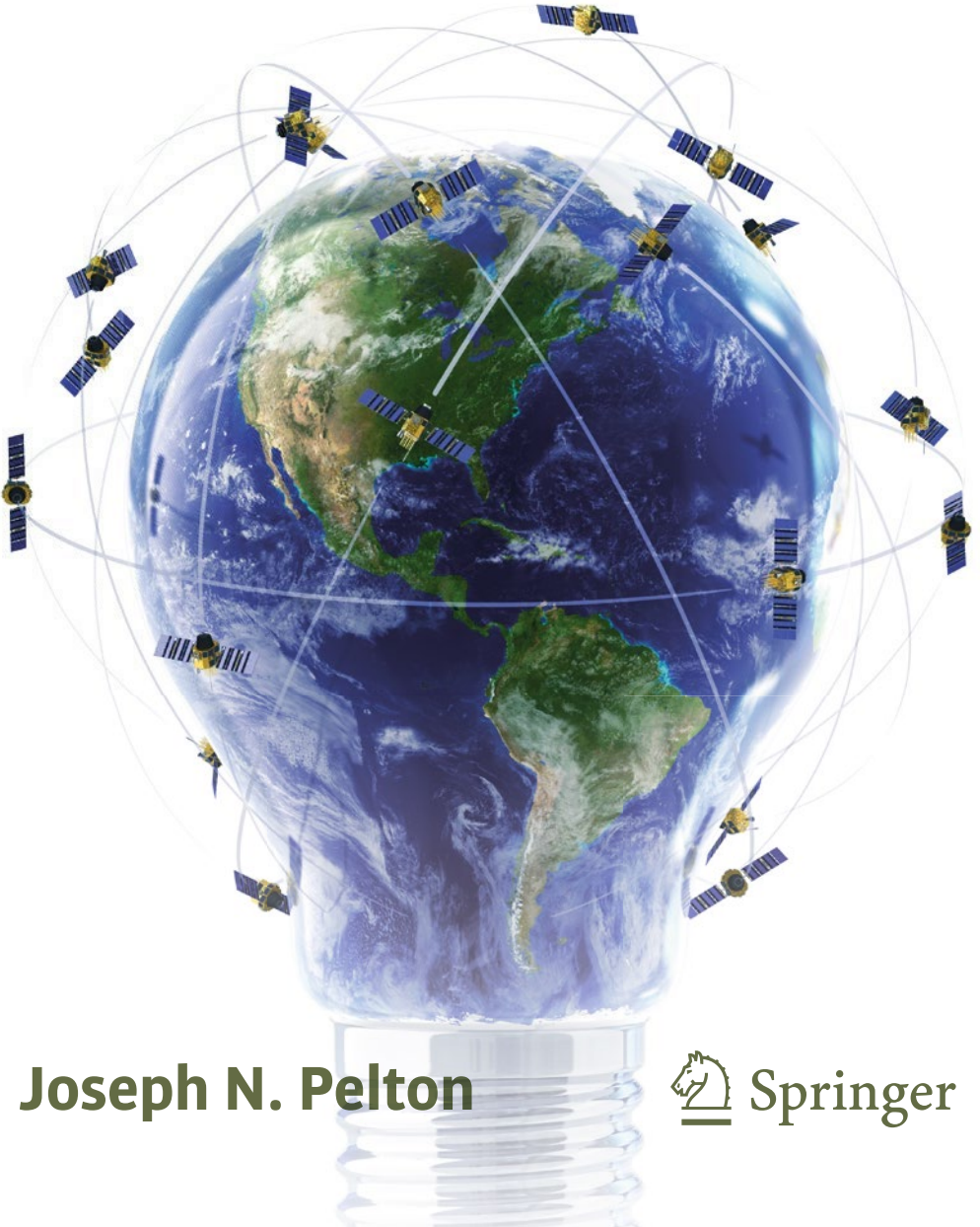
SPACE SYSTEMS AND SUSTAINABILITY

From Asteroids and Solar Storms to Pandemics and Climate Change



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ISBN 978-3-030-75734-2 ISBN 978-3-030-75735-9 (eBook)
https://doi.org/10.1007/978-3-030-75735-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to those that believe the time has come for those on Earth to collaborate in new and more effective ways to save our cosmic home. It is about using space systems and technology to take better care of our ailing Spaceship Earth.

The main purpose of such a global collaboration is to save and sustain civilization from a growing number of existential crises. Some of these threats come from cosmic sources such as asteroids, comets, centaurs, solar storms, and orbital space debris. Then there are also the many and growing crises here on Earth. These include pandemics, natural disasters, global pollution, climate change, nuclear and biochemical weapons, nuclear waste, pathogens, overpopulation, and other "hyperobject" grand challenges discussed in this book.

I dedicate this book to the fledging initiative outlined in Chap. 14, namely the creation of a new international agreement that could ultimately lead to a global sustainability treaty. The goal is to create a unified effort to undertake planetary defense. We need such a global initiative in order to achieve the long-term survival of our species.

Acknowledgment

This book has been a true challenge because of the diverse areas of concern when it comes to long-term human survival in the so-called Anthropocene epoch, which others call the Holocene epoch. We are in a geological time in which human activity is the prime shaper of change to planet Earth. This book thus needed to call upon a wide range of expertise to help readers understand the various crises that the modern world now faces.

I must first start with my thanks to my friend, colleague, and editor, Peter Marshall in England, with whom I have worked on nearly ten different book projects. I truly appreciate his help to format and improve the coherence of this text. I also wish to thank my friend and colleague Dr. Donald Daniel for his expertise in disarmament, nuclear weapons, and nuclear waste materials. He also helped me understand the particular problems with the monitoring of biological weapons. Likewise, my colleague and friend Prof. Scott Madry helped with understanding some of the latest breakthroughs in hyper-spectral sensing and data analytics that are zooming ahead at warp speed.

A special thank you must go to Prof. Ram S. Jakhu, Acting Director of the Institute of Air and Space Law, McGill University, and his colleague, Dr. Karin Vazhapully. They collaborated with me in the writing of Chap. 14, which addresses the creation of a global sustainability treaty. This new international agreement would facilitate the nations of the world to collaborate and identify the world's greatest existential crises, and then to seek unified ways to mitigate these risks.

There are many others from around the world and in many different fields that have assisted in different ways. My sincere appreciation is extended to President Juan de Daumau, Gary Martin, Prof. Su-Yin Tan, and Prof. Chris Welch, all of the International Space University; Chris Johnson of the Secure

World Foundation; Lord Martin Rees, Royal Astronomer of the UK; Matteo Madi of Sirin Orbital Sciences; Olga Sokolova, risk analyst from Zurich, Switzerland; Prof. Steven Freeland of Western Sydney University of Australia; Dr. James Green, Chief Scientist at NASA; Prof. Giovanni Fazio, Harvard University; Michael Potter, Paradigm Inc.; Prof. Madhu Thangavelu , Viterbi School of Engineering, University of Southern California; Ranjana Kaul, space lawyer from New Delhi, India; Dr. Carlos Niderstrasser; Dr. Darren McKnight of Centauri Corporation; Tommaso Sgobba, Executive Director of the IAASS; and Michelle Hanlon, co-founder of For All Moonkind.

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Joseph N. Pelton, Ph.D., is the dean emeritus and former chairman of the board of trustees of the International Space University. He is the founder of the Arthur C. Clarke Foundation and the founding president of the Society of Satellite Professionals International—now known as the Space and Satellite Professionals International (SSPI). Dr. Pelton currently serves on the executive board of the International Association for the Advancement of Space Safety. He is the director emeritus of the Space and Advanced Communications Research Institute (SACRI) at George Washington University, where he also served as director of the accelerated masters' program in telecommunications and computers from 1998 to 2004. Previously, he headed the interdisciplinary telecommunications program (ITP) at the University of Colorado-Boulder. Dr. Pelton has also served as president of the International Space Safety Foundation and president of the Global Legal Information Network (GLIN). Further, he served as the founding chairman of the board of The Global Alliance for International Collaboration in Space (GALIX). Earlier in his career he held a number of executive and management positions at COMSAT and INTELSAT, the global satellite organization where he was director of strategic policy.A prolific author, Dr. Pelton has now published over 50 books and over 400 articles, encyclopedia entries, op-ed pieces, and other research publications during his career. He has been speaker on national media in the USA (PBS New Hour, Public Radio's All Things Considered, ABC, and CBS) and internationally on BBC, CBC, and FR-3. He has spoken

and testified before Congress and the United Nations, and delivered talks in over 40 countries around the world. His honors include the Sir Arthur Clarke International Achievement Award of the British Interplanetary Society; the Arthur C. Clarke Foundation Award; the ICA Educator's award; the ISCe Excellence in Education Award; and being elected to the International Academy of Astronautics. Most recently, in 2017, he won the Da Vinci Award of the International Association for the Advancement of Space Safety and the Guardian Award of the Lifeboat Foundation.Dr. Pelton is a member of the SSPI Hall of Fame, fellow of the IAASS, and associate fellow of the AIAA. Pelton's *Global Talk* won the Eugene Emme Literature Award of the International Astronautics Association and was nominated for a Pulitzer Prize. His most recent books are: *Preparing for the Next Cyber Revolution, Space 2.0: Revolutionary Advances in the Space Industry, The New Gold Rush: The Riches of Space Beckon*, *The Handbook of Space Satellites*, *Global Space Governance: An International Study,* and the second editions of *The Handbook of Satellite Applications* and *The Farthest Shore: A 21st Century Guide to Space.*He received his degrees from the University of Tulsa, New York University, and from Georgetown University, where he received his doctorate.

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Ten Existential Risks to Life on Earth

We are the intelligent elite among animal life on earth and whatever our mistakes, [Earth] needs us. This may seem an odd statement after all that I have said about the way twentieth century humans became almost a planetary disease organism. But it has taken [Earth] 2.5 billion years to evolve an animal that can think and communicate its thoughts. If we become extinct she has little chance of evolving another.

–James Lovelock, scientist and advocate of the Gaia theory of Earth

Preserving Humanity: Ready, Set, Go!

The *Wired Magazine* devoted its entire April 2020 issue to Earth Day and climate change. This particular edition was emblazoned across the top with the admonition: "We have one Earth—and the technology to save it—Go!"

This book is about this admonition—but with a large caveat. Humans need to be much more careful with the technology we use to save Earth, as inappropriate use of technology can often be a large part of the problem. There is a need to deploy innovative and re-envisioned technology in order to meet a myriad of twenty-first-century challenges. These are real challenges to the long-term survival of the human species in our native habitat, called throughout this book "Spaceship Earth." This is important to emphasize: Earth is indeed a modestly shielded planet, with only a thin protective atmosphere and a puny magnetic cage that protects the world from solar wind and the occasional solar superstorms.

J. N. Pelton, *Space Systems and Sustainability*, https://doi.org/10.1007/978-3-030-75735-9_1

We have embraced technology to industrialize the world for centuries now. This has been done without adopting protective practices or safeguards for the environment. Too often, technology is seen as a way to increase economic throughput and strengthen corporate profits. This book suggests that there is another and more important role for technology: to create new ways to sustain life on Earth. Profits are fine. Continuation of the species, however, needs to be ranked just a smidgen higher on humanity's value scale.

The willingness of humans and governmental and corporate entities to spend more money and resources to save Earth as a viable biosphere is the great ethical question of contemporary times. Humans now officially live in what is known as the "Anthropocene Epoch." The geologists of the world have decided on this new designation only in the past decade. Anthropomorphic beings—that is, humans—for better or more likely for worse, seem to have pushed Mother Nature out of the way and now dictate the future of the third rock from the Sun.

For millennia, humans relied on their skills as hunters and gathers, but today, we are dependent on increasingly complex technology often separated from the world of nature. This separation has provided many benefits and created wealth, but it has also contributed to new types of crises. Our dependence on essential technology also makes modern society more vulnerable in the event our infrastructure is disabled or destroyed.

There is a need to urgently deploy what might be called sustainable and nature-friendly technology to compensate for the negative impacts that humanity is making on the world through unrestrained growth and environmental excess. This book sets forth ten challenges that humanity now faces as a civilization. These challenges are examined in some depth, along with the needed new technologies that may help solve them. An effective response requires more global cooperation, interdisciplinary skills, and a better overview and understanding of how many of these threats are interrelated. Shifts in policy, regulation, and law are essential to preserving a livable world. The bottom line is that new technology, policies, laws, and regulation, and significant amounts of money, time, and resources, need to be invested. And indeed, some of the technology developed to "save" Spaceship Earth might create their own problems, giving rise to concerns about personal privacy or perhaps runaway space debris, to name only two. Technology is clearly not a cure-all, but rather a tool to be used carefully and wisely.

Slow and lackadaisical reaction by the general public and politicians to these great challenges calls to mind the stock-in-trade joke of radio and television comedian Jack Benny from the 1940s through the 1980s. More than once, Benny is confronted by a robber. As the robber points a gun

menacingly and demands "Your money or your life?" Jack Benny just stands there and does not respond. It seems as if minutes go by, and the robber again threatens him urgently at gunpoint: "Listen mac this gun is loaded. I said your money or your LIFE—what is it going to be?" Jack Benny replies, "I'm thinking, I'm thinking."

But global society is not thinking. Political and business leaders are not always considering the needs of everyone on the planet. Often, those in "technically agile" and economically advanced countries are unconsciously choosing their money and luxury lifestyles over the future of life on the planet. Many times the push for corporate profits tends to outweigh consideration of future children, grandchildren, and great grandchildren. In the case of the Jack Benny joke, he is facing an immediate threat but still trying to keep his money even in the face of mortal danger. In the case of most of the challenges that humanity faces today, the mortal threat is perhaps many decades into the future or even longer. Humans do not deal well with longer term risks. It is not easy for the average citizen or a politician to decide how to prioritize spending of resources. How does one choose to spend money wisely? How does one decide to act? Is it best to address a real problem today, such as a pothole in the street? Or is it best to be prepared for a potential cataclysmic event that may hit Earth years from now? In short, humans and dinosaurs often have an equal capacity to think strategically.

"Hyperobject" Threats to Human Civilization

Environmentalist Tim Morton invented a useful term that applies to major long-term societal threats. In Morton's view, such challenges will ultimately be devastating, but they are still likely a long way off and are very complex in a scientific or technological way. He coined the term "hyperobject" to refer to such long-term and very difficult questions. According to Morton, a hyperobject is something so gigantic in its impact, so long-lasting over a substantial period of time, and so complex and difficult to address, that most people simply dismiss it. Let other people face hyperobject challenges. This might perhaps be a scientist in a laboratory somewhere, an astronomer in an observatory, or a meteorologist taking measurements. Often, it is a politician who says, let elected officials that come after me face this problem—the repair of potholes come first. The key is to be able to place the blame elsewhere if something goes very, very wrong. For many leaders, the key is to be well out of office when the s—t hits the fan.

This book suggests that it is time to understand that in the Anthropocene Epoch, the world is changing and existential risks are mounting. Existential risks, or even true threats are problems that impact humanity and all life on Earth, possibly to the catastrophic point of extinction. Significant changes due to massive urbanization, population growth, and reliance on modern infrastructure mean that the challenges once small and remote are now increasingly large and the likelihood of devastating impact greater. As the world becomes more technologically dependent, the fragility of the modern world becomes more real. It is an irony of the time that new technology can make modern society safer and more comfortable, at the same time that it makes society more vulnerable.

Fortunately, many of the newest space systems and associated data analytic capabilities can help identify the most pressing risks and also the best means to address them. New and promising developments are coming from the world of space and satellite systems, information technology, cybersecurity, and environmental sciences. But solutions are not just technological or scientific. In many cases, the answer must involve a change in governmental legislation. It also requires new, proactive policies. One of the solutions offered here is the adoption of a new International Agreement that ultimately leads to a Global Sustainability Treaty.

Don't worry—this is not a proposal to create a new international agency. The purpose of this treaty, or international agreement, is largely to knock down disciplinary silos that keep apart useful information and applications in a world that is overly specialized and does not share information wisely or well. The object of such a treaty would be to have more effective information sharing across disciplines and to work nicely together. It would encourage various existing international and national agencies to work on longer term problems on a wider scale.

Just what are the crises we are facing? Future chapters will reveal their nature, along with the new types of protective systems and technologies that might deployed against them. These challenges to humanity include pandemics and climate change. But there are also eight other challenges to consider. Some are cosmic in nature, including massive solar storms, coronal mass ejections, asteroid strikes, and comets. There are also natural disasters, which in many ways are now more dangerous than ever before and will systematically kill more people and destroy more infrastructure. Still others include modern destructive capabilities, such as overpopulation, nuclear and biochemical weapons, species extinction, and global pollution. Indeed, we even consider artificial intelligence (AI) and various forms of cyberattacks.

The next 80 years, by the start of the twenty-second century, is the critical time to transform to a sustainable society. There are many reforms that are

required along the way. There is an urgent need for more worldwide sharing of scientific, technological, and other information to achieve sustainability. This new level of sharing comes from a much broader range of fields than in the past. Some of the key fields are agriculture, banking, finance and taxation, cybernetics, disaster recovery, energy systems, environmental studies, medical research, infectious diseases and pandemics, meteorology, water supply, atmospheric studies, nuclear and biochemical weapons disarmament, space systems (including especially Earth observation systems, precise navigation, positioning, timing, telecommunications, and IT services), transportation and shipping, and much more. There are breakthroughs in many technical applications not even dreamed of just a few years ago. The key is to begin prioritizing them for global sustainability over all other values. We might call this the Jack Benny rule: You can't spend your money if you are dead.

These new capabilities can help provide much greater control from pandemics to pollution cleanup. They can help us monitor natural disasters and nuclear and biochemical weapons. There are new space systems that can provide instant (three times a second) high-resolution imaging of the entire world in near-real time. There are space communications systems that can provide broadband links to any point on the planet, and others that can provide precision navigation, positioning, or timing services. Much of the technology is already here, but it needs to be deployed in the efforts of sustainability. The potential impact of new space applications could turn out to be as significant as the invention of the wheel, farming, electricity, or even spandex.

What follows is a plausible listing of modern crises that human civilization will face in the twenty-first century, as well as a brief introduction to the technology and policies that might help millions of people—quite possibly within the lifetime of anyone reading this book.

Pandemics

The 2020 COVID-19 pandemic calls to mind the "Spanish Flu" of 1917–1918. Incidentally, it is called that because the brave Spanish government was the first to acknowledge this pandemic, not because it started in Spain. If the end result of the COVID-19 virus was to create a stronger global defense against future pandemics and also to address other planetary threats seriously, then it will have served at least one noble purpose. Those that died of this disease will not have done so in vain. The increased linkages of medical research centers, hospitals, and governmental agencies might prove to be one of the best things to happen to humanity in decades.

A shift to the latest in space technology information processing and AI could help detect and contain future pandemic outbreaks with much greater speed. New space systems and data analytics can help monitor native habitats that are known to give rise to zoonotic diseases, that is, diseases that jump from animal hosts to humans. Certainly, new global communication systems can share information much more efficiently with regard to therapeutics and vaccines. Remote-sensing satellites linked to instant data-analytic systems could confirm outbreaks of infectious diseases and pinpoint the location of those infected in a matter of minutes and hours, rather than days or weeks. The right combination of sensors in space and on the ground could signal a pandemic even before a government officially notifies the World Health Organization that there is a problem.

Global coordination of pandemic responses can be greatly improved via broadband networking that is available across the globe. Leaders and medical professionals across these systems can share key information on health practices and medical treatment. These areas will be addressed more fully in Chap. 2.

As we've seen, most political leaders find ways to respond to disasters, but this is typically after the fact and after great damage has been done. There is little or none by way of proactive disaster prevention or mitigation programs in most countries. This may be particularly true with regard to pandemics. Always, it is a matter of trying to lock the barn door after the livestock has escaped.

Sorting out what should now be spent to prevent pandemics is a bit difficult to estimate. Trillions of dollars are now spent on medical care and research around the world. Yet of all the money spent on medical care and research on new medications, hundreds of times less than that amount is devoted to the detection and prevention of pandemics. It is well documented that the unit devoted to pandemic prevention and response established in the White House by the Obama administration was abolished by the Trump administration. The answer to this ill-advised action was something like: "We will recreate such a unit if a need for it arises." The irony of that statement today is overwhelming.

But other governments and organizations are seldom proactive in the prevention of pandemics too. Even though the World Health Organization (WHO) and the U.S. Center for Disease Control (CDC) have traditionally viewed their prime mission as the containment of infectious diseases, their response was clearly lacking. As will be explored in the following chapter, "an ounce of prevention is now worth many pounds of cure." If a billion dollars more had been spent on new technology, alert systems, and pandemic-related

protocols, this might have saved many billions more in business, governmental, and personal losses.

The point in Chap. 2 is not to condemn the lack of planning in the past, but to lay out a blueprint of action that involves more effective use of information and detection technology along with proactive programs to prevent a repeat of the COVID-19 disaster anytime in the future.

The Threat of Nuclear and Biochemical Weapons

COVID-19 *could* have been a human-engineered biological weapon released from a weapons lab—but it most certainly wasn't. Conspiracy theorists might have found reason to spread such a rumor, but it is well understood that the virus was most likely spread from either a bat or a monkey in the vicinity of Wuhan, China. Yet, the threat of a biochemical attack or even a nuclear war unfortunately remains a real one in today's world.

If we had seen, for instance, the release of a small pox agent, this would have made the current pandemic seem like a walk in the park. And atomic weapons remain an enormous and legitimate concern, even though they have not killed people in several decades. Legitimate efforts have been made to reduce the stockpile of over 13,000 nuclear weapons, but with little success in recent years. In contrast to the perhaps $20 trillion spent on armaments over the last decade, only a trifling amount has been spent on peace. Today, there are new armament initiatives in the United States, Russia, China, North Korea, and possibly other countries. The threat of mass destruction, as monitored by the Union of Concerned Scientists, remains quite real (Fig. 1.1). There is no truly effective system for containing the spread and possible use of nuclear and biochemical weapons. International agreements on this issue need to be strengthened. Technical systems to monitor and detect their use need to be enhanced. Today, there are monitoring systems on GPS satellite to detect nuclear device explosions and asteroid strikes, but these can only report on such events after the fact.

New initiatives must seek disarmament and monitoring and verification systems. This thinking must be considered a high priority in any rational future of humankind. As these efforts move forward, it should perhaps be recognized that biochemical weapons may be a bigger threat to humanity in the twenty-first century than nuclear weapons. The efforts of rare political leaders, as exemplified by Senator Samuel Nunn in his nuclear decommissioning campaign and others of his ilk around the world, must be initiated with renewed vigor.

Fig. 1.1 The sharp teeth of nuclear weapons. (Cartoon courtesy of the Union of Concerned Scientists)

Potentially Hazardous Asteroids and Bolides

It is little known that even a 30- to 40-meter asteroid could potentially destroy the entire San Francisco Bay area, including Silicon Valley, or megacities such as Beijing, Mumbai, London, Cairo, Lagos, and Mexico City. Yet NASA, under U.S. Congressional directives, was initially told to scan the skies for asteroids that were at least 1 kilometer in diameter.

After some thought and through the leadership of Congressman George Brown, this asteroid survey guidance was reduced down to asteroids at least 140 meters in diameter. This revised figure may seem to be a more logical search strategy. Yet, astrophysicists and astronauts such as Rusty Schweickart and Ed Lu of the B612 Foundation have said not so fast! The Tunguska asteroid that struck Siberia in 1908 was only a 40-meter rock, yet still caused incredible damage to the surrounding area. Further space rocks of the type that caused the Tunguska event are at least a hundred times more common than a 1-kilometer asteroid and tens of times more common than even 140-meter asteroids. The amount of money we devote to detecting world-ending

objects and assorted city-killer rocks is less than 0.01% of what we spend on defense. Again and again, the rationale of how humans spend money comes into question.

We now have the technology to detect potentially hazardous asteroids with much greater precision. NASA and other space agencies should be finding asteroid threats above 30 meters in diameter. In addition, there are a host of possible technologies that could be used to detect and divert asteroid threats from creating cataclysmic harm to planet Earth. These need to be funded and developed as a priority. Only recently, a killer asteroid flew near Earth, reminding us that deadly space threats are indeed quite real [1].

Comets and Other Space Dangers

Comets are an even bigger problem than asteroids when it comes to potential extreme danger. This is because comets travel even faster and generally are large enough to do tremendous damage. Additionally, they are in some ways harder to detect. The more than 20 pieces of the comet Shoemaker-Levy 9 that blasted into Jupiter in July 1994 would have ended life as we know it on Earth. Many of these pieces were much greater than the 6-kilometer asteroid that killed off the dinosaurs some 65 million years ago, along with perhaps 80% of all the species on the planet. Techniques developed to address hazards from asteroids might be adapted to comets as well.

Comets, antimatter, and manmade perils such as space debris are discussed in Chap. 7. They are obscure to most of the public, but these could represent true challenges to humanity. Orbital debris, in particular, is a danger to many of types of space systems on which humanity now relies. It is also perhaps the most directly addressable space threat that could be diminished through active debris removal and stringent debris mitigation procedures.

Cosmic threats may seem exotic and unlikely to most people, but they are very real and potentially very dangerous as well. The first step is to develop new forms of space situational awareness, and the second step is to develop better planetary defense capabilities.

Solar Storms and Electromagnetic Pulses

The biggest cosmic hazard that is most likely to occur is a *coronal mass ejection* (CME). These CMEs could contain quintillions of ions traveling at millions of mph (or km/hr), which could wipe out the world's electronic power

systems. This same event could also destroy the controls of thousands of pipelines, shut down the Internet, and much more. A Lloyds of London study estimated that a big CME strike could cause close to some 3 *trillion* of damages to the North American grid alone.

The best current estimate is that a massive solar stream of ions typically occurs about every 150 years. The last really big one, called the Carrington Event, came in 1859. This event zapped Earth big time. Telegraph offices caught on fire when ions flew off the wires and onto the paper in these buildings. The Northern Lights moved so far south that they could be seen in Hawaii and Cuba. Records in China seem to show that a similar event occurred there in the early 1700s. We are likely overdue for something as violent and damaging. The CME Halloween occurrence of 2003 in Scandinavia and the similar one that crippled electrical grids from Chicago to Montreal in 1989 were much less violent, yet prove that this phenomenon is a true and tangible danger.

Technologies such as Faraday cages, heavy-duty circuit breakers, and more can be used to defend against a massive CME. But more research is needed to defend vital electronic infrastructure against a giant solar storm. NASA and other space agencies need to look at current changes to the Earth's natural electromagnetic shielding against solar storms. The shift of the magnetic poles that satellite systems rely on has been detected by both NASA and ESA satellites, meaning our natural protective shielding is being systematically degraded. Research scientists and the author of this book have suggested that a space-based shielding could be developed for both the Earth and Mars to lessen the effects of solar wind and solar storms in the form of CMEs to protect against these types of cosmic dangers.

Electromagnetic Pulse (EMP) Events

Most people think of nuclear events that occur in warfare to be in the form of bombs, like those that fell on Hiroshima and Nagasaki, Japan, in August 1945. Yet, we now know that a nuclear device that explodes in the upper atmosphere can create an electromagnetic pulse (EMP). Such an EMP would not destroy buildings or kill people, but it might have enormous destructive impact on the country over which it is exploded. It might knock out most of the computers. It might destroy yottabytes of data stored all over the country and destroy banking and savings records, social security information and medical records, utility information, and more. It might destroy the so-called SCADA devices.

Most people do not know about SCADA networks, yet millions of them control power distribution, elevator systems, traffic lights, water and sewage pumps, pipelines, and utilities. Almost everything that is automated works

under their control. Today, these systems are often being retrofitted with the *Internet of Things* (IoT), or addressable smart devices. This transition is happening so fast that the entire world is becoming the Internet of Everything. A high-power EMP, which might be generated by a high-altitude nuclear explosion or come from a powerful solar storm in the form of a CME, would likely knock out almost anything that is electronic. People and buildings would remain, but the economy and society would shut down. Essentially every electronic object in range of the ion blast would be dead. Zapped! Caput!

It would be difficult to distinguish quickly if the EMP catastrophe was triggered by a deliberate attack via a nuclear explosion in the atmosphere or rather by a large solar event in the form of a coronal mass ejection (CME). As noted, smaller solar storms do occur and these tend to cause more localized effects. The Montreal Event of 1989, however, took out transformers and significant electrical power from Chicago to Montreal. Figure 1.2 shows a zapped transformer in Chicago before and after that event.

Fig. 1.2 The damage from a solar CME event that occurred in Chicago in 1989

New programs are needed to provide electromagnetic shielding, high-performance circuit breakers, decentralization and sequestration of urban power supplies, better protection of satellites, pipeline systems, and Internet synchronization processes. Solar space shields might protect against solar storms, but not high-altitude nuclear explosions.

Population Growth and a Disposable Economy

The current *disposable economy*—as opposed to a circular or sustainable economy—is eating up the Earth's natural resources at a rapid clip. It is a world that is growing out of control. In 1800, there were 800 million people. In 1900, there were 1.8 billion people. In 2000, there were nearly 7 billion people. By 2100, there could be as many as 12 billion people. Try to imagine what the world will be like in 2200, 2300, 2400.

A world population that will reach perhaps 12 billion by 2100 is going through a growing list of rare Earth metals and exponentially consuming large amounts of food. A lack of food and water leads to mass relocation, which will prompt territorial wars. The rise of population leads to urbanization, destruction of trees and rainforests, and various forms of pollution to the atmosphere, the rivers and oceans, and the lands.

Spaceship Earth has only so many resources. When these run out, humanity and all living things, except perhaps some bugs and smaller biota, are going to be in big trouble.

It can be easy to see many of the megathreats we face as disjointed from each other. The relationships between pollution, lack of education and health care, vulnerability from huge rocks from the sky, food supplies, supply changes, and more are not always clear. Yet many of our greatest threats are deeply interrelated. In two centuries, we have gone from a world that was less than 20% urban to over 50% urban, and we may hit 80% urban by 2100. Overcrowding, overurbanization, overpopulation, and overconsumption are all part of a human megathreat that is unfolding in slow motion. Yet, this gradual bomb has a force over the longer term that is as great as many nuclear devices.

Our technical agility has allowed this unprecedented growth of human population in just two centuries. Yet this agility has made us all the more fragile. This book, if it achieves no other purpose, will help society at large question what we mean by "progress." There already exist many key technologies that may help us cope with population growth. Satellite capabilities that range from ocean, atmospheric, weather, and climate change

monitoring to remote sensing and inventorying of vital supplies will be increasingly vital. These space systems plus enhanced data analytics will track key supplies of water, crops, animal life, trees, forest fires, plant disease, and severe storm systems.

Climate Change and Natural Disasters

Most people think that they understand the term *climate change*. It means that global warming is occurring and the seas are rising. They even might understand that so-called greenhouse gases are trapping heat in the atmosphere. Heat is not escaping into outer space like it used to, and the trapped gas is warming the Earth. But climate change is far more than warmer temperatures. The trapped heat is strengthening storms, typhoons, hurricanes, and tornadoes. Desertification is shrinking arable land. Massive amounts of water once held in underground rivers and aquifers are drying up. Rainfall patterns are changing, with areas of drought getting more arid and wetter areas in some cases getting more rainfall. With more severe storm systems, there are more and more lightning strikes. Significantly more lightning strikes are now resulting in many more forest fires.

Pollution of the oceans is raising the acidity of the water. Oil spills are drifting to the Polar Regions and changing the albedo of the icecaps, partially melting the ice much more quickly. Once the pure water in the ice melts, it become saltwater and does not re-freeze. The warming trend now threatens to thaw the massive frozen peat fields of Siberia and other Northern regions. This thawing peat releases methane, which traps heat more efficiently than carbon dioxide.

It is all of these changes together that result in less arable land for agriculture, which is already being reduced by urbanization and population growth. Rainforests are being depleted to create more farms and provide more food to ever-expanding cities. Millions of people are leaving arid regions to migrate to better climes. These self-reinforcing processes threaten the livability of the planet. All efforts to reduce the release of carbon-based greenhouse gases are offset by net population growth that is still in the 2.5–4% range in some countries. Nigeria, for instance, is set to overtake the United States as the third most populous country at current growth rates.

Perhaps, only modest adjustments to governmental budgets could make a big difference. The range of steps that could be taken to slow climate change could be vast and unconventional, such as to start building solar shields to reduce solar heating of the Earth or to darken clouds and make

them more reflective. Dozens of lesser actions could be taken as well, as discussed in Chap. 9. There is a huge amount of useful information now written on climate change. The focus of this chapter will thus be on new space and IT systems.

Nuclear Waste, Industrial Poisons, and Pathogens

There is growing concern about the safe disposal of radioactive waste materials from nuclear power plants, industrial poisons that can pollute water supplies, and the creation of pathogens that can lead to infection, illness, and even genetic damage. Today, even the disposal of plastic is becoming a major issue. Microplastic poisoning of fish and ultimately humans is now recognized as a serious problem. Countries in Asia are banning the import of plastic waste. Many materials such as asbestos, arsenic poisons in flooring materials, and waste products are becoming a serious problem.

We must develop new processes to cope with the disposal of everything from radioactive materials to Styrofoam, from metallic poisons to various pathogens. The idea of shipping waste to developing countries is no longer an acceptable answer. New technology to process this waste material will become a major challenge of our time.

Artificial Intelligence, Cyber Attacks, and Digital Defense

Virtually all of the issues addressed in this book involve risks and threats that have been identified for some time but are now being raised to new levels of concern. This heightened response is largely because the magnitude of the problem is increasing with more people; larger cities; faster throughput of industrial cycles that produce more waste, pollution, acidity, poison, or radiation; scarcity of resources; vulnerability of vital infrastructure; or some combination of these things.

A new risk factor comes from the rise of AI, super-automation, cybernetics, and criticality of information and data analytics. In modern society, information is power and the index of wealth. The ability to access, deploy, attack, manipulate, and steal information is increasingly the pathway to some form of power. The rising power and impact of information is redefining work, restructuring wealth, and reshaping many aspects of society. This includes questions of personal privacy, concepts of work, compensation

systems, education and training, income taxation, government, regulation, legislation, and international relations.

Existential Threats to Humanity Are Increasingly Real

The above existential threats and risks to human survival are real. In most cases, they are only growing. Now is the time to develop and deploy the right technology to lower these threat levels. Some of the technologies are as simple as new systems of planning and development. These might include decentralizing urban centers and creating telecities instead of mega-cities. Other solutions might involve new systems of taxation or cleanup. We could do a great deal more to provide improved warning systems and other mitigative strategies for weather-related events and natural disasters. We could get much better returns in certain technologies than we currently do on government investments that often focus on "tanks, toys, trinkets, and trifles."

Bad news, predictions of doom and gloom, and widespread angst from political and business leaders as well as the popular news media do not play well with the public. Downer news tends to kill morale. Ignoring problems, putting off maintenance, and attacking the most urgent tasks of the day are always easier. All longer term issues are easily deferred. Let the politicians next term worry about solar storms, dangerous rocks from orbit, overcrowding of cities, nuclear disarmament, or any other problem. If this is true of politicians, it is doubly true of corporate executives, whose main job is to worry about the next quarterly profit report.

The Vulnerabilities of the Technological Human

The technological human needs to set new priorities and goals. This means elevating survival and sustainability to make these the top priority within the global economy. This represents a fundamental shift. It means downgrading the priority of profit in a free-enterprise world in favor of a new priority of making survival technologies and systems. There is irony in the fact that such priorities, if done well and with conviction, could actually fuel economic growth and create a surge of employment opportunities. This book suggests that green, sustainable, and proactive programs could lead to prosperity, new jobs, and economic expansion. It is particularly true of countries with limited population expansion. China, which has curtailed its demographic growth and