: 33) stated that Earth 'resides in a swarm of asteroids'.

The construction of asteroids as the enemy was accompanied by a range of other militaristic metaphors. In the popular books, asteroids became 'missiles', 'pieces of ordnance' or 'stealth weapons' (Lewis, 1997: 37) which bombard the Earth with a 'death-dealing fusillade' (Clube and Napier, 1990: 7). In a technical paper, too, they were construed as 'astral assailant[s]' (Simenko et al. 1994: 929). Where the military and the politicians talked of rogue states,²⁷ the scientists talked of 'rogue asteroids' (Steel, 1995; Ailor, 2004: 3). This analogy was further reinforced by the construction of scenarios in

which a small impact might be mistaken for the detonation of a nuclear warhead. One technical paper speculated on what would have happened during the first Gulf War if an atmospheric explosion which had been caused by a meteor burning up over the Pacific had actually occurred over Baghdad or Israel (Tagliaferri et al. 1994). The authors suggested that such an event would have been mistaken for a missile detonation by the opposing state. In such scenarios, the actions of interplanetary bodies were not just compared with those of rogue states but came to be identified with them.

With the swarming asteroids filling space, space itself was also resignified. What had been an abstract mathematical space became a narrative place, the location where particular and contingent events occurred. Although the scientists continued to appeal to the predictability of celestial dynamics – it was this that would enable a survey of near-Earth objects to identify any that might pose a threat – they also noted that chaotic processes disturbed the orbits of comets and also, to a lesser degree, asteroids (e.g., Yeomans and Chodas, 1994; Milani et al, 2000). The inherent unpredictability of the orbits was enhanced by the current state of scientific uncertainty. These chaotic and uncertain processes were projected onto space itself, construed as a place of random violence. In the popular books, the Solar System became a 'dangerous cosmic neighbourhood' (Sumners and Allen, 2000b: 3), 'a capricious, violent place' (Verschuur, 1996: 217), a place of 'mindless violence' (Verschuur, 1996: 18) and 'wanton destruction' (Levy, 1998: 13). Even in a peer-reviewed paper, Chapman (2004: 1) described space as a 'cosmic shooting gallery'.

Despite the agency attributed to the asteroids themselves, in the narratives of technological salvation it was the human agents, acting through new technologies, who moved the narratives forwards. Narrative progression was thus generated through an assumption of technological progress. Through technology, humans intervene in space and become agents of cosmic events. The scientists' promotion of the impact threat shared this assumption of technological progress. Like the US Air Force study, their technical papers on mitigation systems considered speculative technologies such as solar sails and mass drivers as well as more established explosive technologies (e.g., Ahrens and Harris, 1992; Melosh and Nemchinov, 1993; Ivashkin and Smirnov, 1995; Gritzner and Kahle, 2004). Even those scientists who warned that it was too early to draw up detailed blueprints of

interception technologies, accepted the narrational implication that there was a problem that needed addressing, that the problem could be addressed by human action, and that this action would involve a technological solution. Technology, in this picture, was configured as inherently progressive. As Morrison and Teller (1994: 1137) put it: 'The development of technology in the past few centuries has been towards increasing understanding and control of natural forces in an effort to improve human life.' Those scientists who argued against the immediate development of mitigation technology shared with its proponents a belief in the inexorable progress of technology. Future generations, they argued, would be better equipped than we are at the moment to meet the technological challenge of an impacting asteroid (e.g., Ahrens and Harris, 1992).

In contrast to traditional astronomical systems which passively watched the skies, asteroid detection systems were to be surveillance systems that actively hunted the skies for objects of human import. The Spaceguard Survey was predicated on a will to action in a way in which the earlier Spacewatch Survey was not. Similarly, when it fired its impactor at Comet Tempel 1, NASA's Deep Impact mission took a far more active intervention in space than did earlier generations of probes. This was not far from Edward Teller's call for 'experimentation' with near-Earth objects to test defence technologies (Tedeschi and Teller, 1994; Teller, 1995), an idea dismissed at the time as extreme by some civilian scientists (Chapman, 1998). Likewise, one of the recommendations of the 2004 Planetary Defense Conference was that deflection techniques should be demonstrated on an actual asteroid (Ailor, 2004: 5).²⁸

The technologisation of space promoted in both the fictional works and the scientists' technical proposals, also formed an integral part of the imagery and rhetoric that surrounded SDI, as its detractors highlighted when they re-named the project Star Wars. SDI was always premised on a vision of space as a technologised theatre of war. In the hands of a techno-enthusiast like Edward Teller, SDI was configured as a space-based technological extravaganza with few limits.²⁹ In SDI, as in asteroid research and science fiction, space became a dynamic arena through which our technologies would move, in which our weapons would be placed, and across which our wars were to be waged.³⁰

As discussed in the introduction to this paper, narrative is an inherently teleological form.

In conventional narratives, the action is moved towards closure by the heroes of the story. In the impact narratives, the heroes are technological heroes set the task of saving the world. By drawing on these narratives and following the call for human agency inherent in the narrative structure, the scientists implicitly accepted this role as a necessary one. Having shifted apocalypse from the realm of nuclear politics to that of natural science, the impact-threat scientists were able to position themselves as heroes whose combined far-sightedness and technological know-how would save us all. Emphasising the role of the unacknowledged hero in a foreword to a volume of conference proceedings, astronomer Tom Gehrels (2002: xiii) claimed: 'There is a beauty also in hazards, because we are taking care of them. We are working to safeguard our planet, even if the world does not seem to want to be saved.' In a paper in another volume of conference proceedings, astrophysicist Eugene Levy was even more explicit about the scientists' expanded role:

In the arms race, the motivating dynamic was a political one. A dynamic in which scientists and engineers provided the technical tools, but, as a group, brought no special and unique wisdom to the table in making judgements about what to do. In the present case, the dynamic is different. The adversary is not another nation; the calculus is not one of political fears, anxieties, and motivations, for which we scientists have no special expertise. Rather the 'adversary' is the physical world. In assessing *this* adversary, we scientists have special and unique expertise. (Levy, 1994: 7; italics in original.)

Eclipsing the political dimension of the impact threat with their appeals to the natural, the scientists appropriated for themselves a heroic role. This technological hero was a moral hero – he would warn us of the danger and save us despite ourselves. Thus the scientists frequently quoted Representative George Brown's opening statement to a Congressional hearing when he warned that if we were to do nothing about the impact threat, it would be 'the greatest abdication in all of human history not to use our gift of rational intellect and conscience to shepherd our own survival and that of all life on Earth'.³¹

Through such claims, the issue of planetary defence became a moral frame through which other threats of more human origin could also be addressed. Increased knowledge and surveillance of asteroids, the scientists insisted, would help stop mistakes by the military decision-makers by preventing the misidentification of asteroid airbursts as enemy nuclear warheads (Chapman and Morrison, 1994: 39). At the same time, destroying asteroids

would provide us with a way of using up those unwanted bombs. As John Lewis (1997: 215) put it: 'The net result of the asteroid deflection is really a two fold benefit to Earth: a devastating impact would be avoided and there would be one less nuclear warhead on Earth.' Similarly, Duncan Steel saw the use of SDI technologies in asteroid missions such as Clementine II as 'a prime example of beating swords into ploughshares' (quoted in Matthews, 1997).

Furthermore, the international tensions that led to the proliferation of nuclear weapons in the first place, would also be resolved by uniting against the common enemy of the asteroid. Thus Carl Sagan and Steve Ostro, although largely critical of the promotion of the impact threat, suggested that:

In an indirect way the threat of interplanetary collision may have a political silver lining. They represent a common enemy to all nations and ethnic groups. By posing two different classes of danger to the human species, one natural and the other of our own making, Earth-approaching objects may provide a new and potent motivation for maturing international relations, ultimately helping to unify the human species. (Sagan and Ostro, 1994b: 72; see also Gehrels, 1988: 303)

Even for Sagan and Ostro, then, as for the other civilian scientists, the impact threat offered hope of salvation.

Like the impact threat, SDI's technological solution to the stalemate of the Cold War was also embedded within a moral frame of technological salvation. As Spencer Weart (1988: 385, 399) points out in his history of nuclear imagery: 'In promoting the Star Wars program Reagan was apparently working to restore . . . trust by affirming that technology, even weapons technology, could be inherently moral and humane. . . . Through all this talk [about SDI] ran the idea of salvation by way of technology in the heavens.' Appropriating images of nuclear holocaust from the anti-nuclear campaigners, the supporters of SDI spoke of protective, defensive technologies which would, in Reagan's words, render nuclear weapons 'impotent and obsolete' (quoted in FitzGerald, 2000: 23). For Reagan, SDI was a moral programme to be pursued by the scientific community for 'the cause of mankind and world peace'. Others in the defence community also spoke of a 'moral imperative' and of protecting the American people rather than avenging them.³² 'Mutually

assured destruction' was to be replaced by 'mutually assured survival'.

The moral programme of SDI hinged on the notion of defensive weapons to replace offensive ones. At the level of rhetoric, therefore, SDI helped consolidate the switch from an offensive to a defensive posture. Research into the asteroid impact threat celebrated this posture. Impact-threat science created an external enemy and deployed the same moral argument of 'defence-shields-as-salvation' as did Reagan and his supporters. Indeed, Thomas Ahrens went so far as to describe the nuclear weapons that might be used to deflect asteroids as 'weapons of mass protection' (quoted in Lewis, 1997: 221).

The construal of asteroids as acting agents, of astronomy as the means to salvation, and of human intervention in space as a moral cause, were also elements of the stories told in the fictional works. Direct references to works of science fiction in the writings of the asteroid scientists were therefore just the most explicit traces of the asteroid scientists' dependence on narratives of technological salvation. Science and science fiction existed in a mutually reinforcing relationship in which civilian scientists, defence experts and science fiction writers all narrated the impact threat. As science and fiction became aligned, asteroids became incorporated into the world of narrative cause-and-effect with its movement towards closure. The asteroid scientists' reliance on such narratives meant that they could not avoid the closure demanded by their stories – they were subject to a narrative imperative. Regardless of their personal feelings about weapons in space, they regularly met with defence scientists to discuss weapons technologies to deflect or destroy an incoming asteroid, for only this could provide a satisfactory resolution to their impact stories. Despite their suspicions about each other's motives, the civilian and defence scientists' dependence on similar narratives of technological salvation meant that they were both drawn towards the same endings.

Conclusion

During the 1980s and 1990s, a small group of planetary scientists and astronomers set about actively promoting the asteroid impact threat. They drew on an expanded empirical base but also on narratives of technological salvation. Despite their concerns that their

warnings were greeted by a 'giggle factor' and that funding remained too low, they succeeded in capturing the attention of the media and of some policy-makers and in establishing the impact threat as a legitimate and serious topic for scientific study. By the eve of the new millennium, the meaning of asteroids had undergone a significant transformation. Asteroids had gone from being distant relics of solar system history to being a hidden enemy that could strike at any time with catastrophic consequences.

The reconceptualisation of asteroids was accompanied by a reconceptualisation of both space and astronomy. In Newtonianism, space had been conceived as an empty geometrical abstraction in which God's handiwork was displayed to the knowing observer. Space was both predictable and distant. Now, with the promotion of the impact threat, space was configured as the source of an enemy against which we must defend ourselves. This threatening conception of space matched the conception of space as a theatre of war promoted by the supporters of SDI. Space had become a place, a technologised location for human action where wars could be fought and human salvation sought.

Thus astronomy was also reconceptualised. Further developing the violent metaphors already appropriated by impact-extinction theory (Davis, 2001), astronomers recast their role as impassioned prophets of doom and saviours of mankind rather than as cold calculators of cosmic order. Traditionally solar system astronomy had dealt with the grand narratives of planetary history and the timeless certainties of celestial dynamics. The technologies of astronomy – telescopes and, later, space probes – were the tools through which new knowledge had been sought. They were not, on the whole, instruments of action. Now, however, astronomy was to be prophetic and interventionist. As comets had been in a far earlier period, both asteroids and comets were now treated as 'monsters' – portents of Earthly calamities. It was the purpose of planetary astronomy to watch for these portents. Equally, it was the duty of astronomers to warn the unsuspecting public and to intervene to save the world. Planetary astronomy was transformed from the passive observation of the heavens to the active surveillance of the heavens, and the instruments of astronomy were to be supplemented with the technologies of war.

By the 1980s and 1990s, asteroid science, defence science and science fiction all presented space as an arena for technological intervention where an invisible enemy would be

defeated for the greater good of mankind. Science fiction provided a culturally available resource that could give concrete form to the ideas of both asteroid scientists and weapons designers. Through narrative, the timeless and universal speculations of science could be converted into a specific sequence of events. By drawing on narratives of technological salvation, asteroid scientists made their case more compelling, but they also became dependent on narrative scenarios shared by the defence scientists.

Even as the scientists themselves attempted to pull back from concrete proposals for weapons systems, their own discourse irresistibly drew them towards the militaristic intervention demanded by the narrative imperative. The identification of asteroids as a threat required a military response. Astronomer Duncan Steel (2000b), writing about the impact threat in the *Guardian* newspaper, put it most clearly when he stated that 'we too, need to declare war on the heavens'. Just as the overlap between science and science fiction was mutually supportive, so the overlap between impact science and defence helped legitimise both. The civilian scientists could draw on a repertoire of metaphors and concepts already articulated by the defence scientists to help make the case for the threat from space. They would no longer be a marginalised and underfunded group of astronomers, but would take on the ultimate role of defending the world. Similarly, in the context of the impact threat, the defence scientists could further develop their weapons systems without being accused of threatening the delicate nuclear balance of mutually assured destruction or, in the period between the fall of the Soviet Union and the 9/11 attacks, of irresponsibly generating a climate of fear in the absence of an identifiable enemy.

The civilian scientists attempted to still their consciences in their dealings with the defence scientists by suggesting that, with the end of the Cold War and the demise of SDI, the latter had lost their traditional role. This argument was naïve at best. In fact, as we have seen, the US defence scientists had taken an interest in the impact threat since the early eighties, from the time that SDI had greatest political support during the defence build-up of the Reagan era. Even at the time of the fractious Interception Workshop, George H.W. Bush was maintaining SDI funding at the same level as it had been during the second Reagan administration. If outwardly the Clinton administration was less supportive when it took office in 1993 and declared that SDI was over, many of those involved in the

programme felt that it would actually go on much as before (Fitzgerald, 2000: 491). SDI was renamed, and to some extent reconceived, but funding continued and was soon increased when the Republicans gained a majority in Congress.³³ After George W. Bush took office in 2001, spending on missile defence research was greatly increased, including programmes to follow on from Brilliant Pebbles (Wall, 2001a; 2001b).

Thus the defence scientists had shown an interest in the impact threat from the time of the very first meeting onwards, regardless of the state of funding for missile defence, which in any case continued throughout the period. This is not to suggest that the impact threat was not used by the defence scientists as a means of maintaining the weapons establishment. Indeed, the impact threat offered a possible means of circumventing or undermining arms treaties.³⁴ But it does mean that the attempt to access new sources of funding, whilst being an important factor in the promotion of asteroids as a threat, did not fully explain either the weapons scientists' interests nor the civilian scientists' repeated meetings with them.

The asteroid impact threat offered a scientifically validated enemy onto which could be projected the fears on which a militaristic culture depends. Far from providing a replacement outlet for weapons technologies, the promotion of the asteroid impact threat helped make the idea of war in space more acceptable and helped justify the continued development of space-based weaponry. Arguably, with the Clementine and Deep Impact missions, the asteroid impact threat even facilitated the testing of SDI-style systems. The asteroid impact threat legitimised a way of talking, and thinking, which was founded on fear of the unknown and the assumption that advanced technology could usher in a safer era. In so doing, it resonated with the politics of fear and the technologies of permanent war which are now at the centre of US defence policy.

In this post-Cold War period, scholars of the relation between military and civilian science need to examine carefully claims about 'ploughshare' or 'conversion' technologies. New technologies arise not just out of funding and policy decisions, but also out of the social imaginaries in which new weapons can be imagined and construed as necessary. Concepts such as 'dual use' or 'cover' also need to be assessed critically.³⁵ One way of characterising the Clementine missions would be as dual-use technologies whose scientific aims served as cover for the testing of SDI technologies. Yet this fails to reveal the ways

in which these missions were just one concrete output of a more fundamental conceptual alliance between weapons designers and astronomers. In this paper I have attempted to show that by also considering the narrative context in which such initiatives are located, it is possible to throw some light on the cultural web that binds civilian science to military programmes.

But the focus on narrative also begs a question: which stories would we prefer to frame our science? Should science be driven by fear or by curiosity? Should it be aimed at creating technologies of war or cultures of compassion? These are normative questions but they are also precisely the questions that make the military influence on science such an important issue. Narratives are inherently ideological and a refusal to see them as such does no more to enhance the scholar's objectivity than it does the scientist's. The stories told by the asteroid scientists led them into collaborations with weapons scientists and helped fuel a discourse of fear that served a particular ideological purpose. This should be both recognised and challenged, not for the sake of regaining some impossible ideal of an undistorted science but because there are other stories, based on different ideological assumptions, which we could tell in order to guide science towards more peaceful ends.

Notes

¹ See also the special issues of *Social Studies of Science* 31: 2 (April 2001) and 33:5 (October 2003).

² 'Civilian' and 'defence' are flexible categories, and individuals' institutional affiliations can easily change. For example, among the 'defence scientists' discussed here, Simon Worden was a former astronomer who became head of a division of the Ballistic Missile Defense Organization. John Rather made the journey in the opposite direction from Lawrence Livermore National Laboratory to NASA headquarters.

³ Exceptions include Kaiser's (2003) analysis of the Cold War logic of manpower and Wolfe's (2002) analysis of the overlap between national security interests and science fiction in the development of exobiology.

⁴ For analyses of the impact-extinction debate, see Clemens (1986), Davis (1996), Davis (2001), and Glen (1994).

⁵ For histories of catastrophism, see Bowler (1993) and Huggett (1997).

⁶ Fictional treatments of comet impacts included works by Edgar Allan Poe, George Griffith, Camille Flammarion and H.G. Wells. Flammarion's novel about a near-miss with a comet, *La Fin du Monde*, became one of the first comet threat movies when it was filmed in 1931.

⁷ In a popular book, astronomer Fletcher Watson (1947: 27) described the Earth-approaching asteroids as

'almost too close for comfort'. 'When these cosmic bullets swing past at a mere million kilometers we start worrying about the likelihood of collision' (p. 29). Yet despite such passing comments, Watson had maintained the focus on the origins and physical properties of interplanetary objects. Similarly, although astronomer Ernst Öpik (1958) had computed the rate of impact with Earth, he too had downplayed the impact threat and had instead framed his work in terms of the evolutionary relation between asteroids and other planetary bodies.

⁸ 'The physical and human consequences of asteroid and comet impacts', NASA workshop, Snowmass, Colorado, July 1981.

⁹ Whipple's post-war meteor reconnaissance programme had been among the first astronomy programmes to be funded by the military in a discipline which at the time was noted for its conservatism and reliance on private funding (Doel, 1996: 68-76; DeVorkin, 2000).

¹⁰ Even these brief allusions to asteroids as a threat were coupled to the earlier view of asteroids as potential resources (Binzel, 1989: 16; McFadden et al. 1989: 443).

¹¹ NASA press release, 'NASA astronomer discovers "near-miss" asteroid that passed Earth', 17th April 1989,

<http://spacelink.nasa.gov/NASA.News/NASA.News.Releases/Previous.News.Releases/89.News.Releases/89-04.News.Releases/89-04-17>.

¹² U.S. House Committee on Science, Space, and Technology, *Report to Accompany H.R. 5649: National Aeronautics and Space Administration Multiyear Authorization Act of 1990*, report 101-763 (26 September): 29-30.

¹³ Data from the first two years of the NEAT survey led to the estimate of the number of near-Earth asteroids larger than 1km being revised downwards by about half (Rabinowitz et al. 2000). The 2002 NASA workshop on mitigation recommended extending the Spaceguard Survey to objects down to 200m in size (Belton, 2003: 20), and a 2003 NASA Science Definition Team study recommended surveying for objects down to 140m in size. NASA (2003) 'Study to Determine the Feasibility of Extending the Search for Near-Earth Objects to Smaller Limiting Diameters', Near-Earth Object Science Definition Team (23 August) <http://neo.jpl.nasa.gov/neo/neoreport030825.pdf>.

¹⁴ For instance, both Steel (2000a: 131) and Chapman (1998) take this position.

¹⁵ 'The Collision of an Asteroid or Comet with the Earth', Erice International Seminars on Planetary Emergencies, 17th Workshop, Erice, Italy, May 1993.

¹⁶ For a cautious approach to the nuclear question, and a more considered and critical analysis of the impact threat than most, see Weissman (1994). Ahrens and Harris (1994) repeated their conclusion that mitigation systems for large impactors should not be developed yet. On the necessity of using nuclear explosives, see: Canavan et al. (1994); Simonenko et al. (1994); Shafer et al. (1994).

¹⁷ Planetary Defense Workshop, Lawrence Livermore National Laboratory, 22-26 May, 1995, <http://www.llnl.gov/planetary>; Workshop on Scientific Requirements for Mitigation of Hazardous Comets and Asteroids, Arlington VI, 3-6 Sept. 2002, <http://www.noao.edu/meetings/mitigation/index2.html>; Planetary Defense Conference: Protecting Earth from Asteroids, Garden Grove, CA, 23-26 February, 2004, <http://www.aero.org/conferences/planetdef>.

¹⁸ Email correspondence from David Morrison to Alan Harris, reproduced in Morrison (2000).

¹⁹ <http://neat.jpl.nasa.gov>; <http://www.ll.mit.edu/LINEAR>.

²⁰ Lawrence Livermore National Laboratory, 'Clementine', <http://www.llnl.gov/timeline/1980s/pdfs/1994.pdf>; NASA Goddard Space Flight Center, 'Clementine Project Information', <http://nssdc.gsfc.nasa.gov/planetary/clementine.html>.

²¹ Alan Hope, Bernard Kaufman and Dean Bakeris, 'A Clementine II Mission to the Asteroids' IAU Colloquium 165, Poznan, Poland, 1-5 July 1996.

²² Spaceguard Foundation, <http://spaceguard.esa.int/SGF/index.html>.

²³ Council of Europe, Resolution on the detection of asteroids and comets potentially dangerous to humankind (9 Feb 1996) doc. 7480, <http://assembly.coe.int>; 'The Space Millennium: Vienna Declaration on Space and Human Development', <http://www.oosa.unvienna.org/unisp-3/res/html/viennadecl.html>. The resolution was adopted at the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna in July 1999. The UN had also sponsored a conference on the impact threat in 1995 (Remo, 1997).

²⁴ Thus the entry on asteroids in Clute and Nicholls (1999) notes that most stories about asteroids portray them as sites for mineral mines.

²⁵ One paper promoting the mining of asteroids (O'Leary, 1977) sought reassurance from asteroid collisions, claiming that mining asteroids wouldn't disrupt the long-term integrity of the solar system because they would be destroyed in collisions anyway. Interest in asteroids as mineral resources continued during the promotion of the impact threat. For instance, two contributions at the 1995 UN conference argued that mining hazardous asteroids could make the problem of deflection easier (Gertsch et al. 1997a; Gertsch et al. 1997b). See also Hartmann and Sokolov (1994).

²⁶ Other popular books offer similar narratives. See, for instance, Chapman and Morrison (1989: 3-4), Clube and Napier (1990: 1-9), and Levy (1998: 217-29).

²⁷ The *OED* dates the phrase 'rogue states' to a *Washington Post* reference of 1973 and the phrase was in common use in newspapers during the 1980s and 1990s to describe states such as Iran, Iraq, Korea, and Libya.

²⁸ The recommendation was endorsed by the American Institute of Aeronautics and Astronautics: AIAA Position Paper, 'Protecting Earth from Asteroids and Comets' (Oct 2004) <http://pdf.aiaa.org/downloads/publicpolicypositionpapers//Asteroids-Final.pdf>.

²⁹ Although for some of the time during which he promoted Livermore's X-ray laser, Teller retreated from the idea of stationing weapons permanently in space, he did later return to the idea of space-based weapons (Broad, 1992). In any case, even ground-based SDI weapons would be activated in space.

³⁰ Redfield (1996) has argued that prior to the launching of the first artificial satellites, outer space had not been conceived of as active domain at all.

³¹ George E. Brown Jr., 'Opening statement', *U.S. Congressional Hearing on the Near-Earth Object Threat*, 24 March, 1993, cited in Garshnek (2000: 218) and AIAA (1995) 'Position Paper', <http://impact.arc.nasa.gov/reports/aiaa/index.html>.

³² General Vessey, Chair of Chiefs of Staff, Captain Brooks, Aide to Rear Admiral Holland, and a high

administration official all spoke in these terms (FitzGerald, 2000: 197, 202, 242).

³³ Clinton agreed to an NMD budget twice the size of what the Pentagon had asked for (FitzGerald, 2000: 492).

³⁴ For instance, in April 1996 the Chinese government temporarily withdrew from disarmament talks on the grounds that it wanted to be able to conduct 'peaceful nuclear explosions' (Tyler, 1996). One of the reasons it gave for why such explosions were necessary was the deflection of any asteroids that might be on a collision course with the Earth.

³⁵ For a critical analysis of dual-use technologies in oceanography, see Oreskes (2003).

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